MEDICAL ETHICS
Is Drug Research Trustworthy?

SPACE
Clues to the Milky Way's Evolution

CLIMATE CHANGE
Why Winters Are Harsher

SCIENTIFIC AMERICAN

DECEMBER 2012

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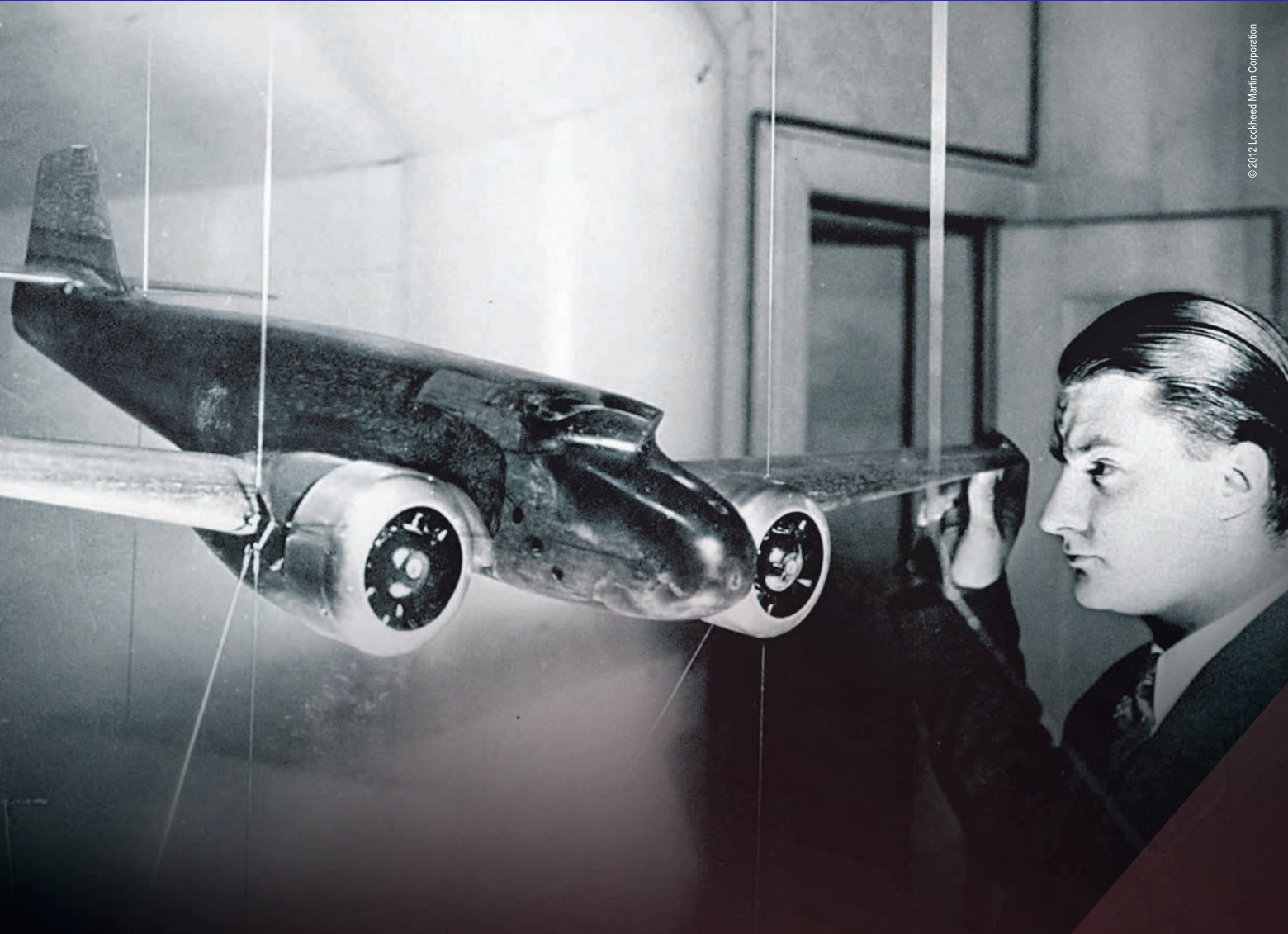
World Changing Ideas

10 Practical Innovations Emerge from the Lab to Improve Our Lives



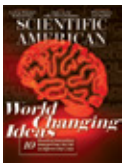
HE SAW THE FUTURE
IN A WIND TUNNEL

Kelly Johnson was onto something. The company he worked for was betting its future on a new all-metal, twin-engine airplane. But after more than 70 wind tunnel tests, Johnson was convinced the single-tail configuration lacked stability. His solution? A twin-tail design that had never been tried before. Not only did the Model 10 Electra become one of Lockheed's most successful aircraft, Kelly Johnson went on to become one of the century's legendary aircraft designers. His story is our story. See it unfold at: **www.lockheedmartin.com/100years**

100 YEARS OF ACCELERATING TOMORROW

LOCKHEED MARTIN

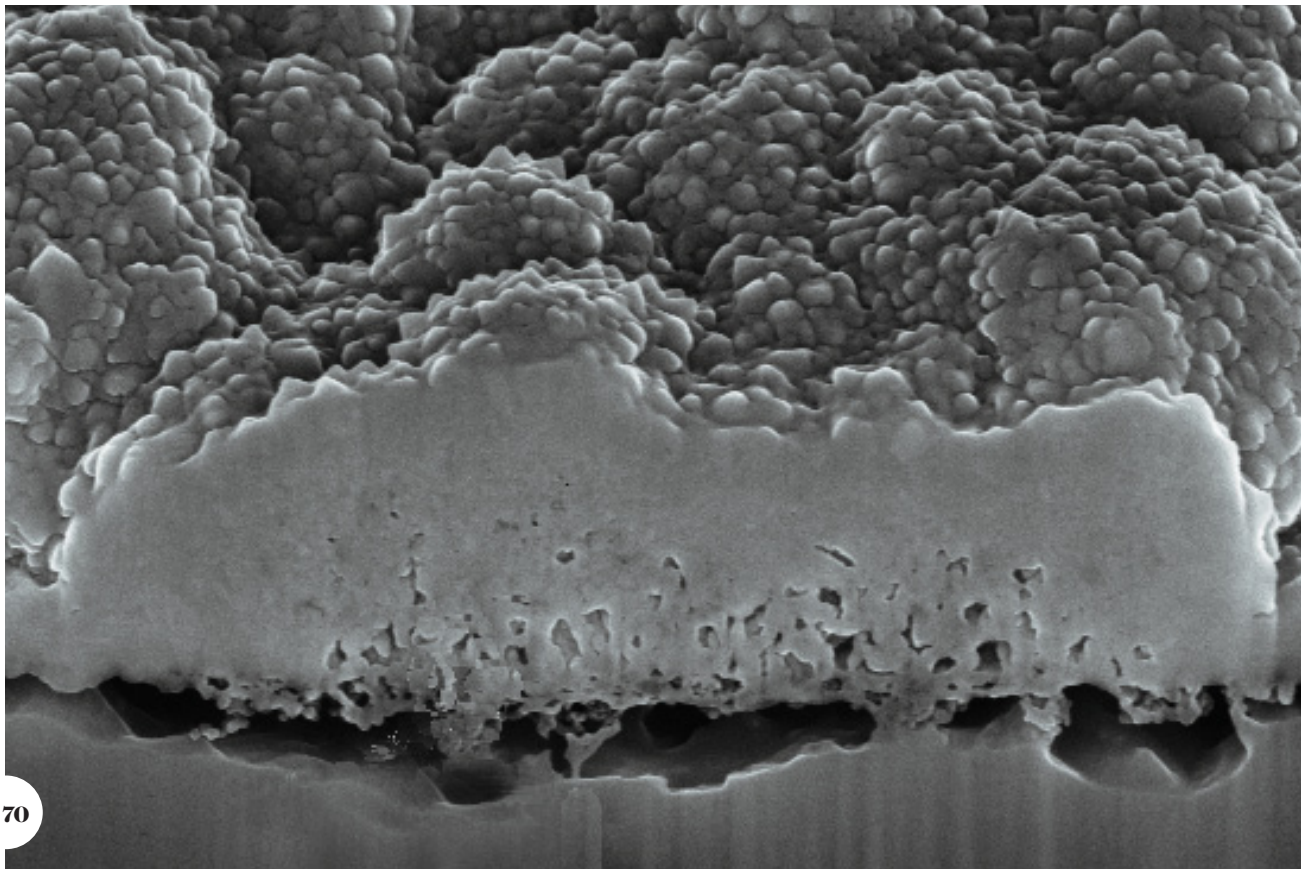
ON THE COVER



Anyone can have a bright idea, but it takes considerable brainpower (and hard work) to figure out how to transform an enticing notion into a practical product or process that can significantly improve people's lives. In this special section, we reveal 10 smart innovations that could scale up to commercial levels soon—and perhaps change the world. Image by Bryan Christie.

SCIENTIFIC AMERICAN

December 2012 Volume 307, Number 6



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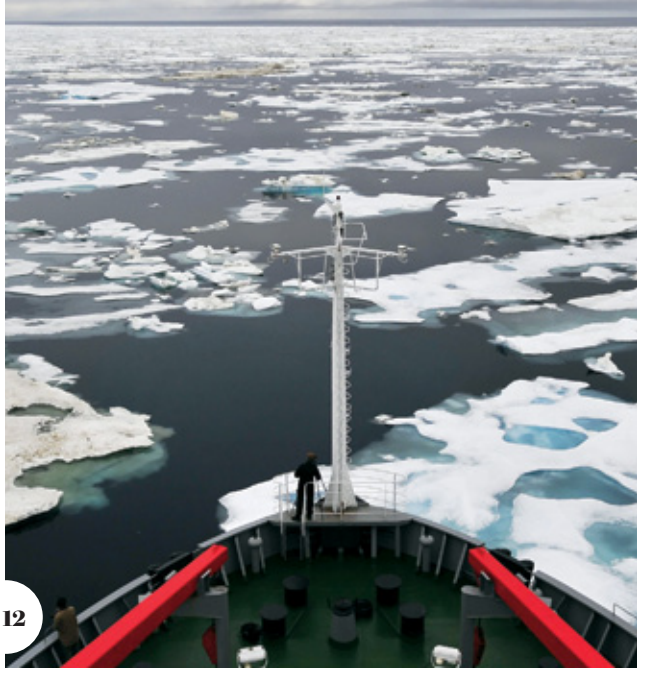
FEATURES

COURTESY OF GEORGE EASTMAN HOUSE



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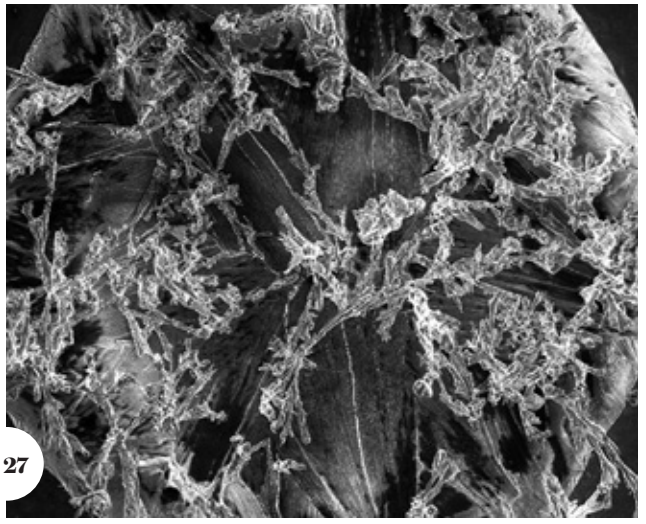

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DEPARTMENTS

ON THE WEB

40 Years after the Final *Apollo* Moon Mission
In December 1972 humans left the moon for the last time. When will the lunar surface once again see fresh boot prints? And whose colors will fly alongside the U.S. flags already planted there?
Go to www.ScientificAmerican.com/dec2012/apollo

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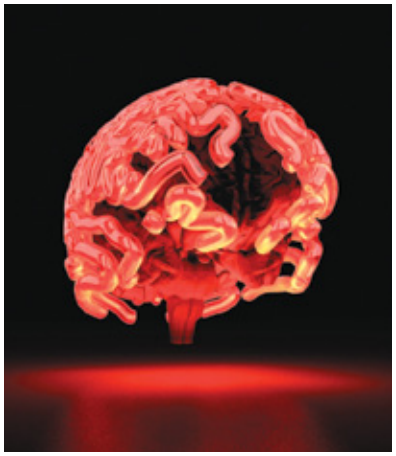
Mariette DiChristina is editor in chief of *Scientific American*. Follow her on Twitter @mdichristina

The Human Factor



FOR HUNDREDS OF YEARS PEOPLE have used the scientific process to build a better future, one step at a time. This year is no exception, as you will see in our cover story and annual appreciation of innovation, "World Changing Ideas," beginning on page 34. The section celebrates ideas as they emerge from the lab to make a practical difference in our lives.

As is usual, strong themes emerge across the developments. As technologies have woven our lives together ever more intricately, our opportunities to take advantage of scale grow commensurately. Consider the "big data" sifting of anonymized information from our innumerable mobile phones to improve services (*page 42*). As the distinctions between technology and biology continue to blur, we note the arrival of bandagelike wearable sensors (*page 44*), blood-sugar-powered pacemakers (*page 43*) and synthetic life built with XNA instead of DNA (*page 36*). In health care, tomorrow's medicines look to prevent ailments before they can occur, such as pills to block the onset of Alzheimer's (*page 38*) and genome sequencing of fetuses (*page 41*).

A natural consequence of the advances propelled forward by our ingenuity, however, is that they are also subject to our very human foibles. For instance, without the support of pharmaceutical companies, researchers could never get their ideas to market. Genentech, laudably, is funding a large portion of the $100-million trials for Alzheimer's prevention drugs; if the company is successful, the work will benefit many millions of people—including patients and their families. Yet in other ways, money from Big Pharma could be exerting an influence on supposedly independent research.

Starting on page 56, journalist Charles Seife explores that important question in his feature article, "Is Drug Research Trustworthy?" He traces the intricate flow of money from drugmakers to medical researchers whose work could benefit those companies, creating conflicts of interest that could, in the worst cases, endanger patients' well-being. The financial support expresses itself in such ways as payments for conference speaking and travel, ghostwritten papers for journals, and consulting fees. To find out what is going on, Seife filed Freedom of Information Act requests over many months and even a lawsuit. The picture he paints of entanglements between companies and researchers is a troubling one—made more so by our institutions' current inability to grapple properly with the matter. We hope his story will inspire the conversations necessary to solve the problem of conflicted science. SA

Illustration by Bryan Christie (brain), *Illustration by Nick Higgins*

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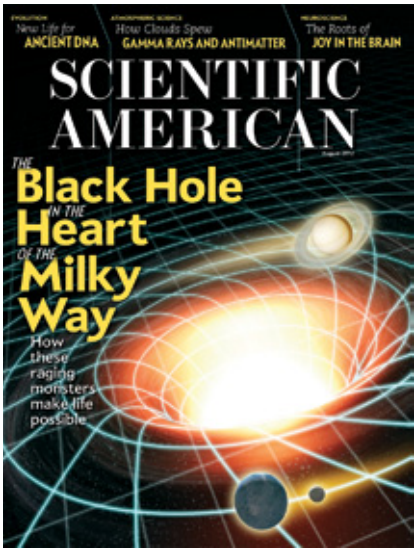

August 2012

ENHANCING EDUCATION

In focusing on the insufficiently rigorous academic preparation of math and science teachers in the U.S. in "Building a Better Science Teacher," Pat Wingert neglects larger issues. The head of a charter school is quoted saying that for every five candidates she observes in teaching demonstrations, she hires only one. What qualities does she look for beyond math mastery? I'd bet they are social and emotional ones.

If a person with deep knowledge lacks empathy and relationship management skills, he will fail as a teacher. Having taught and served as a department chair, I have seen people with expertise extinguish children's nascent interest and others with less knowledge but a greater repertoire of social and emotional skills inspire them.

The article refers to nearly two thirds of math and science teachers departing the profession each year who cite job dissatisfaction, but it doesn't point out some of the factors that fail to attract and retain good teachers: disrespect for the profession and poor or stressful working conditions in public schools, including large class sizes, endless test preparation, lack of autonomy and authoritarian management styles.

Derek Stolp
Math faculty member
Inly School, Scituate, Mass.

BLACK HOLE ORIGINS

"The Benevolence of Black Holes," by Caleb Scharf, refers to a relationship in which a galaxy is a "host" to a black hole, such as the supermassive one at the center of the Milky Way. Are we really certain which is the host and which the "guest"?

Francis Jones
Amarillo, Tex.

SCHARF REPLIES: Two of the biggest unsolved mysteries of supermassive black holes are: Where did they come from—and when? There is clear evidence that such holes existed at the very dawn of the formation of galaxies and stars. It seems that they already inhabited galaxies or the clumps of material that were merging to form bigger galaxies. The largest of such holes seem unlikely to have had time to grow from smaller, star-mass holes by eating matter, which suggests they started out pretty big. One of several theories about how this could happen is that the conditions of a young, element-poor universe could produce black holes of about 100,000 to a million times the mass of the sun in the dense regions inside forming galaxies. These "seed" holes could then grow rapidly while the rest of the galaxy assembled and gravity coalesced cooling matter from the surrounding universe. So their relationship is perhaps better described as being "symbiotic"!

"If a person with deep knowledge lacks empathy and relationship management skills, he will fail as a teacher."
Derek Stolp *Inly School, Scituate, Mass.*

FREE WILL OR NOT?

Michael Shermer defends free will in "Free Won't" [Skeptic] by arguing that although the individual may not be making choices, he is free to veto choices presented by the brain. Yet a veto is simply a choice to reject a previous choice. Similarly, in arguing that the veto takes place in a separate part of the brain, Shermer ignores that all locations within the brain are part of that organ—there is no outside authority.

James Leritz
San Francisco

SHERMER REPLIES: The fact that we can be conscious of the consequences of our choices means that we can choose to veto them, and we can even train ourselves to have more self-control over temptations to make choices that we know will not be good for us. Through practice and positive feedback, I can train myself to resist eating fatty foods and can even choose to design my lifestyle to avoid such temptations. All these choices happen in a determined universe, but they are nonetheless my choices.

FRACTURE FACTORS

"Cracks in the Bone Test," by Deborah Franklin, refers to the online fracture-risk calculator FRAX. I am surprised that it does not include exercise level as a risk factor, which other sources indicate is important in preventing fractures.

Richard Polinsky
Barton, Ohio

FRANKLIN REPLIES: FRAX remains an imperfect, though useful, tool that its developers agree does not include every factor. On the upside, it still provides more context than the DXA (dual-energy x-ray absorptiometry) bone mineral density test, which also does not include physical activity. Perhaps as doctors become better at quantifying exactly how much and what kinds of physical activity provide exactly how much protection, it will be included in a future update of the FRAX calculator.

GAMMA-RAY MYSTERIES

In "Deadly Rays from Clouds," Joseph R. Dwyer and David M. Smith rule out sprites—brief, high-altitude electrical discharges—as the source of gamma rays produced by such thunderstorms.

I was a member of the team that discovered another high-altitude optical phenomenon, called blue jets. A gamma-ray burst could explain many of their features. Have the authors considered the blue jets as manifestation of such bursts?

Daniel L. Osborne
Fairbanks, Alaska

The authors describe the radiation dose received while flying through a thunderstorm as potentially a lifetime's worth within a fraction of a second. Would it be possible to estimate the radiation dosage

received while flying above a thunderstorm, which airlines routinely do?

Omri Guttman
Haifa, Israel

If the storms here on Earth are producing gamma rays and antimatter, I wonder what the lightning storms on Jupiter and Saturn are doing. Could they be the source of some cosmic rays seen on Earth or even have an effect on the sun?

Steven Brenner
via e-mail

DWYER AND SMITH REPLY: After terrestrial gamma-ray flashes (TGFs) were found to originate from lower altitudes than sprites, blue jets were considered as an alternative. Blue jets, however, last about 1,000 times longer than TGFs, so it is not clear what part of the blue jet, if any, might be responsible. Although we cannot rule out that some TGFs might be produced by blue jets, recent radio observations of TGFs now show that most are associated with lightning processes within thunderclouds.

Regarding Guttman's question: our simulations suggest that if the airplane is just above the electron acceleration region, the radiation dose from gamma rays is about 10 percent of the worst case inside the storm. As you get higher, this drops off quickly, and any horizontal distance reduces the dose even more sharply.

As for storms on Jupiter and Saturn, calculations show that thunderstorms within their hydrogen-helium atmospheres are probably efficient particle accelerators. Thunderstorms in those outer planets, however, take place deep within their atmospheres, so any energetic electrons and gamma rays are probably absorbed before they can escape to space. Although Jupiter's magnetosphere does accelerate particles by other mechanisms, which can be detected throughout the solar system, we doubt that these could have a significant effect on solar flares and the solar cycle because the particle and energy densities are so much greater in the solar corona than anything Jupiter would contribute at that distance.

On the other hand, the magnetospheres of "hot Jupiters" in other solar systems—circling red dwarf stars in extremely close orbits—could possibly have a strong influence on magnetic activity in those stars.

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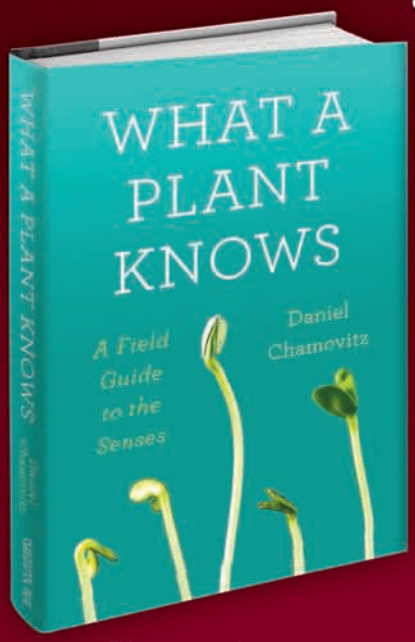
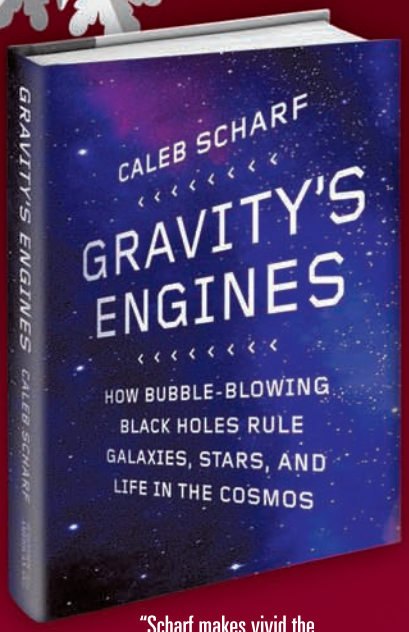
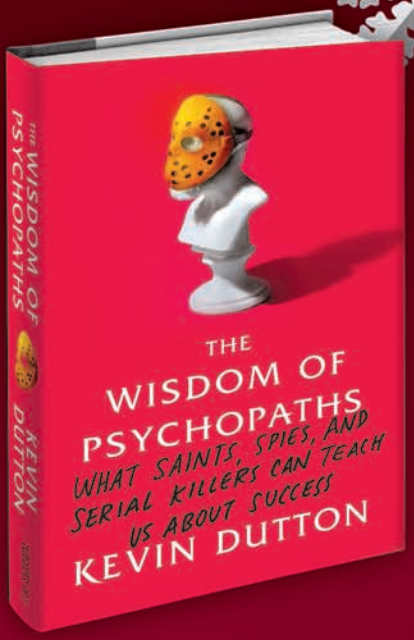


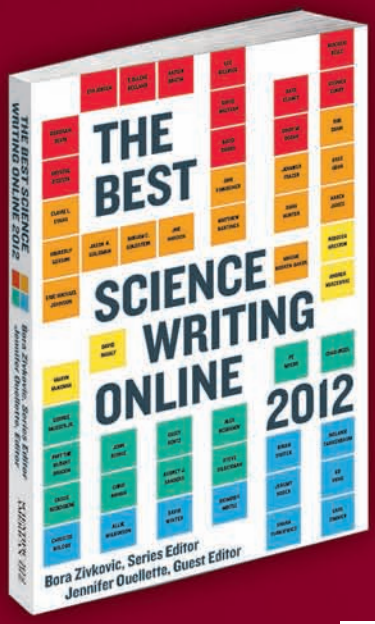
"This elegantly written account of plant biology will change the way you see your garden."
—P. D. Smith, *The Guardian*



"Scharf makes vivid the mind-boggling nature of the universe."
—John Gribbin, *The Wall Street Journal*



"An irreverent romp through the bright side and the dark side of the mysterious psychopath."
—Scott O. Lilienfeld, professor of psychology at Emory University and coauthor of *50 Great Myths of Popular Psychology*



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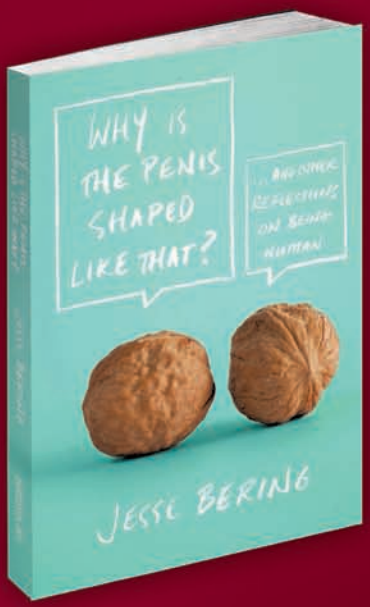

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THE SMARTEST GIFTS IN SCIENCE

OIL FIRE: Giant blazes clear forests to make room for oil palm plantations in Indonesia.

The Other Oil Problem

The world's growing appetite for cheap palm oil is destroying rain forests and amplifying climate change

In the Tripa forest in Indonesia's Aceh province, the rare Sumatran orangutans were dying. Flames devoured the trees, smoke filled the air and the red apes had nowhere to go. The fires had been set intentionally, to clear the land for planting oil palms—trees whose fruit yields palm oil, a widely used component of biofuels, cosmetics and food. Although the land was supposed to be protected, the Aceh governor issued a permit in August 2011 for Indonesian palm oil firm PT Kallista Alam to develop some 1,600 hectares in Tripa. In September 2012, under pressure from environmental groups, the permit was revoked. It seemed like a significant win for conservation. Yet the controversial Tripa permit was just a small part of the country's palm oil–driven deforestation crisis.

With its low price tag and long shelf life, palm oil is the cooking oil of choice in many parts of the world. The plant is a major cash crop for poor farmers in developing countries such as Indonesia, the world's largest producer of palm oil. Palm oil estates there cover an estimated 8.2 million hectares of land—an area the size of Maine—and that number is poised to skyrocket as the country prepares to double its output by 2030. Palm oil exports bring Indonesia and neighboring Malaysia $40 billion a year.

Yet this profit comes at a terrible toll. Converting forests into oil palm plantations destroys the home of not only orangutans but also such critically endangered creatures as the Sumatran tiger and the Sumatran rhino.

Moreover, the denuding of this land through logging and burning releases large quantities of the greenhouse gas carbon dioxide. Much of this forest sits on peatland, the draining and burning of which releases even more carbon dioxide than the clearing of the overlying trees does. A study published online in *Nature Climate Change* in October projected that with planned oil palm plantation expansion, Indonesian Borneo will release 558 million metric tons of carbon dioxide into the atmosphere in 2020. (*Scientific American* is part of Nature Publishing Group.)

The spread of palm oil plantations at the expense of natural forest must not continue. The most promising plan to stop it comes courtesy of the United Nations's Reducing Emissions from Deforestation and Forest Degradation (REDD) program, which would get developed countries to pay developing countries to not cut down trees. In December the annual session of the Conference of the Parties to the U.N. Framework Convention on Climate Change will convene in Doha, Qatar. The meeting presents an opportunity for signatories to finalize REDD. They should do so.

The U.S. can play a part closer to home. This past January the Environmental Protection Agency found that biofuel derived from palm oil does not meet renewable fuel standards. The announcement prompted palm oil firms abroad to hire prominent lobbyists to oppose the decision. In the absence of evidence that its science is flawed, the agency should remain firm.

Meanwhile consumers, as ever, have the power to force companies to change. KFC and Cadbury have in recent years replaced palm oil with other vegetable oils in products made for the markets in Australia, where public awareness about the environmental cost of palm oil is high. And in April the British-Dutch consumer goods giant Unilever, the single biggest buyer of palm oil in the world, pledged to purchase all its palm oil from traceable, sustainable sources by 2020.

Americans should demand transparency about where the palm oil in all consumer products comes from—and take our money elsewhere when products endanger ecosystems. Our role will become only more important as other nations, such as Brazil and Cameroon, ramp up their efforts to get in on the palm oil boom. SA

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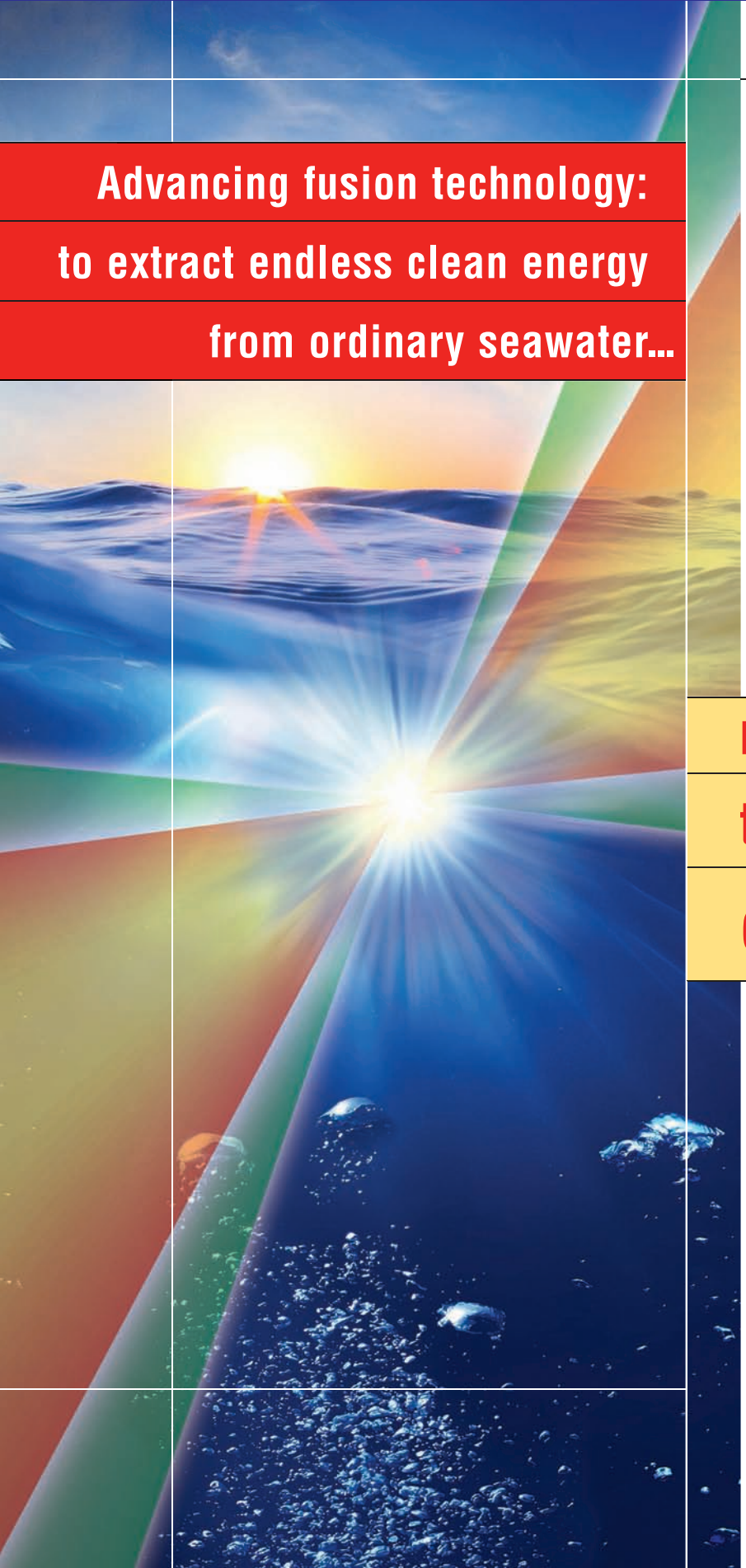
ROBERT NICKELSBERG *Getty Images*

Advancing fusion technology: to extract endless clean energy from ordinary seawater...

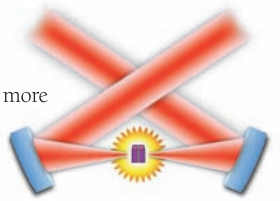


The fusion of deuterium and tritium nuclei, triggered by high-intensity lasers, can release tremendous amounts of heat to boil water and drive turbines to generate electric power. Seawater can be a limitless source of the hydrogen isotopes deuterium and tritium.

A breakthrough in laser fusion

Nuclear fusion of deuterium and tritium is a very attractive energy source. It's clean, safe and virtually inexhaustible, since both isotopes can come from seawater. But the technology to enable fusion power plants still remains elusive...

So Hamamatsu has been developing more powerful lasers, more advanced fusion targets and higher performance laser fusion diagnostics.



From two sides, laser beams implode a fuel pellet to high density and then immediately superheat it, triggering nuclear fusion and release of heat.

Using an elegantly simple *direct fast ignition* scheme, Hamamatsu works with inventor Professor Y. Kitagawa of The Graduate School for the Creation of New Photonics Industries. In this concept, laser beams strike a tiny fuel pellet from opposite directions, imploding it to extreme density. Two subsequent beams trace the same path to superheat the compressed fuel and trigger fusion of nuclei.

Artist's conception of a new laser fusion power plant.

This demonstrates the world's first generation of fusion neutrons from direct heating by an ultra-high intensity laser. It helps confirm the viability of small fusion power plants and enlightens future energy development.

Laser fusion research—it's Hamamatsu's way of helping provide plentiful energy for our world.

http://jp.hamamatsu.com/en/rd/publication/

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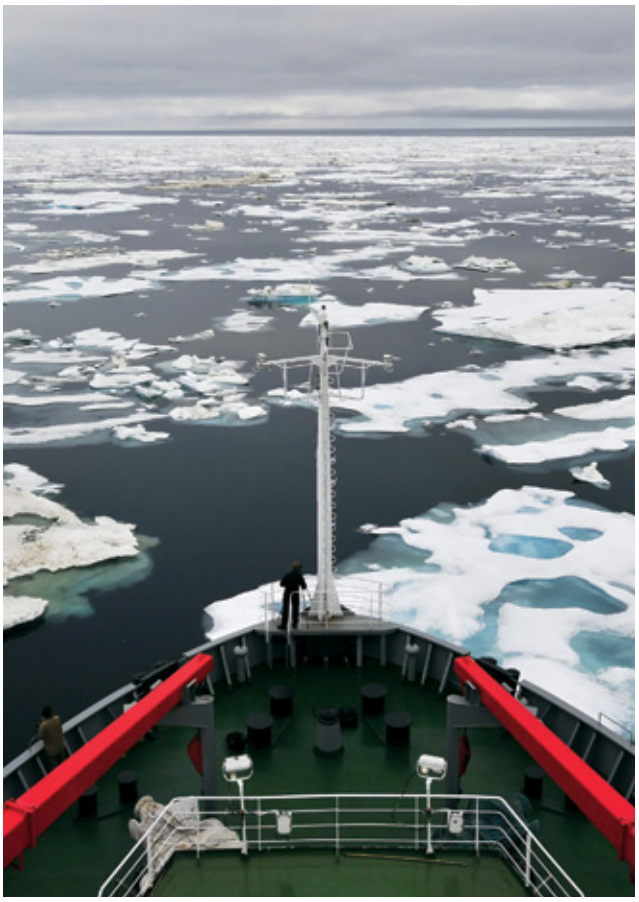
PHOTON IS OUR BUSINESS

Commentary on science in the news from the experts

Peter Wadhams is professor of ocean physics at the University of Cambridge.



The Arctic "Death Spiral"

Geoengineering may be our best chance to save what sea ice is left

I first went to the Arctic in the summer of 1970, aboard the Canadian oceanographic ship *Hudson,* which was carrying out the first circumnavigation of the Americas. The ship was ice-strengthened and needed to be. Along the coasts of Alaska and the Northwest Territories, Arctic Ocean ice lay close in to land, leaving a gap of only a few miles to do our survey. Sometimes ice went right up to the coast. That was considered normal.

Today a ship entering the Arctic from the Bering Strait in summer finds an ocean of open water in front of her. Water extends far to the north, stopping only a few miles short of the pole. From space the top of the world now looks blue instead of white. Things are worse than appearances would suggest, however. What ice is still left is thin—average thickness dropped 43 percent between 1976 and 1999, sonar measurements show. By 2015, at this rate, summer melting will outstrip the accumulation of new ice in winter, and the entire ice cover will collapse. Once summer ice goes away entirely, the physics of latent heat will make it very difficult, if not impossible, to get it back. We will have entered what Mark C. Serreze, director of the National Snow and Ice Data Center at the University of Colorado at Boulder, calls the Arctic "death spiral."

Once ice yields to open water, the albedo—the fraction of solar radiation reflected back into space—drops from 0.6 to 0.1, which will accelerate warming of the Arctic. According to my calculations, the loss of the remaining summer ice will have the same warming effect on the earth as the past 25 years of carbon dioxide emissions. Because a third of the Arctic Ocean is composed of shallow shelf seas, surface warming will extend to the seabed, melt offshore permafrost and trigger the release of methane, which has a much greater greenhouse warming effect than CO_2. A Russian-U.S. expedition led by Igor Semiletov has recently observed more than 200 sites off the coast of Siberia where methane is welling up from the seabed. Atmospheric measurements also show that methane levels are rising, most likely largely from Arctic emissions.

To avoid the consequences of a collapse of summer ice, we need to bring back the ice we have lost. That will require more than merely slowing the pace of warming—we need to *reverse* it.

Reducing carbon emissions and replacing fossil fuels with renewables, including nuclear power, are the most sensible long-term solutions, of course. But these measures are not going to save the Arctic ice. After decades of our trying, CO_2 levels in the global atmosphere continue to rise at a more than exponential rate.

It is time to consider a radical course: geoengineering. By this I mean techniques to artificially lower surface temperatures by blocking the sun. One proposal entails "whitening" low-level clouds by injecting fine sprays of water into them; another involves releasing solid sulfates into the atmosphere from balloons, causing radiation-reflecting aerosols to form. A simpler step would be to paint roofs and pavements white. Such measures are sticking-plaster solutions. They would have to be continuously applied, given that any cessation would bring warming back at an accelerated rate. Nor do they counter direct CO_2 effects such as ocean acidification. But they might buy us time.

Is there a geoengineering technique that would cool the entire planet? Is there a way to cool only the Arctic in summer, to keep sea ice from disappearing? What effect would cloud whitening or chemical release over the Arctic have on precipitation patterns and on temperature? Finding out will require much research and modeling. This must be done urgently. We can no longer afford the luxury of talking about reducing CO_2 emissions by some conveniently distant date in the future. We need action now. SA

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REDUX PICTURES

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TECHNOLOGY

Digital Danger

Security experts are working to thwart a potentially devastating cyberattack

As microchips have grown smaller and more powerful, they have infiltrated virtually every corner of society, from smartphones to medical devices to the controls that regulate rail lines, power grids and water treatment facilities. Computer security experts have been warning that these embedded computers are highly vulnerable to attack because they are increasingly networked with other computers and because they have virtually no defenses protecting their firmware, programs that are hardwired onto the chip. In October, following a wave of network attacks believed to have originated in Iran, Secretary of Defense Leon Panetta warned that a "cyber Pearl Harbor" could be imminent.

Security experts used to take firmware for granted, notes Scott Borg, director of the nonprofit Cyber Consequences Unit, because, unlike software, it was designed to operate unchanged for long periods of time. "Yet the circuits embodying these programs are designed to accept a significant number of rewrites, so they can still be altered by cyberattackers," he says.

Engineers are making headway in protecting these chips. One new approach, described at a computer security conference in July, is a program that would scan random chunks of firmware code to check for signs of intrusion. Developers Ang Cui and Sal Stolfo of Columbia University say their "symbiote" can work with any type of firmware without slowing a computer's processing speed. It may also detect malware that no one had any way of noticing before, potentially shedding light on an "untold chapter of the history of Internet warfare," Cui says. They plan to deliver a prototype for U.S. government testing by the end of 2012.

Borg calls Stolfo and Cui's approach "very promising." Marc Dacier, a senior director at Symantec Research Labs, asserts that a major obstacle to any defense measure is getting companies to adopt it. The Pentagon is pushing for legislation to require the private sector to cooperate with government on cybersecurity issues. Without such legislation, Panetta said in his October speech, "we are, and we will be, vulnerable." —*Charles Q. Choi*

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ASTRONOMY

No Star Left Behind

What fuels a white dwarf's luminous nuclear detonation?

A type Ia supernova is perhaps the ultimate combination of insult and injury—a star steals material from a companion star, reaches critical mass, becomes unstable, and then unleashes a nuclear blast powerful enough to pulverize its victim.

The culprit in these cases is clear: type Ia supernovae arise from the cataclysmic explosions of small, dense stars known as white dwarfs. But the victim's identity is clouded. Traditionally, scientists believed that the victims were sunlike main-sequence stars or swollen giant stars. Recent studies have pointed to a major role for a lesser-known mechanism—pairings of two white dwarfs in which one cannibalizes its orbital companion before exploding as a supernova.

A study in the September 27 *Nature* bolsters the latter argument, concluding that only a small minority of type Ia supernovae stem from main-sequence or giant stars. (*Scientific American* is part of Nature Publishing Group.) Jonay González Hernández of the Astrophysics Institute of the Canary Islands and his colleagues looked for remnants of a victim star that precipitated the type Ia supernovae seen from Earth in the year 1006. They came up empty. The lack of a surviving companion seems to rule out any large star as a partner because the core of such a star should have weathered the blast and should remain visible today. But a white dwarf would have left no trace. In conjunction with other, mostly fruitless searches for supernova survivors, the researchers estimate that fewer than 20 percent of type Ia supernovae originate from the classically assumed scenario.

Astronomer Andrew Howell of Las Cumbres Observatory Global Telescope Network in Santa Barbara, Calif., calls the 20 percent figure a "vast overstatement." He notes that a normal star somewhat smaller than the sun also would not leave any detectable traces and would fit the bill for the companion to supernova 1006. *—John Matson*

Supernova 1006 remnant

X-RAY: NASA/CXC/RUTGERS/G.CASSAM-CHENAÏ, J. HUGHES ET AL.; RADIO: NRAO/AUI/NSF/GBT/VLA/DYER, MADDALENA & CORNWELL; OPTICAL: MIDDLEBURY COLLEGE/F. WINKLER, NOAO/AURA/NSF/CTIO SCHMIDT & DSS

POLICY

Chemically Unsound

The EPA needs to get up to speed, experts say

Traces of some of the nearly 80,000 chemical substances used by U.S. industry end up in the air, in consumer products and in drinking water. Yet the U.S. Environmental Protection Agency has only evaluated the safety of a few hundred of them. Last year the EPA pledged to speed and streamline its evaluation process. But some scientists argue that the agency needs to do more, including update the science behind its assessment approaches and incorporate data from other agencies.

One reason the EPA's chemical risk assessments are slow is that its scientists "tend to … keep trying to improve [an assessment] without thinking how much is too much," says Adam Finkel, executive director of the Penn Program on Regulation at the University of Pennsylvania. But "delay always costs society." The agency could speed its process by incorporating data from other organizations, says George Gray of George Washington University, a former EPA staffer who recently co-wrote an editorial on the topic in *Nature*.

Incorporating personnel from other organizations may help as well. In 2011 eight professional scientific societies, including the Endocrine Society, asked the EPA to put their scientists on regulatory panels to help improve accuracy. Among other things, the EPA has been using outdated science to study the effects of low doses of hormonelike chemicals such as bisphenol A, the societies argue.

Ultimately, Gray and his co-authors say, it makes sense for the EPA to embrace uncertainty. Instead of devising a single threshold value distinguishing safe from unsafe exposure, the agency should consider providing a range of values. "We should describe the risk as well as we can—given what we have—and get it out in the hands of people who have to make decisions that can affect their nation's health," he says. *—Melinda Wenner Moyer*

COMMENT AT ScientificAmerican.com/dec2012

NEUROSCIENCE

Model Mammals

Sheep are helping scientists gain ground against Huntington's disease

When University of Cambridge neurobiologist Jenny Morton began working with sheep five years ago, she anticipated docile, dull creatures. Instead she discovered that sheep are complex and curious. Morton, who studies neurodegenerative diseases such as Huntington's, is helping evaluate sheep as new large animal models for human brain diseases.

Huntington's is a fatal, hereditary illness that causes a cascade of cell death in the brain's basal ganglia region. The idea to use sheep to study this disease arose in 1993 in New Zealand, a country where sheep outnumber humans seven to one. Researchers had already identified disorders shared by humans and sheep, but University of Auckland neuroscientist Richard Faull and geneticist Russell Snell had a more ambitious notion. They decided to develop a line of sheep carrying Huntington's, which is brought on by repeats within the gene *IT15,* in the hopes of studying the condition's progression and developing a treatment. They accomplished their goal in 2006 after extensive efforts.

Why sheep? For one, they have big brains—comparable to macaques, which are the only other large animals currently used to study this disease—with developed, cortical folding like our own. Also, sheep can be kept in large paddocks with their fellows and monitored remotely via data-logger backpacks, allowing scientists to study these creatures in a natural setting with fewer ethical concerns than studying caged primates. What is more, these long-lived, social animals are active and expressive, recognize faces, and have long memories. They also learn quickly and engage in experiments readily. This has allowed Morton to develop cognitive tests similar to those given to humans. The researchers can study the full progression of Huntington's—which in humans is associated with gradual mental and motor decline—and compare the changes with the normal functioning of healthy individuals.

This spring Faull, Snell, Morton and their colleagues will begin monitoring two flocks of Huntington's sheep in Australia. One flock will be inoculated with one of the most promising therapies yet devised—a virus that silences *IT15*'s mutations—and the other will serve as the control. Currently no cure exists for any human brain disease. The researchers believe these studies could be a milestone. "The tragedy of this disease is enormous. It's a curse on the family," Faull says. "Maybe we can lift that curse." —*Daisy Yuhas*

GETTY IMAGES

GIFT GUIDE

All I Want for Christmas Is Dinosaur Dung

SCIENTIFIC AMERICAN combed through a wealth of educational toys and kids' books to come up with picks for the bug lover, the budding engineer, the mathematician, the geologist and even a future fashion designer

1 PARASITES UNLEASHED

$9.95 at zygotegames.com; ages 8 and up
In this zoologist-designed card game, players race to complete a parasite's life cycle, learning gross-out facts along the way.

2 BIRD MODEL KITS

$9.95 each at birdkit.com; ages 14 and up
Build mechanical flying birds that flap their wings with the aid of a wind-up rubber band. The kits require patience and precision, but the hard work pays off.

3 DINOSAUR DUNG

From $29 at theevolutionstore.com
Own your own chunk of fossilized dinosaur feces, aka coprolite, which scientists have used to study dinosaur diets and habitats.

4 ITSPHUN MATH SHAPES

$19.95 at itsphun.com; ages 8 and up
This beautifully designed set of foam interlocking shapes lets you build 3-D geometric sculptures. A pamphlet explains regular polygons and Platonic, Johnson and Archimedean solids. But kids will have fun just experimenting.

5 LITTLEBITS STARTER KIT

$104.95 at fatbraintoys.com; ages 8 and up
Designed by M.I.T. Media Lab alum Ayah Bdeir, littleBits are tiny circuit boards that snap together with magnets. The kit comes with a battery pack, LED lights, a pressure sensor, a dimmer and other components.

6 JR. SCIENTIST *TYRANNOSAURUS REX* SKELETON

$24.95 at abra-electronics.com; ages 8 and up
This build-it-yourself model also comes with gypsum molds for making dinosaur teeth and other fossils. An accompanying booklet details each bone and explains

Photograph by Sam Kaplan

what paleontologists have yet to learn about *Tyrannosaurus.*

7 A-HA! BRAINTEASER PUZZLES
$4.99 each at store.msichicago.org; ages 8 and up
These mini 3-D puzzles come in three levels—easy, medium and hard—and will keep youngsters challenged.

8 PROTOSNAP LILYPAD E-SEWING KIT
$24.95 at sparkfun.com; ages 10 and up
If you've ever wanted to make your own e-textiles, this beginner's kit, with conductive thread, five LED lights and an on/off switch, may help you land a future spot on *Project Runway.* Use the enclosed pattern or make your own.

9 A ROCK IS LIVELY
by Dianna Hutts Aston. Chronicle Books, 2012 ($16.99)
This beautifully illustrated book is packed with information about every rock imaginable: asteroids, geodes, rocks that crocodiles swallow to help them deep dive, and even the marble used to carve the statue of David.

10 INFINITY AND ME
by Kate Hosford. Carolrhoda Books, 2012 ($16.95)
A girl wonders about infinity and finds various imaginative ways to understand it, including the number of times one can cut a noodle in half and a never ending racetrack shaped like the infinity symbol itself.

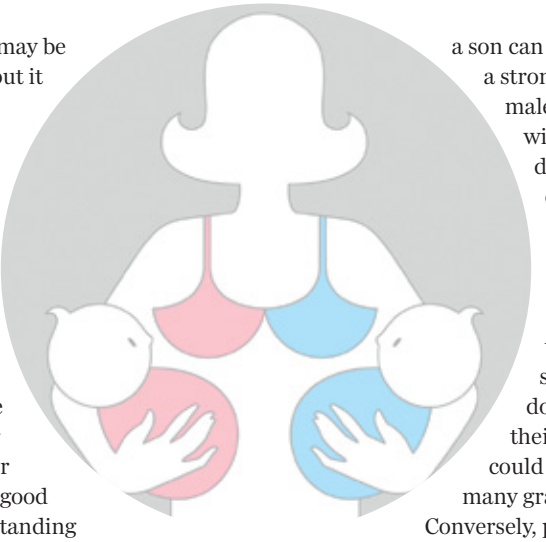
11 THE BEETLE BOOK
by Steve Jenkins. Houghton Mifflin, 2012 ($16.99)
An introduction to the fascinating world of beetles in all their colorful variety, including anatomy, reproduction, feeding habits, and ways they evade predators.

12 UNUSUAL CREATURES
by Michael Hearst. Chronicle Books, 2012 ($16.99)
Hearst's enthusiasm for these 50 animals is infectious as he walks kids through the stories of the blobfish, the three-toed sloth and others, as well as the threats many of them face.

EVOLUTION

His Milk, Her Milk

Milk composition differs based on a baby's sex and a mother's wealth



Mother's milk may be the first food, but it is not created equal. In humans and other mammals, researchers have found that milk composition changes depending on the infant's gender and on whether conditions are good or bad. Understanding those differences can give scientists insights into human evolution.

Researchers at Michigan State University and other institutions found that among 72 mothers in rural Kenya, women with sons generally gave richer milk (2.8 percent fat compared with 0.6 percent for daughters). Poor women, however, favored daughters with creamier milk (2.6 versus 2.3 percent). These findings, published in the *American Journal of Physical Anthropology* in September, echo previous work that showed milk composition varying with infant gender in gray seals and red deer and with infant gender and the mother's condition in rhesus macaques. The new study also follows findings that affluent, well-nourished moms in Massachusetts produced more energy-dense milk for male infants.

Together the studies provide support for a 40-year-old theory in evolutionary biology. The Trivers-Willard hypothesis states that natural selection favors parental investment in daughters when times are hard and in sons when times are easy. The imbalance should be greatest in polygamous societies, in which men can father offspring with multiple wives, such as the Kenyan villages. In those societies, a son can grow to be a strong, popular male with many wives and children, or he can end up with neither. Well-off parents who can afford to invest in sons should do so because their gamble could give them many grandchildren. Conversely, poor parents should not heavily invest in sons because it is unlikely to pay off—their offspring start at the bottom of the socioeconomic ladder. For those families, daughters are a safer bet because as long as they survive to adulthood, they are likely to produce young.

The new study is "exciting and enthralling," says Robert Trivers, an evolutionary biologist at Rutgers University and co-author of the hypothesis, who was not involved in the recent work. "It is a Trivers-Willard effect I wouldn't have the guts to predict."

Even beyond fat and protein, other milk components might vary in humans, says Katie Hinde, an assistant professor in human evolutionary biology at Harvard University. She has found higher levels of cortisol, a hormone that regulates metabolism, in rhesus macaque milk for male infants. Her work shows that milk differences could change infant behavior and might affect growth and development. "Only half the story is what the mom's producing," Hinde says. "The other [half] is how the infant uses the milk." These findings could have implications for formula, which could be tweaked to optimize development for both boys and girls.

—Marissa Fessenden

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Museum of Mathematics

EDUCATION

Too Cool for School

A Manhattan museum for math

Glen Whitney, a mathematician and former hedge fund manager, was disappointed when Long Island's Goudreau Museum, a small space devoted to math, closed a few years ago. His response: think much bigger. In December his Museum of Mathematics is scheduled to open near Manhattan's Flatiron District.

"From the moment you walk in, you will be surrounded by math, whether you know it or not," Whitney says. The museum is designed to be fun, but it also has a serious purpose. Cindy Lawrence, the museum's associate director, says the U.S. is not producing enough mathematically competent workers. That can be a national security concern because the National Security Agency is the country's leading employer of mathematicians and relies on them to analyze intelligence data. Part of the museum's mission, Lawrence says, is to educate kids about the range of mathematical careers available.

The museum will feature a wide range of interactive exhibits, from a square-wheeled tricycle that visitors can ride smoothly on a bumpy surface to a video camera that will allow users to "become" fractals. In the "Hyper Hyperboloid," a visitor can sit inside a mathematical surface and transform it with the twist of a dial.

Whitney and Lawrence hope that the museum will appeal to people across the spectrum of mathematical knowledge. As visitors enter the building, they select their mathematical comfort level on a computer, which encodes their ticket. Computers at exhibits will then display the appropriate explanation. Those who want to learn more can manually scroll through all the text.

The museum will also help support teachers. Its Rosenthal Prize for math teachers in grades four through 12 offers a cash prize and makes the winner's instructional materials available for others to use. —*Evelyn Lamb*

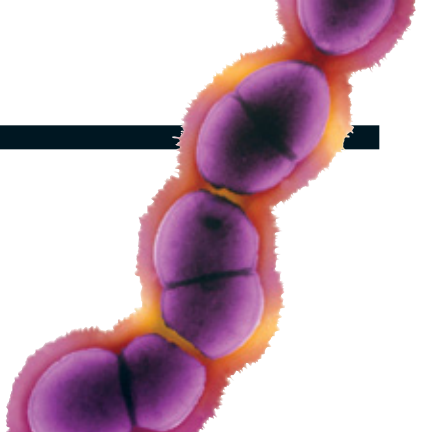
PATENT WATCH

Microfabricated tools and crystallization plates: Proteins catalyze reactions, shape cells and relay signals through the body. To understand how they work, researchers first figure out proteins' 3-D shape. Part of that process involves crystallizing proteins on rectangular plates with hundreds of individual wells. Current tools for protein crystallization have flaws: tiny tools to manipulate the protein crystals are rigid, vibrate easily and can damage fragile samples. Frustrated with the fuss, physicist Robert Thorne of Cornell University developed new tools and plates.

Patent No. 8,210,057 describes tools formed from plastic film. A gentle curve in the tools lends them strength—they are thin without being floppy. This same strategy is used by leaves and petals in nature, Thorne notes. One of the tools has "fingers" that can bend and gently grip protein crystals. Patent No. 7,666,259 details a new kind of protein crystallization plate, in which wells are replaced by micropatterned film. Drops stick to the surface even when the plate is upside down—held in place by surface tension from printed rings just 25 microns tall. The tools are already on the market, and the plates will be available later this year. —*Marissa Fessenden*

COURTESY OF MUSEUM OF MATHEMATICS *momath.org (top)*; FROM "DEVELOPMENT OF HIGH-PERFORMANCE X-RAY TRANSPARENT CRYSTALLIZATION PLATES FOR IN SITU PROTEIN CRYSTAL SCREENING AND ANALYSIS," BY AHMED S. M. SOLIMAN ET AL., IN *ACTA CRYSTALLOGRAPHICA SECTION D*, VOL. 67, NO. 7; JULY 2011 *(bottom)*

COMMENT AT ScientificAmerican.com/dec2012



KWANGSHIN KIM *Photo Researchers, Inc.*

HEALTH

Food Fight

Bacteria are changing the way we think about calories

Our guts are not entirely our own. Inside our intestines, human cells are at war with trillions of bacteria—a war over what happens to food as it moves through the body. Some microbes are beneficial, helping us extract energy from food; others lurk and wait for the chance to overrun our guts at the expense of our health.

A recent study adds nuance to scientists' evolving understanding of gut microbes. Ivana Semova and John Rawls of the University of North Carolina at Chapel Hill, along with their colleagues, studied the absorption of fatty acids in the intestines of tiny translucent zebra fish (*Danio rerio*). They found that the more the fish ate, the larger the population of a tribe of bacteria known as Firmicutes became in their guts and the more efficiently the fish's intestinal cells absorbed fat. The results mirror findings from studies with people and mice that have shown that high-calorie diets stimulate the growth of Firmicutes and that low-fat diets reduce their numbers. What remains unclear is whether Firmicutes are harmful or beneficial. Are they selfishly increasing their own numbers when the eating is good, forcing our cells to sweat to get the most out of our food? Or are they making digestion too easy, liberating so many calories from our food that we absorb far more than we need? Rawls suggests that the fish may recognize the presence of the bacteria and increase their own fatty acid absorption to compete with them. "It may not always be such a friendly arrangement," he says. —*Ferris Jabr*

Best of the Blogs

PALEONTOLOGY

Caveman Couture

Neandertals may have worn dark feathers

Experts agree that Neandertals hunted large game, controlled fire, wore animal furs and made stone tools. But whether they also engaged in activities deemed to be more advanced has been a matter of heated debate. Some researchers have argued that Neandertals lacked the know-how to effectively exploit small prey, such as birds, and that they did not routinely express themselves through language and other symbolic behaviors. Such shortcomings, so the story goes, put the Neandertals at a distinct disadvantage when anatomically modern humans possessing these skills invaded Europe—which was a Neandertal stronghold for hundreds of thousands of years—and presumably began competing with them.

New evidence suggesting that Neandertals hunted birds for their decorative feathers could force skeptics to rethink that view. In a paper published September 17 in *PLoS ONE,* paleontologist Clive Finlayson of the Gibraltar Museum, zooarchaeologist Jordi Rosell of Rovira i Virgili University in Tarragona, Spain, and their colleagues report on their analyses of animal remains from 1,699 fossil sites in Eurasia and North Africa spanning the Pleistocene epoch. Their results show that Neandertals across western Eurasia were strongly associated with corvids (ravens and the like) and raptors (eagles and their relatives)—more so than were the anatomically modern humans who succeeded them.

The Neandertals seem unlikely to have hunted these birds for food. People today do not eat corvids or raptors. Moreover, if the Neandertals did hunt the birds for food, one would expect to see signs of butchery on those bones linked to fleshy parts of the bird, such as the breastbone. Yet the team's study of the bird bones from the Gibraltar sites found the cut marks on wing bones, which have little meat.

Exactly what the Neandertals were doing with the feathers is unknown, but because they specifically sought out birds with dark plumage, the researchers suspect that our kissing cousins were festooning themselves with the resplendent flight feathers.

Bonelli's eagle

This is not the first time scientists have found evidence that Neandertals used feathers. In 2011 a team of Italian researchers reported on cut-marked bird bones from Neandertal levels in Fumane Cave in northern Italy that revealed this practice. Still, some researchers dismissed the find as an isolated phenomenon. The new findings suggest that feathers were de rigueur for thousands of years not only among Gibraltar's Neandertals but quite possibly for Neandertals across Eurasia.

Speakers at a conference on human evolution held in Gibraltar in September extolled the study and agreed with the team's interpretation of the remains as evidence that Neandertals adorned themselves with the feathers as opposed to using them for some strictly utilitarian purpose. Says paleoanthropologist John Hawks of the University of Wisconsin–Madison: "A purely utilitarian kind of person does not put on a feathered headdress." —*Kate Wong*

Adapted from the Observations blog at blogs.ScientificAmerican.com/observations

ASTROPHYSICS

A River Ran through It

Curiosity spots evidence of water on Mars

It's one thing to spot stuff from orbit above an alien world and quite another to get in close.

Earlier Mars Reconnaissance Orbiter imagery of Gale Crater, now home to NASA's Curiosity rover, had shown signs of what appeared to be something akin to an "alluvial fan"—a sign that at some previous time there had been a flow of liquid water washing into and across a section of the crater floor.

In September, Curiosity came across the ground truth, including a rocky outcrop that is made of gravelly pebbles (clasts) cemented together into a crusty conglomerate. This is a chunk of uptilted, uplifted ancient stream bed. The pebbles probably originated from the crater rim a few hundred meters higher up, and their range of sizes, somewhat rounded shapes and placement all point toward their having been washed and rolled in water that was somewhere between ankle and hip deep.

It is a remarkable discovery. Water has always been a prime contender for carving and depositing these structures, and now it really does seem that it once flowed, albeit perhaps temporarily, on the planetary surface to leave this formation of gravel fixed into a mudlike cement. Today Gale Crater may be drier than the driest desert on Earth, but a long time ago there was, at least, a brief respite as water gurgled and sparkled in the sunlight on Mars. —*Caleb A. Scharf*

Adapted from Scharf's Life Unbounded blog at blogs.ScientificAmerican.com/life-unbounded

BAS VAN DEN BOOGAARD *Minden Pictures*

COMMENT AT ScientificAmerican.com/dec2012

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EPIDEMICS

A Deadly Jet Set

A new tool helps airports track disease

The next time an illness like SARS threatens to sicken large numbers of people around the world, airports may have a new tool to help them prevent a pandemic. Transportation officials and public health experts are pilot testing a Web site that calculates the risk that passengers coming off any given flight are carrying an emerging infectious disease. With funding from the Transportation Research Board, part of the National Research Council, a team of investigators at the University of Florida used airline traffic figures, disease risk maps and climate data to come up with its online vector-borne disease airline importation risk (VBD-AIR) tool.

Officials can enter the name of the airport they are tracking, the month in question and the disease to be targeted—current choices are all mosquito-borne and include dengue, malaria, yellow fever and chikungunya, which was detected in Florida a few years ago. The result is a network of lines, color-coded by disease risk, that represent flights to the destination airport from all parts of the world.

If a passenger comes into an airport needing medical assistance or ends up at a hospital near the airport, officials need to be able to assess the situation quickly before it gets worse, says Andrew Tatem, an assistant professor in the University of Florida's Emerging Pathogens Institute and the school's department of geography. The VBD-AIR database might help prioritize which travelers coming into an airport should be screened, based on their risk of exposure and the disease's virulence, adds Tatem, one of the researchers who helped to develop the VBD-AIR program, which could also serve as a preventive measure by warning travelers of areas to avoid.

The researchers plan to expand the program to track infectious diseases such as leishmaniasis (found in certain areas of South America, Africa and the Middle East and transmitted by sand fly bites), Rift Valley fever (discovered in Kenya but now has spread to other areas of Africa and the Middle East), and Chagas disease (most commonly caused by insects found in South and Central America). *—Larry Greenemeier*

ECOLOGY

Cryptic Gardeners

Mole rats may not be pretty, but their mounds of dirt are crucial for biodiversity

Mole rats—known for their small eyes, grublike bodies and sometimes naked skin—mostly live underground. Yet they seem to dramatically affect aboveground ecological processes. A recent report in the *Journal of Zoology* showed that the burrowing activity of mole rats strongly influences the composition of plant communities in one of Africa's biodiversity hotspots, the Cape fynbos region in South Africa.

In the process of excavating their burrows, mole rats churn soil together with vegetation, uneaten food, and their own urine and feces. They then eject this blend of organic and inorganic matter from their burrow, forming characteristic mounds.

Scientists at the University of Pretoria found that mound soil was a lush nutrient resource for plants. It had high concentrations of nitrogen, magnesium, potassium, sodium and calcium, relative to control samples. The disturbed soil was also made of finer particles, as if an expert gardener had aerated it and primed it to retain a maximum amount of water.

Plants cannot pass up a good mineral hotspot, and scientists found that mole rats significantly boosted plant diversity on their mounds—perhaps by uprooting or burying common plants and allowing new ones the opportunity to colonize the site. Yet the total amount of plant material—the "plant biomass"—actually *decreased* on mound sites. Both mole rats and cattle prefer to graze in areas with enriched soil, which can limit the biomass of even the lushest carpet of plants. Also, the rodents sometimes bury living vegetation with soil when they eject refuse from their burrows, effectively removing those plants from the biomass tally.

Naked mole rat

The study is a reminder that animals can affect their environments in unexpected ways and that extinctions could have consequences no one has predicted.

—Anne-Marie Hodge

DIETER SPANNKNEBEL *Getty Images (top);* FRANS LANTING *Corbis (bottom)*

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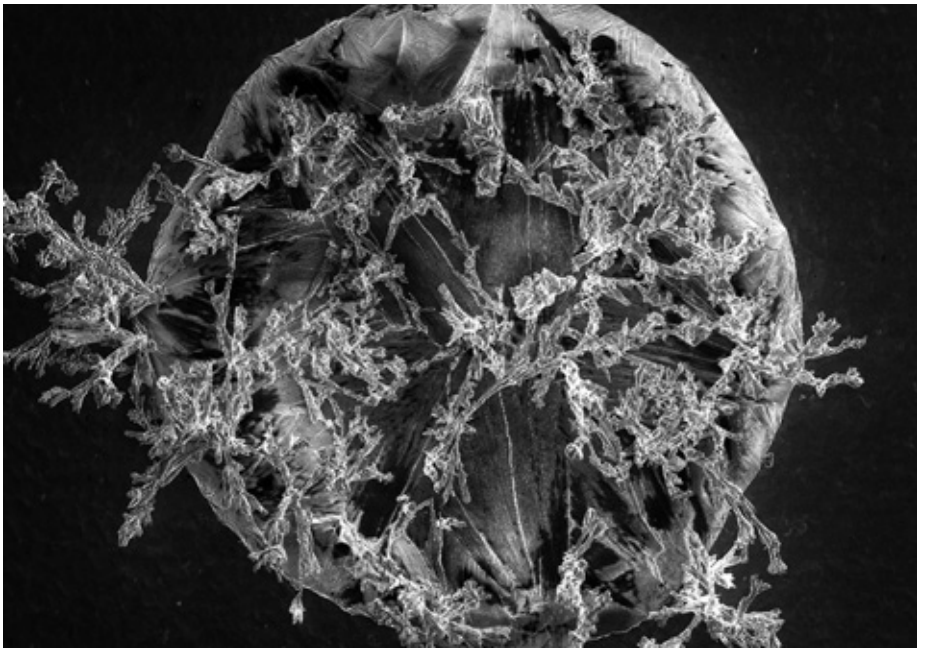


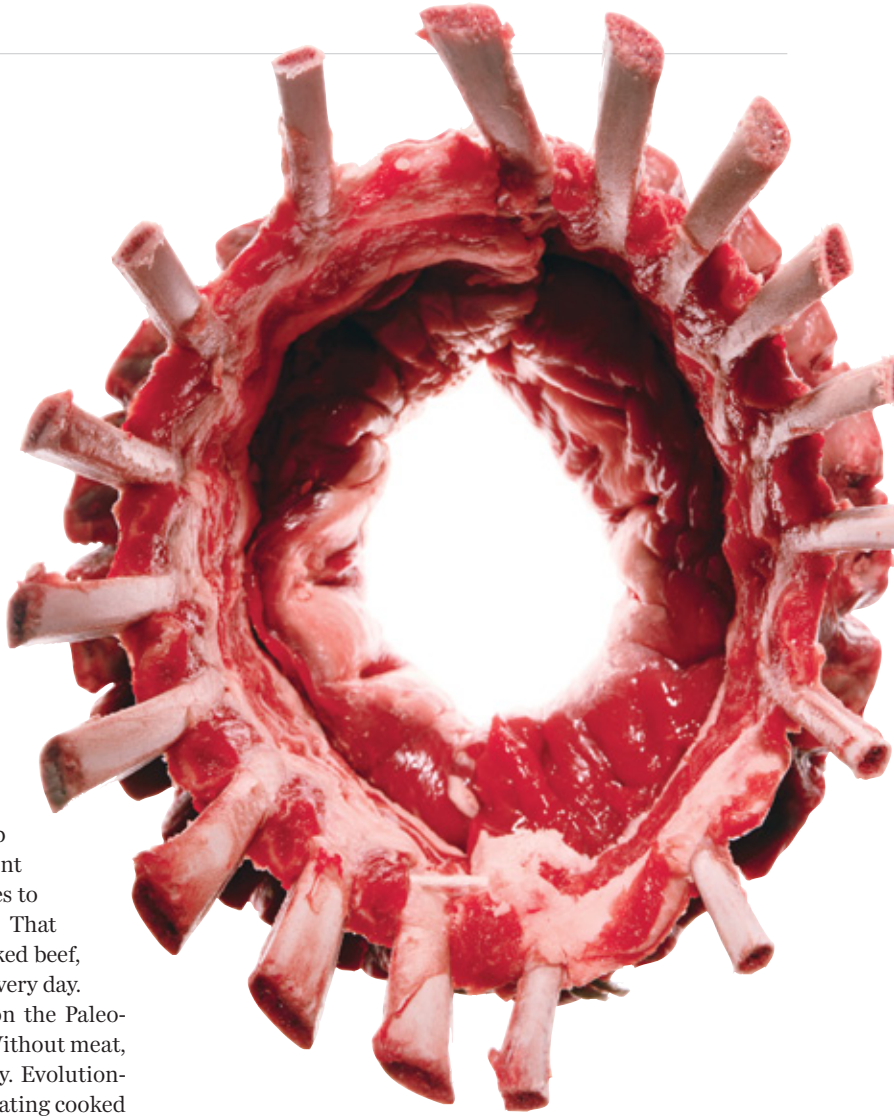
COURTESY OF HOLLIE ROSIER *Swansea University*

WHAT IS IT?

Salt of the sky: Hollie Rosier of Swansea University in Wales studies the tiny grains of salt found in the atmosphere and how they affect jet engines. The salt grain in this image is two millimeters in diameter. "Salt, along with elevated high temperatures and exhaust gases, could potentially accelerate corrosion," Rosier says of her ongoing research. This microscopic image was taken during one of her experiments and recently won the university's annual Research as Art competition. *—Ann Chin*

Meat of the Matter

Why steaks could be in, but hot dogs are still out



John Durant really likes meat, but he does not keep much of it in his refrigerator—there is not enough room. Instead he stores his meat in a large white freezer chest in his shared Manhattan apartment. Durant, 29, opens the chest and pulls out some frozen chunks of venison wrapped in butcher paper. He digs through the ice to find a couple of cuts of grass-fed beef. He shows me lamb kidneys, pork fatback and ham hocks. As a proponent of what is known as the Paleolithic diet, Durant tries to eat the same way our evolutionary ancestors did. That means big portions of meat, usually red meat—cooked beef, pork, lamb or flesh from other mammals—almost every day.

Durant, who is currently completing a book on the Paleolithic lifestyle, is correct about at least one thing. Without meat, humanity would probably not be where it is today. Evolutionary biologists have shown that hunting game and eating cooked meat significantly altered human anatomy and likely helped us develop bigger brains. Today meat is the largest source of protein in all affluent countries except Japan. Annual global consumption of meat might reach 376 million tons by 2030.

Yet most people in industrial nations live far more sedentary lives than early humans living millions of years ago. Whereas our ancestors worked hard to gather any food at all and most likely confronted the possibility of starvation between successful kills, many of us have easy access to calorie-rich meats whenever we want. Are we in fact eating more meat than is healthy?

Twenty years ago most nutritionists would have said, "Yes," especially when it comes to fatty cuts, such as hamburger or ribs. After all, the human body readily converts the saturated fat in such meats into cholesterol in the blood, which can in turn lead to atherosclerosis—a leading cause of both heart attack and stroke. In recent years, however, some researchers have questioned whether the link between red meat and cardiovascular disease is as strong as has long been assumed.

A few studies have begun to suggest that some of the ways in which meat is processed—that is, preserved with chemicals—or cooked may be more worrying than its saturated fat content. In addition, researchers now emphasize the importance of looking at the whole diet when trying to figure out what constitutes healthy eating habits. For example, deciding to cut back on red meat while compensating for the loss with comfort foods such as pizza, white bread and ice cream will probably not help anyone. In line with these more nuanced views, many nutritionists have tempered their advice. "A shotgun approach telling people to avoid all red meats may not be the biggest bang for your buck," says Dariush Mozaffarian, an epidemiologist at Harvard University. "Not all meats are the same. We have choices." How to make those choices, however, is the subject of ongoing debate.

MAN MEETS MEAT

BEFORE DELVING into recent, sometimes contradictory, findings about how eating red meat changes our health, it is worthwhile to consider the dietary habits of our evolutionary ancestors. Although the record is by no means complete—and our ancestors' diets varied widely by geography—paleontologists have gathered enough evidence to mark a few milestones. If we travel far enough back in time, to when our predecessors first split off from the last common ancestor we share with chimpanzees, they probably ate fruits, leaves and a smattering of termites. Meat was a very rare treat. As long as three million years ago, however, our ancestors had apparently learned to slice meat off of animal bones with stone tools. At first, these early humans might have primarily scavenged the kills of other predators, stealing bits of

CHRISTOPHER GRIFFITH *Trunk Archive*

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meat from a felled gazelle or chasing off smaller carnivores. Learning to cook with fire (at least 400,000 years ago) and the invention of stone spearheads (at least 200,000 years ago) dramatically improved our ancestors' chances of eating their fill.

Regularly eating meat and cooked foods changed our anatomy. Our teeth became smaller and less pointy, our colons shrank and our large intestines grew, all of which improved our ability to chew and digest soft, cooked foods. Calorie-dense meats likely enabled the tripling of our brain size as well. These and other adaptations helped our ancestors survive in a time very different from our own. The pertinent questions for today are whether the diets of our evolutionary past have any bearing on our current situation and how our modern approaches to preparing and consuming meat change our health.

RESERVATIONS ABOUT PRESERVATION

IN TRYING TO ANSWER THESE QUESTIONS, it is important to note right away that nutrition research is notoriously difficult to conduct. After all, scientists cannot ethically force some people to dine exclusively on red meat while others munch on lettuce to demonstrate the long-term health effects once and for all. But researchers have done the next best thing: surveying large groups of people about their diets.

Two studies from different teams of Harvard researchers exemplify the growing recognition that not all types of meat are equally unhealthy. This past spring Frank Hu and his colleagues concluded that eating red meat was indeed linked to a greater risk of cardiovascular disease, cancer and death from any cause. Specifically, each additional daily serving of unprocessed red meat (a serving is about the size of a deck of cards) increased the chances that someone would die by 13 percent; processed meat bumped up the death risk to 20 percent. These risks were calculated over a 22-year period for men and 28 years for women.

Translating those numbers into everyday terms requires some sophisticated math. Statistician David Spiegelhalter of the University of Cambridge used Hu's results to calculate that an adult who eats an extra serving of red meat each day would lose one year of life expectancy. Consider what that means for a healthy 40-year-old male, who can be expected to live another 36.2 years, according to FindtheData.org's analysis of the relevant Social Security data. Instead of making it just past his 76th birthday, he instead lives to 75.2 years. Nothing to shrug off—but certainly not the most deadly habit. Men and women who smoke, for example, lose an average of 13.2 and 14.5 years of life, respectively according to the Centers for Disease Control and Prevention.

Hu's study was not without limitations. It relied on self-reported surveys, which can skew the results in several ways. Equally problematic, it turns out that the participants who ate the most red meat were also more likely to smoke, drink alcohol in excess and exercise less often, making meat consumption seem unhealthier than it may truly be.

An alternative to Hu's conclusions emerged from another team at Harvard, led by Mozaffarian, who compiled and reviewed the results of 20 studies on eating meat. These 20 studies included data from more than 1.2 million people, whereas Hu's study looked at data from just over 120,000. The meta-analysis found no greater risk of death or disease tied to red meat in general; instead it singled out the dangers of processed red meat, such as bacon, salami and hot dogs. Mozaffarian and his colleagues associated each daily 50-gram serving of processed red meat with a 42 percent higher risk of heart disease and a 19 percent higher risk of diabetes.

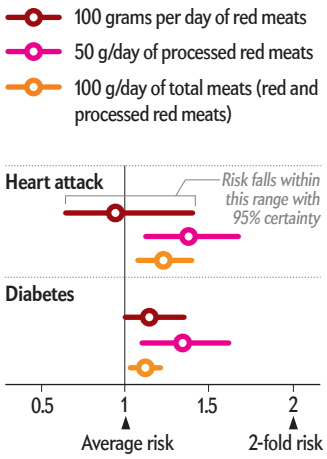
As in Hu's study, people who eat a lot of hot dogs and cold cuts might be less healthy overall. But such strong associations from a large review are nonetheless intriguing. Why would processed red meat be so much worse than unprocessed red meat? Both have fairly similar levels of saturated and unsaturated fats. In every 50-gram serving, however, processed meats contain more calories and less cholesterol, protein and iron than red meat.

The biggest discrepancy is the level of salt and other preservatives: processed meats generally contain four times more sodium than red meats and 50 percent more preservatives, particularly chemical compounds known as nitrates and nitrites, which help to kill bacteria and give meat an appealing pink or red hue. Some processed meats also contain nitrosamines, which form nitrites when meat is cooked at high temperatures or exposed to the acidity of the human stomach. Salt has been linked to higher blood pressure in susceptible individuals. Nitrates harden arteries and trigger metabolic changes that mimic diabetes. And nitrosamines have been linked to cancer in rodents, monkeys and people. (Mozaffarian's study did not address cooking methods. Survey studies suggest that people who eat a lot of well-done, fried or barbecued meat are slightly more likely to develop colorectal or pancreatic cancer.)

Ultimately, evaluating someone's health based on meat consumption alone, while ignoring other dietary choices and personal habits, does not make sense. Although humans no longer depend on meat in the same way as our ancestors, red meat remains an important global source of protein, iron and vitamin B_{12}. The best available evidence makes a convincing case against consuming too much processed red meat and overcooked meats but not necessarily against modest amounts of red meat. That is welcome news for those of us who enjoy the occasional steak—as well as for John Durant and his meat locker. SA

Ferris Jabr is an associate editor at Scientific American.

The Perils of Processed Meat



META-ANALYSIS of 20 studies found that eating red meat is not associated with statistically significant higher risks of cardiovascular disease or diabetes, despite a positive trend for the latter. Processed red meat, however, did increase risk for both conditions.

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GRAPHIC BY JEN CHRISTIANSEN; SOURCE: "RED AND PROCESSED MEAT CONSUMPTION AND RISK OF INCIDENT CORONARY HEART DISEASE, STROKE, AND DIABETES MELLITUS: A SYSTEMATIC REVIEW AND META-ANALYSIS," BY RENATA MICHA, SARAH K. WALLACE AND DARIUSH MOZAFFARIAN, IN *CIRCULATION*, VOL. 212, 2010

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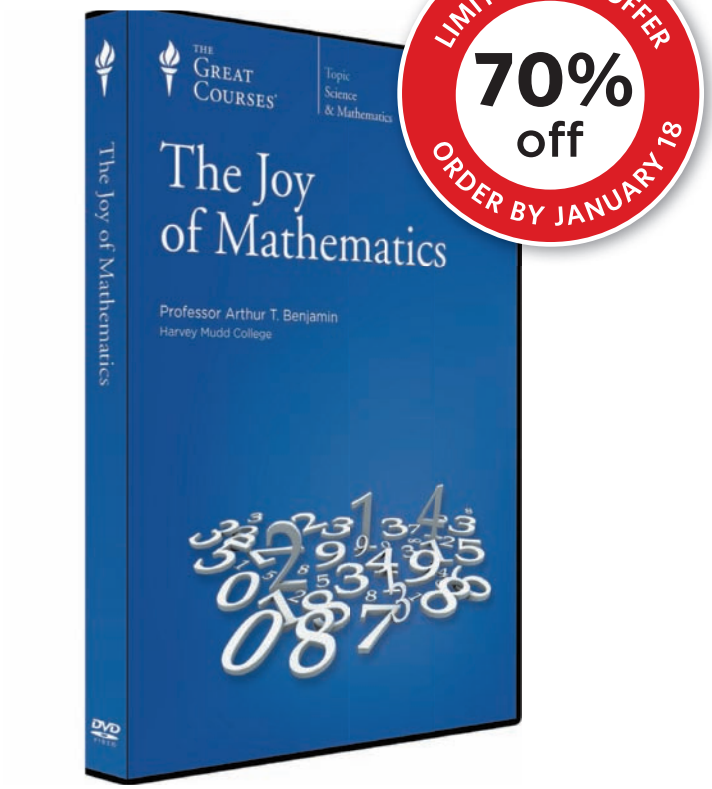

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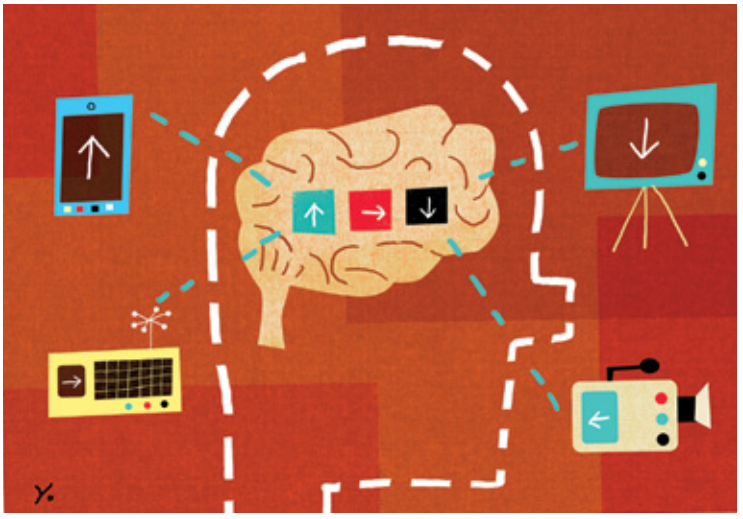
David Pogue is the personal-technology columnist for the *New York Times* and an Emmy Award–winning correspondent for *CBS News*.

The Remote Control in Your Mind

Forget voice control or gesture recognition. Gadgets may soon link directly to our brain



Okay, great: we can control our phones with speech recognition and our television sets with gesture recognition. But those technologies don't work in all situations for all people. So I say, forget about those crude beginnings; what we really want is *thought* recognition.

As I found out during research for a recent *NOVA* episode, it mostly appears that brain-computer interface (BCI) technology has not advanced very far just yet. For example, I tried to make a toy helicopter fly by thinking "up" as I wore a $300 commercial EEG headset. It barely worked.

Such "mind-reading" caps are quick to put on and noninvasive. They listen, through your scalp, for the incredibly weak remnants of electrical signals from your brain activity. But they're lousy at figuring out *where* in your brain they originated. Furthermore, the headset software didn't even know that I was thinking "up." I could just as easily have thought "goofy" or "shoelace" or "pickle"—whatever I had thought about during the 15-second training session.

There are other noninvasive brain scanners—magnetoencephalography, positron-emission tomography and near-infrared spectroscopy, and so on—but each also has its trade-offs.

Of course, you can implant sensors *inside* someone's skull for the best readings of all; immobilized patients have successfully manipulated computer cursors and robotic arms using this approach. Still, when it comes to controlling everyday electronics, brain surgery might be a tough sell.

My most astonishing discovery came at Carnegie Mellon University, where Marcel Just and Tom Mitchell have been using real-time functional MRI scanners to do some actual mind reading—or thought recognition, as they more responsibly call it.

As I lay in the fMRI, I saw 20 images on the screen (of a strawberry, skyscraper, cave, and so on). I was instructed to imagine the qualities of each object. The computer would try to figure out, from every two objects, the sequence of the two images I had just seen (whether strawberry had come before skyscraper, for example). It got them 100 percent right.

It turns out that, regardless of our native language or personal history, the same parts of our brain "light up" when we think of certain nouns. For "strawberry," we might think "red," "eat" or "hold in one hand." The computer knows which brain areas are active for which qualities. The system can also guess what number you're thinking of or which of 15 emotions you're feeling.

Now, much needs to happen before we can change TV channels just by thinking "CBS." In these early days, most BCI research is focused on how to help the disabled move or how to detect lies. And that work is raising plenty of questions about ethics, privacy and credibility. There will be other questions when thought recognition does come to gadgets. What happens if you get distracted when you're mind dictating an e-mail? Who wins if your spouse and you think about two different channels? And who's going to submit to an MRI to adjust music volume?

Just, who runs the Center for Cognitive Brain Imaging at Carnegie Mellon, isn't worried about that part. "Our machine is a monster," he told me. But "someday some biophysicist is going to develop some far smaller device, probably operating on a different principle." At this point, it is too early to see where BCI will land or even when it will take off. And that's fine. After all, when somebody invented the wheel, he or she probably didn't imagine Acela trains, roller coasters or skateboards right away.

Still, I've had my mind read, and I'm a believer. There's something brewing, and millions of dollars are being poured into the effort to refine it. The next great interface breakthrough may tap into the electrical device you were born with. SA

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WORLD CHANGING IDEAS

10 innovations that are radical enough to alter our lives

Illustrations by The Heads of State

Scientists and engineers dream about big advances that could change the world, and then they try to create them. On the following pages, *Scientific American* reveals 10 innovations that could be game changers: an artificial alternative to DNA, oil that cleans water, pacemakers powered by our blood, and more. These are not pie-in-the-sky notions but practical breakthroughs that have been proved or prototyped and are poised to scale up greatly. Each has the potential to make what may now seem impossible possible. *—The Editors*

New Life-Forms, No DNA Required

Artificial organisms based on man-made molecules could thrive and evolve

DNA IS PASSÉ. Synthetic biologists have invented an array of new molecules called XNAs that boast all the talents of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), as well as some special powers. XNAs could allow scientists to safely create life-forms in the laboratory that do not depend on DNA to survive and evolve.

"Life is inconceivable without a system for genetic information storage and replication, but DNA and RNA are not unique," explains Philipp Holliger of the Medical Research Council's Laboratory of Molecular Biology in Cambridge, England. "Related polymers—at least six more—can do the same function." That the earth's flora and fauna rely only on DNA and RNA, he says, is an "accident from the origin of life."

XNA stands for xeno nucleic acid (*xeno* meaning "foreign"). Like DNA, XNA has a structure that resembles a twisted ladder. In DNA, four different nucleobases, represented by the letters A, C, G and T, form the steps. Phosphate groups and sugars form the ladders' sides, also known as the backbone. For 30 years scientists have been tweaking the sugars to create artificial nucleic acids, which serve as research tools in medicine that can bind to DNA.

To make XNAs, Holliger and his colleagues did not simply alter the sugars in DNA's backbone—they substituted entirely different molecules, such as cyclohexane and threose. Just as important, they created enzymes that work with the XNAs to form a complete genetic system.

The enzymes enable XNAs to do something no other artificial nucleic acids can do: they evolve. Inside living cells, enzymes called polymerases cut, paste and splice DNA to access the genetic information. Without that interaction, DNA would remain as inert as dusty encyclopedias on a shelf. Holliger reprogrammed natural polymerase enzymes to translate DNA into XNA and back again, establishing a novel system for storing and transmitting genetic information, which is the foundation of evolution. One of the XNAs, HNA (anhydrohexitol nucleic acid), reliably preserved changes to its genetic code and evolved to attach to a protein with increasing precision.

Once Holliger improves the functionality of XNA and its enzymes, the set of molecules could replace DNA and RNA in a living cell. Researchers might take a simple bacterium, for instance, suck out its DNA and replace it with XNA.

Alternatively, scientists could enclose XNA within protocells—the origin of a new life-form that could evolve in ways no one can predict. Whereas other synthetic biologists such as J. Craig Venter have made remarkable advances in rewriting the existing genetic code, no one has created truly synthetic life—life that does not depend on what evolution has already provided but on humankind's inventions.

Holliger emphasizes that XNA-based life-forms are a long way off, but he already recognizes a distinct advantage. If such a creature escaped into the wild, it would die without a steady supply of XNA-specific enzymes. And XNA could not weave itself into the genomes of natural organisms, because their native enzymes would not recognize it. XNA-based bacteria designed to devour oil spills or turn wastewater into electricity, for example, could not interfere with native organisms.

The fact that XNA is complementary to DNA, yet structurally unique, makes it immediately useful for medicine, biotechnology and biology research. Holliger imagines XNAs that could be injected into the human body to detect early, subtle signs of disease that current technologies miss.

Steven Benner, a fellow at the Foundation for Applied Molecular Evolution in Gainesville, Fla., has also advanced the effort by expanding the genetic alphabet with two new nucleobases, Z and P. A larger alphabet could form a wider array of genes and, eventually, proteins. "The goal is to create chemically controlled systems that behave like biological systems, without being biological systems," Benner says. "We believe whatever you can draw on a page, you can make." —*Ferris Jabr*

Foam That Restores Breathing

Injectable oxygen microbubbles could give asthma and choking victims precious minutes

Only a few minutes after someone stops breathing—whether it is from a piece of meat stuck in the throat, a severe asthma attack or a lung injury—the brain starts to shut down. Cardiac arrest and death are imminent. Emergency responders and hospital workers have one primary recourse: insert a breathing tube through a patient's mouth. That procedure can be risky and time-consuming.

A new injectable solution could keep such people alive for 15 minutes or more, buying crucial time to get victims to a hospital or to do some surgical gymnastics in an operating room. The solution contains oxygen microbubbles, which the blood can absorb within seconds. The bubbles are too small to cause an air embolism—a gas pocket that stops blood flow, thus causing a stroke or heart attack.

To create this lifesaving foam, John Kheir, a cardiologist at Boston Children's Hospital, and his colleagues adapted existing medical nanotechnology. Microparticles with lipid membranes already deliver drugs, as well as dyes for ultrasound imaging. Kheir's team propelled phospholipids through an oxygenated chamber and used sound waves to spur the ingredients to self-assemble into microparticles. The

researchers then used a centrifuge to superconcentrate them into solution. Each four-micron-wide microbubble contains pure oxygen, surrounded by a lipid film that is just a few nanometers thick.

Because the bubbles contain oxygen at a pressure that is higher than in the bloodstream, the gas diffuses into red blood cells on contact. Once a bubble is depleted, the shell collapses to a disk that is less than a micron wide, easily passing through the circulatory system.

In a test, researchers blocked the airways of anesthetized rabbits for 15 minutes. Those injected with the solution were much less likely to go into cardiac arrest or have other organ damage than those who got saline solution—despite not taking a single breath.

The approach is "a fairly innovative idea compared to what we have now," says Raymond Koehler of Johns Hopkins University, who is not involved in the work, because most emergency oxygen procedures require the pulmonary system to function at least at a minimal level.

One drawback is that because the blood absorbs the oxygen so quickly, a constant infusion is necessary, which involves a lot of saline to help the foam move smoothly into the bloodstream. The amount of solution that a patient would receive after 15 minutes could lead to edema, a fluid overload that can cause heart failure. Kheir's team is trying to improve the formulation so that it requires less saline.

Another concern is that without normal respiration, carbon dioxide builds up in the body, which can be toxic. As Koehler notes, however, the body can handle a little excess carbon dioxide better than it can handle a total lack of oxygen. If the microbubbles prove successful in further animal (and subsequent human) trials, the solution could help emergency crews or operating room technicians buy crucial minutes before they can implement other lifesaving treatments. In those situations, Koehler says, "you want to have a backup plan." —*Katherine Harmon*

Early Treatment for Alzheimer's

A drug trial of 300 Colombians could reveal a way to prevent the disease from ever starting

Alzheimer's disease remains virtually untreatable. More than 100 experimental drugs have failed to halt the condition that robs people of their memories, their relationships and, ultimately, their identity. Now scientists will be testing a new strategy for preventing this horrific condition from starting in the first place. Just as healthy people take statins to lower their cholesterol and avoid heart disease, people at risk for Alzheimer's could conceivably pop pills to keep the disease at bay.

Researchers will be investigating a drug that flushes away an intrusive protein called amyloid, suspected as a primary contributor to Alzheimer's. Until recently, amyloid clumps could only be seen by dissecting the brain after death. Yet advanced positron-emission tomography scans of living people's brains, a recent innovation, show that by the time symptoms appear, amyloid has been silently accumulating for up to 20 years. Perhaps by then the brain is irreversibly damaged, making any drug useless. No one knows for sure, however, whether amyloid causes Alzheimer's or is merely a by-product of the disease. The new study may provide an answer to this mystery.

Set to start early in 2013 if all approvals are granted, the investigation will involve 300 members of distantly related families in Colombia whose rare and particularly devastating form of Alzheimer's strikes in the prime of life. By their 50s and 60s, many are as helpless as infants. Normally it is impossible to predict who will

Water Purified with Oil

A simple chemical trick could clean wastewater much less expensively

ANURAG BAJPAYEE started out looking for a better way to preserve human cells in deep freeze. Such cryopreservation must carefully avoid frostbite—the formation of ice crystals that rupture and kill cells. In 2008, while conducting experiments at Massachusetts General Hospital, Bajpayee inserted the antifreeze glycerol into the cells, along with soybean oil, which helped to concentrate the glycerol. During his Ph.D. qualifying exam the next year, at the Massachusetts Institute of Technology—typically a tense affair—a curious conversation broke out with his interviewers when he described the soybean oil's effect. Why not use the soybean oil, they proposed, to remove impurities from water? "I think it's one of the very few qualifying exams that resulted in a patent application," Bajpayee says.

Bajpayee soon created a simple process that uses an unusual class of oils to take contaminants out of water. The process could be a boon to cities, industries and agricultural operations—all of which create vast amounts of dirty water—by providing ways to clean that water that could be much less energy-intensive or expensive, or both.

Soybean oil is among a small number of oils that seem to serve as so-called directional solvents. That is, they dissolve water without dissolving other molecules that are in the water, such as salts. Soybean oil can absorb water when heated to as little as 40 degrees Celsius, leaving behind contaminant molecules, which are then skimmed away. Simply cooling the mixture allows the cleansed water to flow back out to be captured. The solvent thus remains undisturbed, ready to clean more water.

The key is the carbon backbone of the oil, a fatty acid. Most of it repels water, but at one end is a molecule, known as a carboxylic acid group, that readily forms a hydrogen bond with water.

"It surprised me that it would actually work," says organic chemist Jean-Claude Bradley of Drexel University, who also noted that the phenomenon could have been discovered a century ago. "It's the coolest thing I've seen in chemistry for a long time."

Bajpayee's experiments showed, however, that purifying a single cup of water would require enough soybean oil to fill a swimming pool. So he looked for another directional solvent that would be more efficient and settled on decanoic acid, which occurs naturally in milk and which bonds even more readily to water. This fatty acid could turn seawater into fresh, but it appears to work best for even saltier brines, such as the residue of mining or the chemical-laden water that flows back up oil and gas wells, including fracking wells. "If you thought that seawater was salty, this is eight times saltier," Bajpayee notes of the more than nine billion liters of contaminated water produced by the nation's oil and gas wells every day.

Encouraged, Bajpayee is already testing decanoic acid against six different oil and gas brines that were taken from different parts of the U.S. Conventional technologies for treating such wastewater include reverse osmosis, which requires special membranes that can clog and foul easily; distillation, which consumes copious amounts of energy; and, most commonly, dumping the water back down a disposal well. Bajpayee will also need to figure out a way to speedily process wastewater continuously rather than treating batches of it in beakers and test tubes.

To make a real impact in oil and gas drilling, "we'll have to beat the cost of the cheapest alternative, which right now is dumping," Bajpayee admits, although more and more communities do not want wastewater sent underground and lost that way. In the meantime, more research will tell if decanoic oil or some other directional solvent could cleanse dirty wastewater or desalinate seawater more inexpensively than current processes—giving water treatment a new direction.

—David Biello

develop Alzheimer's, but in this extended family, a single genetic mutation, detectable by a blood test, spells doom.

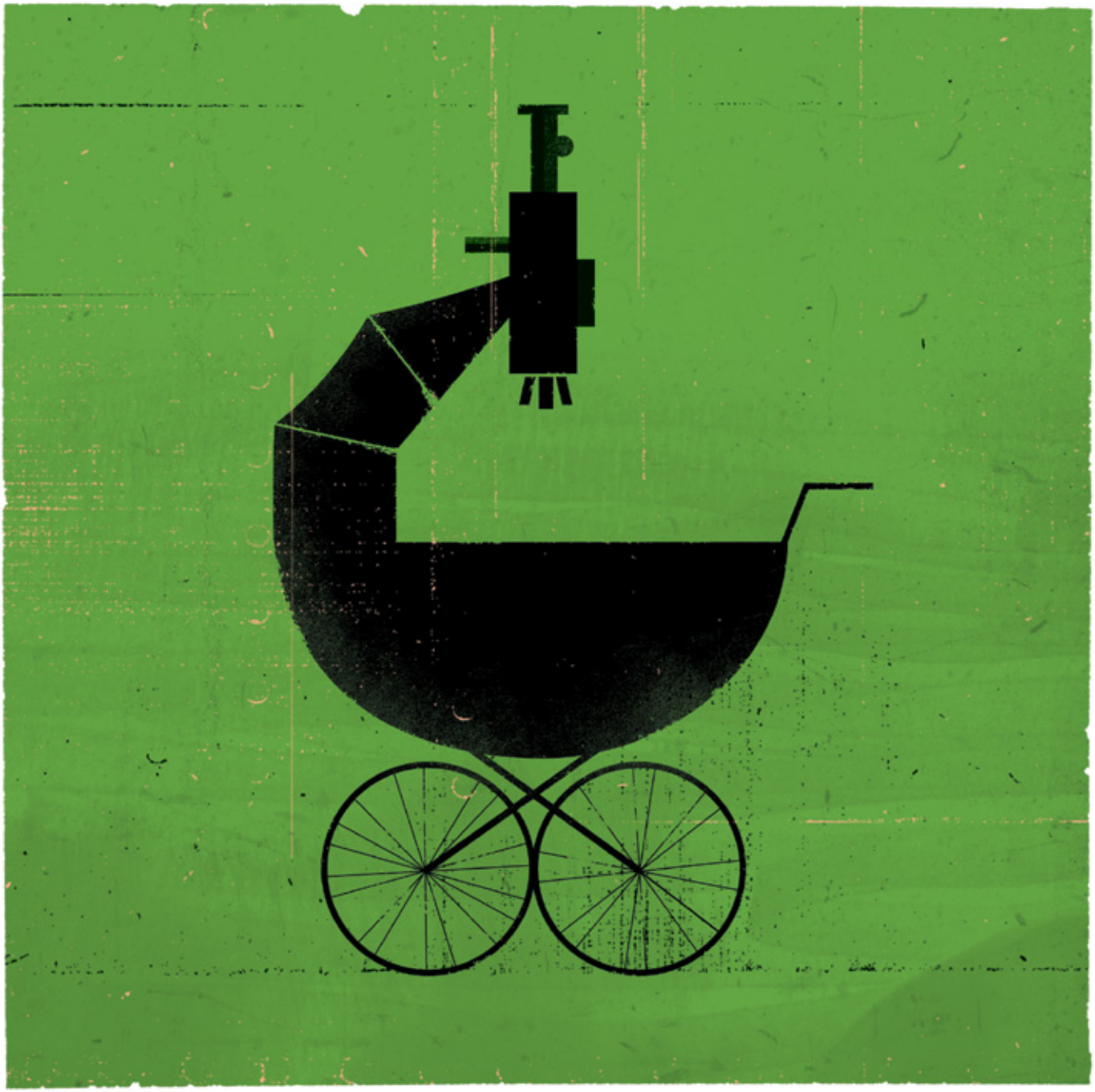
Eric Reiman, executive director of the Banner Alzheimer's Institute in Phoenix, his colleague Pierre Tariot and their Colombian collaborator Francisco Lopera realized that the family provided a unique opportunity to test the benefits of early intervention. They plan to give an experimental drug, crenezumab, to 100 family members who are on the cusp of developing Alzheimer's symptoms and a placebo to 100 others. A third group not destined to get the disease will also receive the placebo.

Participants will receive biweekly injections for at least five years. Every few months they will undergo extensive testing: magnetic resonance imaging to track brain shrinkage; spinal taps to measure tau protein, which is associated with brain cell death; and memory and thinking tests designed to pick up subtle cognitive lapses, such as forgetting a list of words that were memorized only minutes or hours earlier, a marker of emerging Alzheimer's.

The study will also enlist up to three dozen patients in the U.S. The Americans, who will receive the same treatment, will be a less homogeneous bunch, possessing various mutations in any of three genes linked to early-onset Alzheimer's. Investigators hope to learn whether it is possible to extrapolate from the Colombian family to others who are destined to develop dementia in middle age.

The $100-million study is funded by the drug's maker, Genentech, as well as by philanthropists and the National Institutes of Health. Even if the drug succeeds, there is no guarantee that the results will translate to the much more common form of Alzheimer's that afflicts the elderly. Yet the researchers hope this trial will establish for Alzheimer's what cholesterol and high blood pressure are for cardiovascular disease—intermediate signposts that aid research, diagnosis and treatment.

The data they collect could mean that instead of having to wait years to see whether an experimental drug helps patients, researchers could quickly gauge results from subtle biological shifts such as smaller brain size or changes in tau or amyloid deposits. "We need to develop faster ways to test the range of promising therapies and find ones that work as soon as possible," Reiman says. *—Emily Laber-Warren*



The Ultimate Sustainability Index

A new rating system exploits corporate pressure to clean up all stages of the supply chain

How "sustainable" is a can of soda or a bottle of shampoo? An increasing number of consumers want to base their buying decisions on the answer, but finding a comprehensive measure for the negative impact that the making of a product might have on the planet is difficult. Scores of "sustainability indexes" scrutinize discrete stages of the supply chain or different effects—such as landfill waste generated or carbon dioxide emitted—and use different metrics supported by different groups. The problem is not a lack of information; it is too much of it.

Judging products would be much easier if there were one set of metrics to evaluate environmental and social costs. That is the idea behind the Sustainability Consortium, a collection of 10 leading universities, large nonprofit organizations and 80 international companies—including Walmart, Coca-Cola and Disney—that have agreed to devise a standard index covering the entire supply chain. The group recently unveiled the measures its members will use to evaluate a first set of 100 products, ranging from breakfast cereals to laundry detergents to televisions.

Advocates such as Jeff Rice, Walmart's director of sustainability, argue that sustainable practices across the supply chain not only can clean up the environment but also can cut costs by, for instance, reducing the

Genome Sequencing for Fetuses

A noninvasive procedure could reveal thousands of disorders not discernible now

RESEARCHERS have recently shown that they can construct a complete genetic picture of a fetus—the full genome—simply by taking a blood sample from the mother. The procedure could revolutionize genetic screening by revealing single-gene disorders such as cystic fibrosis, Tay-Sachs disease or fragile X syndrome long before a fetus is born—giving doctors time to begin possible prenatal therapies and giving families time to prepare for their child's needs.

One percent of the population lives with a single-gene disorder. Since 2011 doctors have been able to determine from a mother's blood sample if her fetus has an abnormal chromosome, which could indicate conditions such as Down syndrome. That level of information cannot reveal most of the roughly 3,500 single-gene disorders, however. Physicians can withdraw a placental tissue or an amniotic fluid sample to check for those conditions, but these invasive tests carry a risk of miscarriage women may not be willing to take.

The new noninvasive approach would give mothers unprecedented detail about their child without endangering their pregnancy. It could also reach more women worldwide because the procedure does not require a trained obstetrician. Some researchers envision do-it-yourself kits that mothers would send to a lab.

The procedure stems from a discovery made in 1997, when chemical pathologist Dennis Lo, then at the University of Oxford, and his colleagues detected the presence of fetal DNA in a pregnant woman's blood plasma. That meant it was possible to separate the two DNA types and use the fetal portion to construct a full genome. Researchers started looking for haplotypes—clusters of adjacent gene sequences. Different search methods could distinguish the variety of haplotypes in a plasma sample and indicate which came from the mother or fetus. The haplotypes could then be reassembled into a full genome.

The approach was easier said than done; it would require sophisticated technology that has only recently become practical. In the past year geneticist Jay Shendure of the University of Washington developed a technique that entailed sequencing a full paternal and maternal genome from a father's saliva and a mother's blood, then using those data to distinguish between maternal and fetal haplotypes in the mother's plasma. In the process, Shendure can discern mutations that arise spontaneously in the fetus, which could help in spotting rare conditions.

Scientists led by Stanford University bioengineer Stephen Quake have reconstructed the fetal genome using only a maternal blood sample. They first seek haplotypes that the fetus inherits from the mother, which will likely be the most common in the plasma because mother and child share them. Quake then uses genetic markers from the mother to identify the rest of her genome. Haplotypes that do not appear in the mother's genome are unique to the fetus and may have come from the father or a mutation.

Despite progress, challenges remain—notably, lowering the cost and raising the accuracy of sequencing. The larger challenge is how to interpret the genome. "Our ability to detect genomic changes has outpaced our ability to correlate many of those changes with human diseases and characteristics," says Brenda Finucane, president of the National Society of Genetic Counselors. Many doctors believe it is premature to embrace screening before clear guidelines are set for its use.

Critics also fear that the procedure could lead to abortions, as parents discover that their fetus has an incurable condition. Yet doctors such as Diana Bianchi of Tufts University believe the benefits could outweigh fears—particularly if screening enables prenatal treatments that can alter debilitating diseases. *—Daisy Yuhas*

amount of waste that needs to be hauled away. Walmart is building the metrics into "scorecards" that it has begun distributing to the roughly 400 buyers who procure the retailer's products. Buyers will develop plans with suppliers to reduce environmental impacts, and whether suppliers act will be discussed in the buyers' performance reviews.

Consortium member Dell is already asking contractors that produce its LCD screens to figure out how to reduce the emission of perfluorocarbons (powerful greenhouse gases) created when the screens are manufactured. The consortium's data "gave us a guide of where to target our efforts," says Scott O'Connell, director of environmental affairs at Dell.

The consortium believes its index will ultimately supersede other ratings schemes. Consumers can already walk into a grocery store, whip out their mobile phones, scan a bar code on a bottle of shampoo and pull up a sustainability ranking compiled by GoodGuide. But the guide is built only on publicly available information. The consortium's ratings will factor in closely held data on emissions, waste, labor practices, water usage and other sensitive factors that will become available only as large corporate players exert pressure on suppliers to disclose them. The data should make the index more comprehensive than others. Companies the size of Walmart, Best Buy and Dell control hundreds of billions of dollars in annual spending by suppliers. "That in and of itself is going to make sustainability more mainstream than anything else ever has," Rice says.

It will be several years before consumers can access the index's data. Consortium leaders expect to make it available but have not yet determined how consumers would be able to access it. In the meantime, the index could spur innovation. Researchers at the University of California, Berkeley, for one, produced a white paper for the consortium reviewing the advantages of using bio-based materials in laptops instead of plastics. And scientists at the University of Arkansas are studying the best ways to evaluate impacts of various crop practices on water scarcity. *—Adam Piore*

Mining the Mobile Life

A wealth of data from smartphones is waiting to change our lives, if only we let it

The dream—or nightmare—of near-flawless surveillance is on us, and it is starting to change our lives in ways few of us could have imagined. Companies that parse location data emitted by our cell phones can now accurately predict where each of us will be at any point during the day. They can also figure out from phone records who our friends, family and co-workers are, when we are likely to get the flu, and what the demographics of any major metropolitan street corner will be at any moment.

The key to this explosion of data is smartphone penetration, which surpassed 50 percent in the U.S. this year. Nearly every one of those devices, by default, sends a steady stream of location data back to centralized servers because few users bother to opt out of such data collection or are even aware that they can. Scientists and commercial researchers are figuring out how to plow through the billions of coordinates, enough to chart the movements of millions of people.

This reality mining, a classic "big data" challenge, is in its infancy. Companies are just beginning to sell the data to marketers, and cell phone carriers are releasing to researchers only limited data sets that are "anonymized" to preserve the privacy of individuals. The three biggest players—Google, Apple and Skyhook in Boston, one of the original location service providers—are all treading lightly in handling this information, for fear that intrusive uses might provoke a consumer backlash.

The technology could provide widespread benefits such as fewer annoying ads and the containment of disease outbreaks. Yet to the few consumers who are aware of it, "this is very scary stuff—it's Promethean fire," says Alex "Sandy" Pentland, who coined the term

"reality mining" when he and his students pioneered the analysis of smartphone location data in the mid-2000s.

Currently firms such as Skyhook and PlaceIQ in New York City that repackage data for marketers are careful to make location traces on individual devices unavailable. Google says that it deletes almost all location data after about a week. Apple made the mistake of storing such data on the iPhone itself; the company has since rectified this faux pas, but it is still less than forthcoming about how it stores such information centrally and what it plans to do with it.

If the privacy concerns holding back greater use of the data can be addressed, reality mining could become essential to how we navigate our everyday lives, not to mention enormously useful for corporations and governments. For example, work in Haiti allowed relief agencies to send texts to cell phone users whose location histories indicated that they might have been exposed to cholera.

For reality mining to really take off, consumers would have to authorize use of even more of their data. That is one reason why Pentland pushed discussions that led to the proposal of the Consumer Privacy Bill of Rights in the U.S. and an update to the European Union's Data Protection Directive. If users feel like they control their data, they are more likely to let companies, governments and individuals selectively access the information to provide services. "There's no part of society that's not going to use these data," says Ted Morgan, CEO of Skyhook. "It fundamentally changes how you view human behavior."

Insights into consumer behavior could expand as a result. Researchers have already found that the people most likely to click on a smartphone ad—and therefore who offer the highest payoff to advertisers—are those who are sitting in a movie theater before a film has begun, anyone at home on a Sunday morning and fishers waiting for a bite. (PlaceIQ can guess that individuals are fishing because their coordinates put them in the middle of a lake and they happen to match a particular demographic profile.)

Pentland believes that once enough data are available, reality mining will enhance public health, transportation and the electric grid, just for starters. "I like this notion of society's nervous system," Pentland says. "Finally, humanity can sense what humanity is doing." *—Christopher Mims*

Sugar-Powered Pacemakers

The glucose in our blood could drive medical implants

PACEMAKERS, insulin pumps and other medical devices of the future may run without batteries, powered instead by the same energy that fuels the body: sugar. Researchers first dreamed of glucose-powered implants in the 1960s, but the advent of lithium-ion batteries in the late 1970s provided a simpler, more powerful fix. Batteries have always had a major drawback, however: they must be surgically replaced—every five to 15 years for pacemakers. Rechargeables connect to electronics outside the body with wires that pierce the skin and leave a person open to infection.

Several advances have prompted researchers to look again at glucose, which is plentiful in blood and the interstitial fluid that bathes our cells. More efficient circuitry in implants, for example, has reduced power requirements. And glucose biofuel cells are becoming much more efficient and body-friendly.

In most biofuel cells, enzymes at the anode strip electrons from glucose molecules. The electrons provide current as they flow to the cathode, where they react with oxygen, forming only small amounts of water. Unlike batteries, however, fuel cells need to be immersed in a constant supply of fuel—which blood or interstitial fluid can readily provide.

Excitement started to build in 2003, when researchers at the University of Texas at Austin built a tiny biofuel cell that generated power from a grape. Since then, a handful of groups have demonstrated practical devices. Past models demanded acidic conditions not found in the body, but researchers at Joseph Fourier University in Grenoble, France, packed biocompatible enzymes on a graphite base, which produced a milder chemistry. Their disk-shaped cell is half the diameter of a dime and slightly thinner. It is wrapped in material used for dialysis bags, which allows small molecules of glucose in but keeps enzymes from getting out. In a 2010 lab rat experiment, the device drew glucose from interstitial fluid and produced a stable power output of 1.8 microwatts for 11 days.

This year researchers at the Massachusetts Institute of Technology took another step toward commercialization. Engineer Rahul Sarpeshkar built a fuel cell as an integrated circuit on a silicon chip, using "the same easy-to-manufacture process as semiconductors," he says. His team wants to use cerebrospinal fluid to power brain-machine interfaces. The fluid, which cushions the brain and spinal cord, contains plenty of glucose yet few immune system cells that could work to reject the implant.

Sarpeshkar has crafted platinum electrodes, which do not irritate tissue or corrode, notes Sven Kerzenmacher, a chemical engineer at the University of Freiburg in Germany, who is also using the material in his designs. Still, the body can mount opposition to such an incursion; Kerzenmacher says biocompatibility is the biggest hurdle. His prototype fuel cell works well in buffer solutions in the lab, he says, but in body-fluid tests, amino acids in blood or serum caused the device to lose power.

While a Clarkson University group has implanted a biofuel cell in a snail, the Grenoble group is still the only one to successfully operate a glucose fuel cell inside a vertebrate. The M.I.T. design has not been tested in cerebrospinal fluid but in a buffer that approximates body-fluid chemistry. Yet Sarpeshkar is optimistic that biofuel cells could enter the market in 10 years. His silicon device produces a reliable power output of 3.4 microwatts per square centimeter. Current pacemakers need eight to 10 microwatts, a feasible goal. Cochlear implants require a few milliwatts, and artificial organs would require even more.

As sugar-powered implants advance, they are opening up the possibility of tiny medical devices. Perhaps nanoscale robots that run on glucose and dispense targeted drugs will one day swim from science fiction to reality. *—Marissa Fessenden*

Drones at Home

Tiny, unmanned aircraft are ready to warn you about traffic or spy on you in your backyard

Airborne eyes that peer down from the sky are already changing how science gets done and how wars are fought, and a commercial fleet of them is destined to radically change how we live our lives.

Scientists such as Lian Pin Koh of the Swiss Federal Institute of Technology and Serge Wich of Liverpool John Moores University in England are helping to create that intriguing and possibly unnerving future. After spending two and a half years and $250,000 tracking orangutans in Sumatra on foot, Koh and Wich devised a quicker, cheaper method. They bought a battery-powered model airplane and added an inexpensive open-source autopilot and high-resolution camera. For less than $2,000, they created a Conservation Drone—an autonomous plane with a 4.5-foot wingspan that uses GPS signals to fly preprogrammed routes and bring back remarkably detailed pictures and data about orangutan nests and new areas of deforestation. "We're still surprised how easy it was to assemble from off-the-shelf components," Koh says.

The first tests in early 2012 were so successful that other conservationists have been clamoring for their own planes. Working with a Swiss startup company, Koh and Wich have now built more than 20 drones.

The military already depends on big drones such as the Predator to fight enemies and on small autonomous planes and helicopters to scout paths for convoys or ferret out ambushes. Officers use them to find illegal activity along the U.S.-Mexico border. But civilian enthusiasts are getting into the act, too; they have customized drones to nab polluters, inspect drilling rigs, and take stunning pictures for movies and real

Electronic Tattoos

Ultrathin, flexible sensors could adorn packaging, accessories, even our bodies

Engineers have built circuitry on flexible plastics, but electronics may soon reach a far more pliable realm: circuits that we can wear on our bodies, like tattoos, to monitor our vital signs. The circuits could also be woven into clothing to power our smartphones and into food packaging to alert us about contamination.

Rather than looking for flexible substances that can conduct electricity, John Rogers, a materials scientist at the University of Illinois at Urbana-Champaign, got the idea to take common silicon circuitry and make it bendable. He and engineers at mc10, a firm in Cambridge, Mass., sanded silicon microchips, usually millimeters thick, down to 10 or 20 microns using well-established manufacturing processes. They also devised ultrathin wires to connect those chips to one another and to traditional input-output ports—wires that can bend, fold and stretch up to twice their original dimension.

Kevin Dowling, vice president of research and development at mc10, likens this configuration to "islands [the chips] that are anchored and oceans of interconnects" between them that can stretch or bend. "If you take a Slinky made of spring steel, that steel itself doesn't stretch very much," Dowling explains. "But a Slinky can stretch 40 to 50 times its original length without exceeding the plastic limits of the steel. In the same way, we can create metal or silicon interconnects."

Rogers, who co-founded mc10 and whose laboratory is the company's de facto R&D operation, says that in the next five to 10 years stretchable electronics will show up in forms no thicker than a Band-Aid. These sensors could monitor a person's body and transmit the results wirelessly. Already mc10 has a contract with Reebok for an apparel-based health monitor. The company also has a contract with the U.S. Army to determine whether it can produce flexible solar cells that can be integrated into soldiers' clothing and backpacks. In April, NASCAR driver Paulie Harraka tested a transparent skin patch during a race. The patch measured Harraka's level of hydration, an important consideration in a cockpit that can roast drivers for hours. Other engineers are also pursuing flexible biomedical tattoos, including Nanshu Lu of the University of Texas at Austin and a team at Korea University in Seoul.

Band-Aid-like sensors could stay on the body for up to a week, acting as "biostamps" or medical tattoos that could measure heart rate and perspiration. The circuitry is so thin and transparent that it looks like a small, see-through film on the skin.

The circuitry could one day be embedded inside the heart or the brain. Rogers imagines that hearts with arrhythmias could be sheathed in an artificial sac that would electronically sense and correct the organ's flawed rhythm. Such a sheath could deliver variable electrical stimulation to any location on the heart, thereby creating a much more nuanced shaping of the heart's beating than a pacemaker. Rogers also envisions "artificial skin over a burn site to provide artificial vasculature and, at the same time, drug delivery and stimulation to accelerate healing of that wound."

If mc10's technology scales up, one product could be a roll of stickers, each one a sensor. A person could bug a room with tiny stickers designed to pick up sound. Anything that a silicon chip can sense—strain, vibration, electric fields—could be measured by little paper-thin sensors. Worn on the body or in clothing, such devices could be powered by weak electromagnetic fields and could then use those same fields to report back via people's smartphones.

Wide application will depend on manufacturing innovations from electronics makers that license mc10's technology. As with other transformative electronics innovations—think of the LEDs that now light up everything from household bulbs to grocery stores—it is ultimately up to the thousands of consumer device makers to figure out how best to apply this foundational technology.

—Christopher Mims

estate listings. "Drones are going to change the world in profound ways," says Matthew Waite, a journalist-turned-professor at the University of Nebraska–Lincoln who is exploring the use of drones for journalism.

This revolution is being propelled by rapid advances in technology. With powerful smartphone chips and open-source hardware platforms such as Arduino, do-it-yourselfers and communities such as DIY Drones have begun to build inexpensive but sophisticated autopilots that transform radio-controlled aircraft into autonomous ones. Companies that build drones for the military are pitching their wares to police departments and government agencies. The U.S. Department of the Interior has already obtained 60 Raven planes, weighing 4.8 pounds apiece, from aviation pioneer AeroVironment, to observe roosting sandhill cranes and measure stream temperatures and sediment flows, among other tasks. Future possibilities seem endless: with sophisticated cameras and sensors, small drones could tell when crops need water, chart oil spills and report on traffic jams. "We're just at the tip of the iceberg of what's possible," says Mike Hutt, manager of the U.S. Geological Survey's National Unmanned Aircraft Systems Project Office.

The full iceberg will not come into view for several years, however, because the Federal Aviation Administration has banned commercial uses of drones, fearing the confusion and accidents that could occur if thousands of unmanned craft take to already crowded skies. The FAA basically allows flying by hobbyists, government agencies and researchers and usually limits the altitude to a few hundred feet. But the FAA Modernization and Reform Act of 2012, signed by President Barack Obama in February, requires the agency to develop rules permitting more civilian uses. The FAA is working with companies on the key technology: systems that allow drones to sense and avoid other flying objects. Final rules are expected by 2015, opening the door to an explosion of commercial applications.

The current pause before that explosion is a boon, Waite suggests. "Drones raise humongous questions about safety and ethics and law and privacy," he says. "But now we have a rare opportunity to think about how we are going to use a technology before we actually use it."

—John Carey

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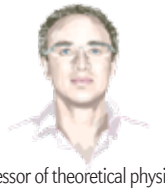


David Tong is professor of theoretical physics at the University of Cambridge. He previously held research positions in Boston, New York City, London and Mumbai. His interests have centered on quantum field theory, string theory, solitons and cosmology.

PHYSICS

The *Unquantum* Quantum

Quantum theorists often speak of the world as being pointillist at the smallest scales. Yet a closer look at the laws of nature suggests that the physical world is actually continuous—more analog than digital

By David Tong

Illustration by Kenn Brown, Mondolithic Studios

EDITORS' NOTE

Last year the Foundational Questions Institute's third essay contest posed the following question to physicists and philosophers: "Is Reality Digital or Analog?" The organizers expected entrants to come down on the side of digital. After all, the word "quantum" in quantum physics connotes "discrete"—hence, "digital." Many of the best essays held, however, that the world is analog. Among them was the entry by David Tong, who shared the second-place prize. The article here is a version of his essay.

In the late 1800s the famous German mathematician Leopold Kronecker proclaimed, "God made the integers, all else is the work of man." He believed that whole numbers play a fundamental role in mathematics. For today's physicists, the quote has a different resonance. It ties in with a belief that has become increasingly common over the past several decades: that nature is, at heart, discrete—that the building blocks of matter and of spacetime can be counted out, one by one. This idea goes back to the ancient Greek atomists but has extra potency in the digital age. Many physicists have come to think of the natural world as a vast computer described by discrete bits of information, with the laws of physics an algorithm, like the green digital rain seen by Neo at the end of the 1999 film *The Matrix*.

Yet is that really the way the laws of physics work? Although it might seem to contradict the spirit of the times, I, among many others, think that reality is ultimately analog rather than digital. In this view, the world is a true continuum. No matter how closely you zoom in, you will not find irreducible building blocks. Physical quantities are not integers but real numbers—continuous numbers, with an infinite number of digits after the decimal point. The known laws of physics, *Matrix* fans will be disappointed to learn, have features that no one knows how to simulate on a computer, no matter how many bytes its memory has. Appreciating this aspect of these laws is essential to developing a fully unified theory of physics.

AN ANCIENT ENIGMA

The debate between digital and analog is one of the oldest in physics. Whereas the atomists conceived of reality as discrete, other Greek philosophers such as Aristotle thought of it as a continuum. In Isaac Newton's day, which spanned the 17th and 18th centuries, natural philosophers were torn between particle (discrete) theories and wave (continuous) theories. By Kronecker's time, advocates of atomism, such as John Dalton, James Clerk Maxwell and Ludwig Boltzmann, were able to derive the laws of chemistry, thermodynamics and gases. But many scientists remained unconvinced.

Wilhelm Ostwald, winner of the 1909 Nobel Prize in Chemistry, pointed out that the laws of thermodynamics refer only to continuous quantities such as energy. Similarly, Maxwell's theory of electromagnetism describes electric and magnetic fields as continuous. Max Planck, who would later pioneer quantum mechanics, finished an influential paper in 1882 with the words: "Despite the great success that the atomic theory has so far enjoyed, ultimately it will have to be abandoned in favor of the assumption of continuous matter."

One of the most powerful arguments of the continuous camp was the seeming arbitrariness of discreteness. As an example: How many planets are there in the solar system? I was told at school that there are nine. In 2006 astronomers officially demoted Pluto from the planetary A-list, leaving just eight. At the same time, they introduced a B-list of dwarf planets. If you include these, the number increases to 13. In short, the only honest answer to the question of the number of planets is that it depends on how you count. The Kuiper belt beyond Neptune contains objects in size ranging from mere microns to a few thousand kilometers. You can count the number of planets only if you make a fairly arbitrary distinction between what is a planet, what is a dwarf planet, and what is just a lump of rock or ice.

Quantum mechanics ultimately transformed the digital-analog debate. Whereas the definition of a planet may be arbitrary, the definition of an atom or an elementary particle is not. The integers labeling chemical elements—which, we now know, count the number of protons in their constituent atoms—are objective. Regardless of what developments occur in physics, I will happily take bets that we will never observe an element with $\sqrt{500}$ protons that sits between titanium and vanadium. The integers in atomic physics are here to stay.

Another example occurs in spectroscopy, the study of light emitted and absorbed by matter. An atom of a particular type can emit only very specific colors of light, resulting in a distinctive fingerprint for each atom. Unlike human fingerprints, the spectra of atoms obey fixed mathematical rules. And these rules are governed by integers. The early attempts to understand quantum theory, most notably by Danish physicist Niels Bohr, placed discreteness at its heart.

EMERGENT INTEGERS

But Bohr's was not the final word. Erwin Schrödinger developed an alternative approach to quantum theory based on the idea of waves in 1925. The equation that he formulated to describe how these waves evolve contains only continuous quantities—no integers. Yet when you solve the Schrödinger equation for a specific system, a little bit of mathematical magic happens. Take the hydrogen atom: the electron orbits the proton at very specific distances. These fixed orbits translate into the spectrum of the atom. The atom is analogous to an organ pipe, which produces a discrete series of notes even though the air movement is continuous. At least as far as the atom is concerned, the lesson is clear: God did not make the integers. He made continuous numbers, and the rest is the work of the Schrödinger equation.

In other words, integers are not inputs of the theory, as Bohr thought. They are

IN BRIEF

Quantum mechanics is usually thought of as inherently discrete, yet its equations are formulated in terms of continuous quantities. Discrete values emerge depending on how a system is set up.

Digital partisans insist that the continuous quantities are, on closer inspection, discrete: they lie on a tightly spaced grid that gives the illusion of a continuum, like the pixels on a computer screen.

This idea of pixilated, discrete space contradicts at least one feature of nature, however: the asymmetry between left- and right-handed versions of elementary particles of matter.

outputs. The integers are an example of what physicists call an emergent quantity. In this view, the term "quantum mechanics" is a misnomer. Deep down, the theory is not quantum. In systems such as the hydrogen atom, the processes described by the theory mold discreteness from underlying continuity.

Perhaps more surprisingly, the existence of atoms, or indeed of any elementary particle, is also not an input of our theories. Physicists routinely teach that the building blocks of nature are discrete particles such as the electron or quark. That is a lie. The building blocks of our theories are not particles but fields: continuous, fluidlike objects spread throughout space. The electric and magnetic fields are familiar examples, but there are also an electron field, a quark field, a Higgs field, and several more. The objects that we call fundamental particles are not fundamental. Instead they are ripples of continuous fields.

A skeptic might say that the laws of physics do contain some integers. For example, these laws describe three kinds of neutrinos, six kinds of quarks (each of which comes in three varieties called colors), and so on. Integers, integers everywhere. Or are there? All these examples are really counting the number of particle species in the Standard Model, a quantity that is famously difficult to make mathematically precise when particles interact with one another. Particles can mutate: a neutron can split into a proton, an electron and a neutrino. Should we count it as one particle or three particles or four particles? The claim that there are three kinds of neutrinos, six kinds of quarks, and so on is an artifact of neglecting the interactions between particles.

Here is another example of an integer in the laws of physics: the number of observed spatial dimensions is three. Or is it? The famous late mathematician Benoît Mandelbrot pointed out that the number of spatial dimensions does not have to be an integer. The coastline of Great Britain, for example, has a dimension of around 1.3. Moreover, in many proposed unified theories of physics, such as string theory, the dimension of space is ambiguous. Spatial dimensions can emerge or dissolve.

I venture to say only one true integer may occur in all of physics. The laws of physics refer to one dimension of time. Without precisely one dimension of time, physics appears to become inconsistent.

INDISCRETE IDEAS

EVEN IF our current theories assume reality is continuous, many of my fellow physicists think that a discrete reality still underlies the continuity. They point to examples of how continuity can emerge from discreteness. On the macroscopic scales of everyday experience, the water in a glass appears to be smooth and continuous. It is only when you look much much closer that you see the atomic constituents. Could a mechanism of this type perhaps sit at the root of physics? Maybe if we looked at a deeper level, the smooth quantum fields of the Standard Model, or even spacetime itself, would also reveal an underlying discrete structure.

We do not know the answer to this question, but we can glean a clue from 40 years of efforts to simulate the Standard Model on a computer. To perform such a simulation, one must first take equations expressed in terms of continuous quantities and find a discrete formulation that is compatible with the bits of information in which computers trade. Despite decades of effort, no one has succeeded in doing that. It remains one of the most important, yet rarely mentioned, open problems in theoretical physics.

Physicists have developed a discretized version of quantum fields called lattice field theory. It replaces spacetime with a set of points. Computers evaluate quantities at these points to approximate a continuous field. The technique has limitations, however. The difficulty lies with electrons, quarks and other particles of matter, called fermions. Strangely, if you rotate a fermion by 360 degrees, you do not find the same object that you started with. Instead you have to turn a fermion by 720 degrees to get back to the same object. Fermions resist being put on a lattice. In the 1980s Holger Bech Nielsen of the Niels Bohr Institute in Copenhagen and Masao Ninomiya, now at the Okayama Institute for Quantum Physics in Japan, proved a celebrated theorem that it is impossible to discretize the simplest kind of fermion.

Such theorems are only as strong as their assumptions, and in the 1990s theorists, most notably David Kaplan, now at the University of Washington, and Herbert Neuberger of Rutgers University, introduced various creative methods to place fermions on the lattice. Quantum field theories come in many conceivable varieties, each with different possible types of fermions, and people can now formulate nearly every one on a lattice. There is just a single class of quantum field theory that people do not know how to put on a lattice. Unfortunately, that class includes the Standard Model. We can handle all kinds of hypothetical fermions but not the ones that actually exist.

Fermions in the Standard Model have a very special property. Those that spin in a counterclockwise direction feel the weak nuclear force, and those that spin in a clockwise direction do not. The theory is said to be chiral. A chiral theory is delicate. Subtle effects known as anomalies are always threatening to render it inconsistent. Such theories have so far resisted attempts to be modeled on a computer.

Yet chirality is not a bug of the Standard Model that might go away in a deeper theory; it is a core feature. At first glance, the Standard Model, based on three interlinking forces, seems to be an arbitrary construction. It is only when thinking about the chiral fermions that its true beauty emerges. It is a perfect jigsaw puzzle, with the three pieces locked together in the only manner possible. The chiral nature of fermions in the Standard Model makes everything fit together.

Scientists are not entirely sure what to make of our inability to simulate the Standard Model on a computer. It is difficult to draw strong conclusions from a failure to solve a problem; quite possibly the puzzle is just a very difficult one waiting to be solved with conventional techniques. But aspects of the problem smell deeper than that. The obstacles involved are intimately tied to mathematics of topology and geometry. The difficulty in placing chiral fermions on the lattice may be telling us something important: that the laws of physics are not, at heart, discrete. We are not living inside a computer simulation. SA

MORE TO EXPLORE

Quantum Field Theory in a Nutshell. Second edition. A. Zee. Princeton University Press, 2012.

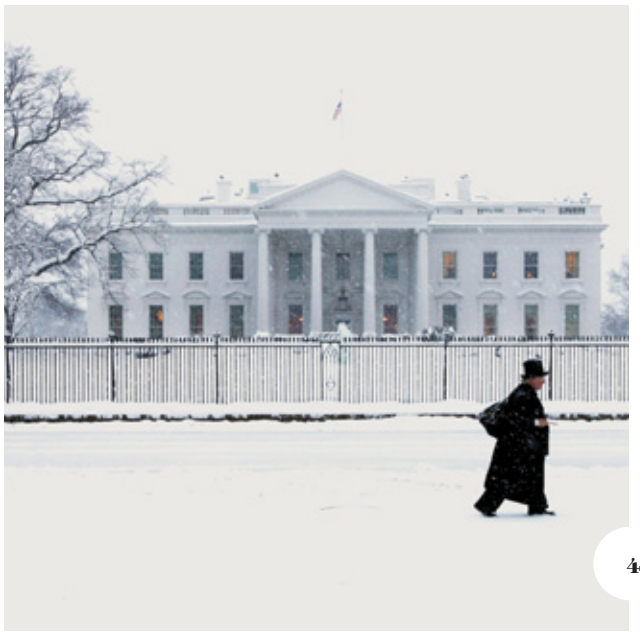
Chiral Symmetry and Lattice Fermions. David B. Kaplan. http://arxiv.org/abs/0912.2560

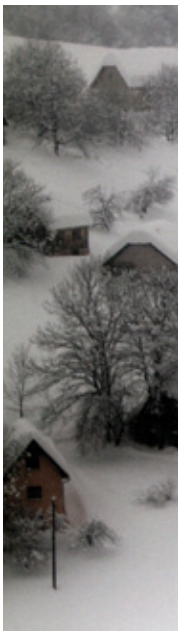
Helicity, Chirality, Mass, and the Higgs. Flip Tanedo. www.quantumdiaries.org/2011/06/19/helicity-chirality-mass-and-the-higgs

The Foundational Questions Institute essay contest entries: www.fqxi.org/community/essay

SCIENTIFIC AMERICAN ONLINE

To hear an interview with Tong, visit ScientificAmerican.com/dec2012/digital





HUMAN CONSEQUENCES

1. **Palma de Mallorca, Spain, Feb. 4, 2012:** Unexpected snow on the warm island of Majorca.
2., 3. **Carligu Mic, Romania, Feb. 11, 2012:** Some 35,000 people in the region were isolated from food and water. Sixteen people in the area died over two days.
4. **Washington, D.C., Feb. 10, 2010:** The "snowmageddon" blizzard shut down the federal government for nearly a week.
5. **Burgos, Spain, Feb. 5, 2012:** Cars ventured lightly on snow-blanketed highways.
6. **Eastern Bosnia and Herzegovina, Feb. 6, 2012:** An isolated village was completely cut off by snow.
7. **Constanta, Romania, on the Black Sea, Feb. 1, 2012:** Temperatures inland dropped to –34 degrees Celsius.
8. **Chicago, Feb. 2, 2011:** Hundreds of drivers were stranded for up to 12 hours on Lake Shore Drive.

3

6

8

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CLIMATE CHANGE

The Winters of Our Discontent

Loss of Arctic sea ice is stacking the deck in favor of harsh winter weather in the U.S. and Europe

By Charles H. Greene

THE PAST THREE WINTERS IN PARTS OF North America and Europe were unusual. First, during the winters of 2009–2011, the eastern seaboard of the U.S. and western and northern Europe endured a series of exceptionally cold and snowy storms—including the February 2010 "snowmageddon" storm in Washington, D.C., that shut down the federal government for

IN BRIEF

Global warming has increased the loss of summer sea ice in the Arctic, which has altered atmospheric conditions that influence winter weather in the U.S. and Europe.

The changes lead to invasions of Arctic air into the middle latitudes, increasing the likelihood of severe winter outbreaks, which occurred in the eastern U.S. and northern Europe in 2010 and 2011 and in eastern Europe in January 2012.

The deck may be stacked for harsh outbreaks during the 2012–2013 winter in North America and Europe.

nearly a week. Later that year, in October, the National Climatic Data Center (NCDC) forecasted a mild 2010–2011 winter for the eastern U.S., based on a La Niña pattern of cooler than usual ocean temperatures in the eastern Pacific. But even with La Niña's moderating effects, very low temperatures and record snowfalls hit New York City and Philadelphia during January 2011, catching the NCDC and other forecasters by surprise.

A weakened jet stream exhibits larger waves in its trajectory, which can get stalled in place, locking an affected region such as the northeastern U.S. in a prolonged deep freeze.

The winter of 2011–2012 brought even more surprises. The eastern U.S. had one of its mildest winters in history, while other parts of North America and Europe were less fortunate. In Alaska, the average January temperature across the state was a stunning 10 degrees Celsius below the month's long-term average. A single storm buried towns in southeastern Alaska in up to two meters of snow. At the same time, an extended outbreak of frigid weather descended on central and eastern Europe, bringing temperatures of –30 degrees C and snowdrifts that reached rooftops. By the time the deep freeze lifted in early February, more than 550 people had lost their lives.

How can we explain these outbreaks of severe weather, during a decade between 2002 and 2012 that was the warmest in the 160 years that instruments have tracked global temperatures? Scientists appear to have found an answer in a very unusual time and place: the recent, record-breaking losses of summer sea ice in the Arctic Ocean.

THE TRIGGER: RECORD ICE LOSS

THE ARCTIC has changed considerably since my first trip above the Arctic Circle in April 1989. The most obvious change has been the diminishing extent of sea ice during the summer. Every winter the Arctic Ocean almost completely freezes over. The winter sea ice is composed of thick, multiyear ice that has accumulated over time and much thinner first-year ice that has frozen in parts of the ocean that had been open water the previous summer. Each September the summer melting reduces the extent of the sea ice to its annual minimum.

Back in 1989, the winter sea-ice extent was slightly more than 14 million square kilometers. About seven million of that was the thick, multiyear ice that persists through the summer. The situation today is different. Although the extent of winter sea ice in 2012 was close to that of 1989, only about half—slightly less than 3.5 million square kilometers—survived through this past September, a record summertime low.

The loss of Arctic sea ice during summer has not been gradual or linear. From the time ice measurements by satellites began in 1979 until 2000, losses in sea-ice extent were not especially obvious. From 2000 to 2006 the rate of decline accelerated, but it was not until a significant change occurred in 2007 that the world took notice. During that one year, the minimum summer sea-ice extent dropped by 26 percent, from about 5.8 million square kilometers in September 2006 to about 4.3 million in September 2007. This unprecedented reduction in multiyear ice caused scientists to reassess their projections for when the Arctic Ocean would experience its first ice-free summer. Based on data collected prior to 2007, the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report had projected that the first ice-free summer would most likely occur toward the end of the 21st century. Most studies now project that the event could happen decades sooner, between 2020 and 2040.

The changes in sea ice are part of the amplification of global warming that has been impacting the Arctic during recent decades. Although the rest of the world has observed a modest average temperature increase of about 0.8 degree C since the beginning of the 20th century, average temperatures in the Arctic have warmed by more than double that amount over the past 50 years. This rapid warming has altered Arctic weather patterns and melted vast areas of permafrost. Such modifications of the physical environment have disrupted critical habitats for the region's wildlife and threatened the long-term survival of many species. Similarly, the Arctic's native peoples, long renowned for their cultural adaptations to the region's cold and ice, are witnessing a significant disruption to their way of life and an increasing threat to their heritage.

Although these changes may seem remote to most of us living below the polar regions, the rest of the Northern Hemisphere is not immune to the effects of Arctic amplification and sea-ice loss. Midlatitude weather patterns are affected by Arctic climate, which raises a key question: Is global warming behind the recently observed outbreaks of severe winter weather, or do the outbreaks simply fit into the general pattern of the planet's natural climate oscillations?

PRESSURE IN THE ATMOSPHERE

NATURE CERTAINLY MADE ITSELF FELT when I was growing up near Washington, D.C., in the 1960s, as I trudged through the snow to school with my friends during a decade of unusually harsh winters. Scientists now know that the sources of those cold and snowy winters were two natural climate oscillations referred to today as the Arctic Oscillation (AO) and the North Atlantic Oscillation (NAO), although they were unnamed at the time [*see box on page 54*]. These two climate oscillations arise from interactions between the atmosphere and ocean, exhibiting their most noticeable effects during the winter.

The strength of each oscillation is characterized by an index that quantifies anomalies—deviations from the long-term average—in the wintertime distribution of atmospheric pressure over a specific region. In the case of the AO index, the region is very large, encompassing most of the Northern Hemisphere, from the North Pole southward to the boundary of the tropics at 20° N (about the latitude of Cuba). The AO index can be positive or negative. Positive values correspond to lower than average pressures in the Arctic and higher than average pressures in the subtropics. During positive phases of the AO index, anomalously low pressures in the Arctic lead to a strengthening of the polar vortex, a persistent circulation of upper atmospheric winds flowing from west to east around the Arctic. A strengthened polar vortex tends to retain cold Arctic air masses north of the Arctic Circle.

In contrast, during negative phases of the AO index, anoma-

PRECEDING PAGES: DANIEL MIHAILESCU *Getty Images (1, 3, 7)*; JAMIE REINA *Getty Images (2)*; PABLO MARTÍNEZ MONSIVÁIS *AP Photo (4)*; CESAR MANSO *Getty Images (5)*; DADO RUVIC *Reuters (6)*; AP PHOTO *(8)*

lously weak low pressures in the Arctic weaken the polar vortex. It is less able to constrain cold Arctic air masses, allowing them to invade the middle latitudes to the south and deliver outbreaks of cold weather and increased snowfall. The U.S. eastern seaboard and northern Europe are especially vulnerable to these events during periods of strongly negative AO conditions.

The NAO index characterizes anomalies in the wintertime distribution of atmospheric pressure over a much smaller region, encompassing the Atlantic sector of the Northern Hemisphere between the subtropical high-pressure center near the Azores and the subarctic low-pressure center near Iceland. As is true for the AO index, the NAO index can also be positive or negative. Positive values correspond to higher than average atmospheric pressures near the subtropical high and lower than average pressures near the subarctic low. During positive NAO conditions, the enhanced pressure differences strengthen the westerly winds that blow year-round from west to east across the Northern Hemisphere's middle latitudes. The pressure differences also steer the fast-moving, circumglobal current of air known as the jet stream on a northeastward path from the eastern seaboard of North America toward northern Europe. Winter storms that cross the North Atlantic follow a similar track, delivering wetter and milder weather to northern Europe.

In contrast, during negative NAO conditions, reduced pressure differences weaken the westerly winds, and the jet stream leaving North America sweeps more sharply to the north, reaching Greenland before swinging back southward toward Europe. In this case, however, the storm track diverges from the jet stream, crossing the North Atlantic directly toward southern Europe and the Mediterranean, delivering wetter and milder weather to those areas. Northern Europe is left cold and dry.

Climate scientists disagree as to whether the AO and NAO should be treated as two distinct modes of natural climate variability. Some argue that the NAO is just a North Atlantic manifestation of the AO; others say that the dynamics of the two are different enough to warrant treating them separately. Although the two indices are highly correlated, their behaviors occasionally diverge in important ways, as they did last winter.

STACKING THE DECK FOR SEVERE WINTER WEATHER

AS SOCIETY'S GREENHOUSE gas emissions continue to alter the earth's climate system, whatever changes occur will be superimposed on the system's natural climate oscillationas. Discerning the human contributions to changes in climate is difficult and requires hypothesis testing. Recent research has provided new evidence strengthening the hypothesis that global warming and Arctic sea-ice loss are affecting our winters today by disrupting the normal rhythms of the AO and NAO.

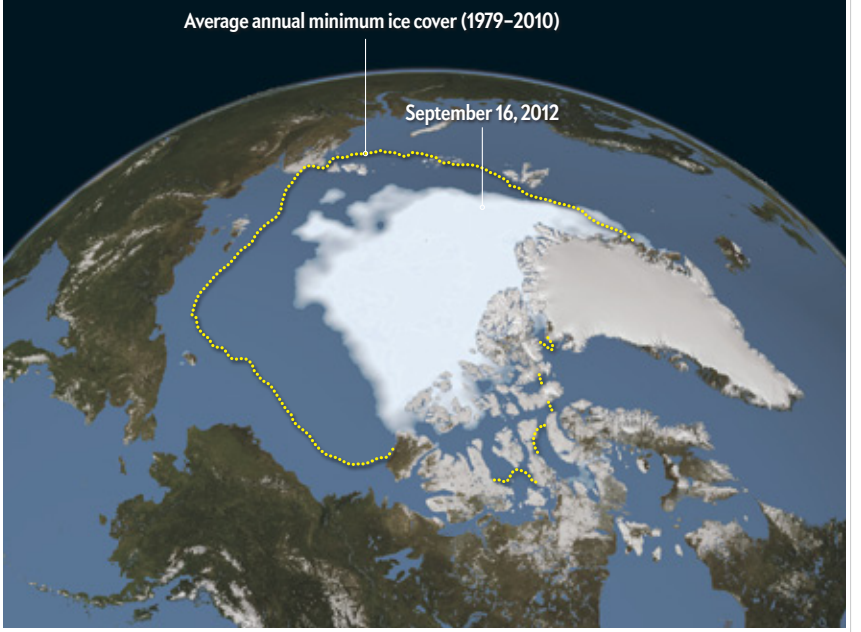
Looking back to my childhood in the 1960s, we see that the AO and NAO indices were predominantly negative, leading to winters that were snowier and colder than average along the eastern seaboard of the U.S. There is no reason to suspect that this decade of inclement winter weather was anything more than the natural variability to be expected from the AO and NAO. In contrast, from the 1970s to 1990s the NAO index was predominantly positive, with only an occasional negative NAO winter. The resulting mild winters coincided with increased societal awareness of global climate change and led many scientists to hypothesize that increasing concentrations of greenhouse gases might be behind what appeared to be an unusually long run of predominantly positive NAO winters. Models referenced by the IPCC predicted that this trend would continue with the steady rise in greenhouse gases. Yet the predominance of strongly positive AO and NAO winters came to a close during the latter half of the 1990s.

Although the run of positive NAO winters ended, that change does not mean the hypothesized relation between increasing greenhouse gases and the NAO was incorrect. What was not anticipated at the time was the acceleration of Arctic amplification starting in the late 1990s. As the amplified effects of global warm-

ROOT CAUSE

Loss of Sea Ice Alters Climate

Every winter ice covers the Arctic Ocean. Every summer a portion is lost, exposing the sea. Global warming has increased summer ice loss, which has altered heat exchange between the ocean and atmosphere, influencing winter weather across the U.S. and Europe [*see box on next page*]. In 1979, when satellite measurements began, the summer sea-ice extent was about seven million square kilometers. Since 2007 losses have increased dramatically; the extent hit a record low of 3.4 million square kilometers on September 16, 2012 (*below*).



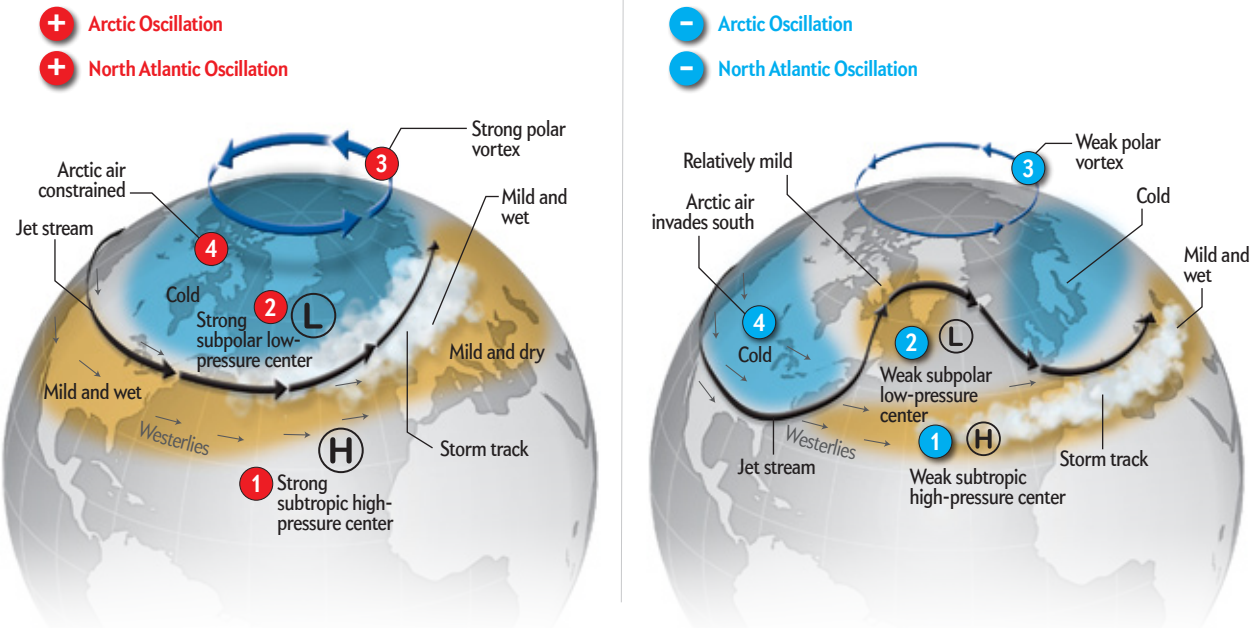
NASA GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO; BLUE MARBLE DATA COURTESY OF RETO STÖCKLI

Linking Climate and Weather

Two natural climate phenomena known as the Arctic Oscillation (AO) and the North Atlantic Oscillation (NAO) can strongly influence U.S. and European winter weather. Both exhibit positive and negative states, which are usually in sync (*below*). Extensive losses of Arctic summer sea ice have altered the climate in ways that favor the development of negative AO and NAO conditions, leading to more severe winters.

Positive AO and NAO states are characterized by a strong atmospheric high-pressure center (H) in the subtropics 1 and a strong low-pressure center (L) in the subarctic 2. The positive AO is also associated with a strong polar vortex 3, which constrains cold Arctic air to the north 4 and allows warm air from southern latitudes to reach far north into the U.S. and Europe. Under these conditions, the jet stream and the typical track of storms follow a northeastward path across the Atlantic, delivering warmth and moisture to northern Europe.

Negative AO and NAO states are characterized by weaker atmospheric pressures in the subtropics 1 and the subarctic 2. The negative AO is also associated with a weakened polar vortex 3, which allows cold air to invade south across the U.S. and northern Europe 4. Under these conditions, the jet stream takes a more sinusoidal path, dipping south over the eastern U.S., cresting over the Atlantic Ocean near Greenland, then dipping again toward southern Europe. Storms tend to follow a more direct, eastward path across the Atlantic, bringing moisture to southern Europe.



ing played out above the Arctic Circle, climatic conditions entered into a period that Jim Overland of the National Oceanic and Atmospheric Administration and his colleagues have called the Arctic Warm Period. This period has been characterized by rapid losses in Arctic sea ice, the Greenland ice sheet, permafrost and continental glaciers. Central to each of those changes is a process referred to as ice-albedo feedback, in which an area's reflection of incoming solar radiation is diminished as its ice cover melts, exposing darker land or sea surfaces.

Scientists have been especially concerned with ice-albedo feedback in the Arctic Ocean. The loss of summer sea ice exposes more ocean water to incoming solar radiation. The absorption of this radiation leads to excess heating of surface waters, which results in two important feedbacks. First, a portion of the excess heat reinforces the summertime melting of sea ice. Second, the ocean gradually releases much of the remaining excess heat into the atmosphere during the fall, increasing atmospheric pressure and moisture in the Arctic while decreasing the temperature differences between the Arctic and middle latitudes.

An increase in the Arctic atmospheric pressure and a decrease in the temperature gradient favor the development of negative AO and NAO conditions during winter. This situation leads to a weakening of the polar vortex and jet stream. A weakened polar vortex is less able to constrain cold Arctic air masses, with their elevated moisture content, from spilling down into the middle latitudes and delivering severe outbreaks of cold weather and snowfall.

Furthermore, a weakened jet stream exhibits larger waves in its trajectory, ones that can get stalled in place, locking an affected region in a deep freeze. In combination, these altered atmospheric circulation patterns tend to stack the deck in favor of more frequent and persistent outbreaks of severe winter weather in North America and Europe.

Other factors can come into play, however. The El Niño/Southern Oscillation, another powerful climate oscillation centered in the Pacific Ocean, can strongly influence winter weath-

Maps by XNR Productions

er across the continental U.S. In the eastern U.S., the jet stream shifts southward during El Niño years, bringing colder and harsher winter weather. It shifts northward during La Niña years, bringing warmer and milder winter weather to the same region. Together negative AO and NAO conditions during El Niño years can exacerbate the chance for cold, harsh winters along the eastern seaboard, which happened in 2009–2010. Negative AO and NAO conditions can also counteract the warm, mild winters expected during La Niña years. This was the situation during winter 2010–2011, when the low temperatures and record snowfalls in New York City and Philadelphia surprised forecasters who, based on the La Niña alone, were anticipating milder conditions.

THE WINTER AHEAD

ALTHOUGH CHANGES in the Arctic may have stacked the deck in favor of more frequent and persistent outbreaks of severe winter weather in the future, we can never be sure what hand will be dealt in any given year. After all, forecasting the weather always entails some level of uncertainty.

The 2011–2012 winter was a good example of the predictive challenges. The NCDC forecasted relatively mild weather in the eastern U.S. because of a developing La Niña in the Pacific. The AO and NAO indices had started off positive during the early winter, but then negative AO conditions emerged during mid-January and persisted through early February, while the NAO stayed positive. Alaska and parts of central and eastern Europe were buffeted by deadly cold and heavy snowstorms, while weather in the eastern U.S. remained unseasonably mild. La Niña had steered the jet stream much farther north over North America than usual during the mid-winter's negative AO conditions, allowing warmth from the Gulf of Mexico to move up to the eastern U.S., leading to the region's fourth warmest winter on record. The jet stream's more northern path also brought relatively mild conditions to the North Atlantic and western Europe.

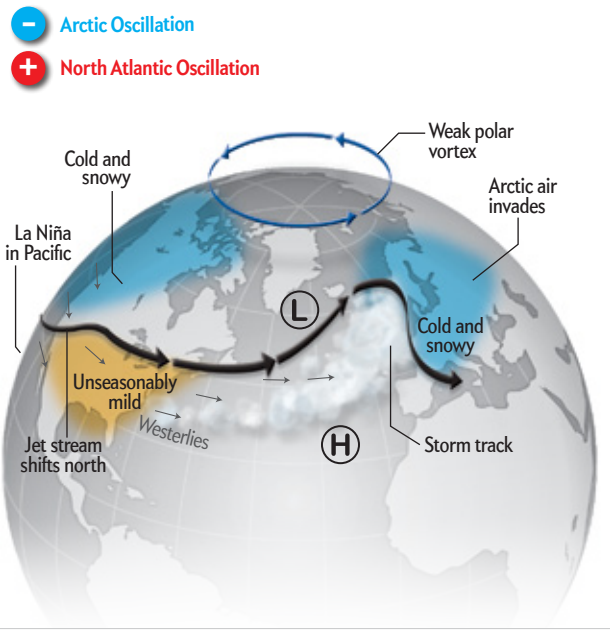
By early March a strong and persistent atmospheric high pressure system developed in the eastern Pacific, further amplifying the unusual weather conditions and resulting in record high temperatures throughout the Midwest and eastern U.S. Despite the persistence of unseasonable warmth there, however, it should be noted that other parts of the Northern Hemisphere ended up with an unusually cold winter and early spring. In fact, the NCDC reported that the average global temperature for March 2012 was the coolest since 1999.

For the upcoming winter of 2012–2013, the cards appear to be especially stacked in favor of harsh weather outbreaks in North America and Europe. The record-setting Arctic sea-ice loss observed during this past summer should enhance the probability of cold Arctic air masses invading midlatitude regions. Although it is difficult to predict which midlatitude regions will be most vulnerable, El Niño conditions developing in the Pacific during fall 2012 may favor a southward shift in the jet stream's trajectory, increasing the odds for a cold and punishing winter in the eastern U.S. The eastern seaboard could be especially vulnerable to the region's infamous nor'easter storms that bring bitter temperatures and deep snow. Although no one can say whether we will see a repeat of the unusually harsh nor'easters of winter 2009–2010, the summer and autumn buildup to the current winter bears a stronger resemblance to the conditions that unfolded during 2009 than to any other year since 2007, when the significant change in Arctic sea-ice loss occurred. As the next few months unfold, we will see what wild cards emerge in the hand we are dealt. SA

PUZZLE SOLVED

What Happened Last Winter

Unusual atmospheric conditions led to an odd combination of extreme cold and warm weather in the U.S. and Europe in 2012. The AO and NAO are usually in sync, either both positive or both negative. Last winter both were positive in December and early January, but the AO went negative from mid-January through early February. The change allowed Arctic air to invade and deliver very cold and snowy weather across central and eastern Europe. At the same time, a combination of negative AO and La Niña conditions in the Pacific resulted in very cold and snowy conditions in Alaska. La Niña also influenced the jet stream's path across the northern U.S., allowing warm air from the Gulf of Mexico to move up into the eastern U.S.



MORE TO EXPLORE

Climate Drives Sea Change. Charles H. Greene and Andrew J. Pershing in *Science,* Vol. 315, pages 1084–1085; February 23, 2007.

The Recent Arctic Warm Period. J. E. Overland, M. Wang and S. Salo in *Tellus,* Vol. 60, No. 4, pages 589–597; 2008.

An Arctic Wild Card in the Weather. Charles H. Greene and Bruce C. Monger in *Oceanography,* Vol. 25, No. 2, pages 7–9; 2012.

Evidence Linking Arctic Amplification to Extreme Weather in Mid-latitude. Jennifer A. Francis and Stephen J. Vavrus in *Geophysical Research Letters,* Vol. 39, Article No. L06801; March 17, 2012.

SCIENTIFIC AMERICAN ONLINE

For an animated map showing the record loss of Arctic sea ice during summer 2012, see ScientificAmerican.com/dec2012/greene

IS DRUG RESEARCH TRUSTWORTHY?

The pharmaceutical industry funnels money to prominent scientists who are doing research that affects its products—and nobody can stop it

By Charles Seife

WHEN ROBERT LINDSAY CHOSE TO BECOME A medical researcher in the early 1970s, he did not do it for the money. His field—the effect of hormones on bone—was a backwater. It was also a perfect opportunity for a young researcher to make his mark and, he hoped, help millions of people who suffered from the bone disease osteoporosis. As the body ages, sometimes bones lose the ability to rebuild themselves fast enough to keep pace with the normal process of

Illustration by Goni Montes

deterioration, and the skeleton weakens. Neither Lindsay nor anyone else understood much about why this happened, but there was reason to think that hormones might play a role. Some women develop osteoporosis shortly after menopause, when their hormone levels drop sharply, perhaps upsetting that balance between bone creation and destruction. If so, Lindsay reasoned, replacing the hormones with a pill might halt or even reverse the progress of the disease. From a tiny, underfunded clinic in Glasgow, Scotland, he set up one of the first clinical trials of estrogen replacement therapy for bone loss in postmenopausal women. Lindsay's star was rising.

His next project had big commercial implications and got the attention of the drug industry. Having moved to Helen Hayes Hospital, a rehabilitation center north of New York City, in 1984 he published work that established the minimum effective dosage of an antiosteoporosis estrogen drug called Premarin. Because the findings suggested that fighting osteoporosis was tantamount to encouraging millions of women to use the drug, it made Lindsay an important person in the eyes of the drug's manufacturer, Wyeth-Ayerst Laboratories. Indeed, the company gave him a role as an author of its informational video *Osteoporosis: A Preventable Tragedy*.

By the mid-1990s, when Wyeth got caught in a patent battle over Premarin, Lindsay was a staunch Wyeth ally. He came out against approval of a generic version of the drug that would have cut into sales even though the generic form would have made it easier for osteoporosis patients to receive therapy. His reasoning was that such versions might not be precisely equivalent to the brand-name drug, a fact that can be true with certain drugs but was also a position that happened to echo the company line. "All we're asking is that we don't approve something now and regret it" later, he told the Associated Press in 1995. Lindsay's close relationship with Wyeth and other drug companies carried on for decades, in ways that were sometimes hidden. He started allowing Wyeth to draft research articles and began taking tens of thousands of dollars from pharmaceutical interests that stood to gain from his research.

The scandal is not what Lindsay did so much as that his case is typical. In the past few years the pharmaceutical industry has come up with many ways to funnel large sums of money—enough sometimes to put a child through college—into the pockets of independent medical researchers who are doing work that bears, directly or indirectly, on the drugs these firms are making and marketing. The problem is not just with the drug companies and the researchers but with the whole system—the granting institutions, the research labs, the journals, the professional societies, and so forth. No one is providing the checks and balances necessary to avoid conflicts. Instead organizations seem to shift responsibility from one to the other, leaving gaps in enforcement that researchers and drug companies navigate with ease, and then shroud their deliberations in secrecy.

Charles Seife is a professor of journalism at New York University and author of *Proofiness: The Dark Arts of Mathematical Deception* (Viking, 2010).

"There isn't a single sector of academic medicine, academic research or medical education in which industry relationships are not a ubiquitous factor," says sociologist Eric Campbell, a professor of medicine at Harvard Medical School. Those relationships are not all bad. After all, without the help of the pharmaceutical industry, medical researchers would not be able to turn their ideas into new drugs. Yet at the same time, Campbell argues, some of these liaisons co-opt scientists into helping sell pharmaceuticals rather than generating new knowledge.

The entanglements between researchers and pharmaceutical companies take many forms. There are speakers bureaus: a drugmaker gives a researcher money to travel—often first class—to gigs around the country, where the researcher sometimes gives a company-written speech and presents company-drafted slides. There is ghostwriting: a pharmaceutical manufacturer has an article drafted and pays a scientist (the "guest author") an honorarium to put his or her name on it and submit it to a peer-reviewed journal. And then there is consulting: a company hires a researcher to render advice. Researchers "think what these companies are after are their brains, but they're really after the brand," says Marcia Angell, former editor in chief of the *New England Journal of Medicine*. "To buy a distinguished, senior academic researcher, the kind of person who speaks at meetings, who writes textbooks, who writes journal articles—that's worth 100,000 salespeople."

Peer-reviewed journals are littered with studies showing how drug industry money is subtly undermining scientific objectivity. A 2009 study in *Cancer* showed that participants somehow survived longer when a study's authors had conflicts of interest than when the authors were clean. A 1998 study in the *New England Journal of Medicine* found a "strong association" between researchers' conclusions about the safety of calcium channel blockers, a class of drugs used to reduce blood pressure, and their financial relationships with the firms producing the drugs.

It is not just an academic problem. Drugs are approved or rejected based on supposedly independent research. When a pill does not work as advertised and is withdrawn from the market or relabeled as dangerous, there is often a trail of biased research and cash to scientists. For example, in the mid-2000s, when patients started suing Wyeth about another estrogen drug, Prempro (which has been linked to the risk of breast cancer, strokes and certain other diseases), Wyeth's ghostwriting/

IN BRIEF

Many researchers maintain close financial ties to the drug companies that stand to gain from the results of their research.
Congress passed the Physician Payments Sunshine Act, which, starting in 2013, will compel pharmaceutical firms and medical device manufacturers to reveal most of the money that they are putting into the pockets of physicians.
Yet as the case study in this article shows, neither scientific institutions nor the scientists themselves have shown a willingness to police conflicts of interest in research.

SOURCE: SIGRID ESTRADA

guest-authorship arrangements became a central part of the case. When it was the turn of Merck's Vioxx painkiller (which was linked to heart attacks and strokes), drug industry money came up, too. In one Vioxx study, for example, academic researchers appear to have signed on to a Merck-sponsored project after the company had already done all the data analysis. According to a 2010 study that appeared in the *British Medical Journal,* 87 percent of researchers who expressed "favorable views" of GlaxoSmithKline's diabetes drug Avandia, despite indications that it might increase the risk of heart attacks, had some financial involvement with the drug's manufacturer. And when a U.S. Food and Drug Administration committee debated whether or not to pull Avandia from the market because of the link to heart attacks, it came out that members of the committee, too, had been taking money from drug companies.

The scientific community's answer to the conflict-of-interest problem is transparency. Journals, grant-making institutions and professional organizations press researchers to openly declare—to their research subjects, their colleagues and anyone else affected by their work—when they have any entanglements that might compromise their objectivity. That way the scientific community decides whether a study is ethical and, when the experiment is done, how far to trust the results. It is an honor system. Researchers often fail to report conflicts of interest—sometimes because they do not even realize that they present a problem. (*Scientific American* also asks for voluntary disclosures about conflicts from researchers who write articles.)

In theory, there is a backup system. Several layers of checking are supposed to ensure that conflicts of interest are caught and exposed even when an oblivious or dishonest researcher does not report them. When a scientist fails to report such a conflict, the university or hospital he or she works for is supposed to spot it and report it. And when a university or hospital is not doing its job catching conflicted research, then the government agency that funds most of that research—the National Institutes of Health—is supposed to step in. Unfortunately, that backup system is badly broken. "Institutions often look the other way, or they have policies in place that are quite weak," says Adriane Fugh-Berman, a professor in Georgetown University's department of pharmacology and physiology. More shockingly, the NIH is not only failing to enforce ethics laws intended to stop the creeping influence of drug company money, but it may also be breaking those laws.

Congress has been trying to stop corruption of medical research through legislation. In 2010, as part of the health care reform package, it passed the Physician Payments Sunshine Act. Starting in 2013, the law compels all pharmaceutical companies and medical device manufacturers to reveal most of the money that they are putting in the pockets of physicians. Because most (but not all) medical researchers are medical doctors, in theory, these data will help universities, research hospitals and the NIH to pin down whether a grantee has a potential conflict of interest. The information, however, will be worthless unless it is used.

The case of Robert Lindsay shows how deep the problem of conflicted medical research is and how difficult it will be to fix.

A THICKET OF ENTANGLEMENTS

THE EFFORT OF PHARMACEUTICAL COMPANIES to influence science discourse often takes the form of ghostwriting. Once a drugmaker can steer the way that a research article is written, it is able to control, to a large degree, how a scientific result is understood and used by clinicians and researchers.

One of Lindsay's most prestigious papers—a 2002 article demonstrating Prempro's beneficial effects on postmenopausal women—was initially drafted by DesignWrite, a firm that had been hired by Wyeth to ghostwrite articles for publication in the peer-reviewed literature. After meeting with Lindsay in mid-April 2001 to discuss developing the paper, DesignWrite then created an outline and forwarded it to Lindsay (and Wyeth). DesignWrite sent a draft to Lindsay for comments by early June, did some additional analysis and revised the manuscript. In August the *Journal of the American Medical Association* accepted it for publication. Later in the year DesignWrite revised the manuscript in response to comments, and the paper was published in May 2002. At the end of the article, Lindsay and his three co-authors thanked Karen Mittleman for her editorial assistance without identifying her as an employee of DesignWrite or disclosing its relationship with Wyeth.

Lindsay denies that DesignWrite had a large role in shaping the 2002 paper or any of his subsequent ones. Rather the firm would merely "provide a draft under our direction," he says. He and the other named co-authors were responsible for the design and direction of the study. If so, Lindsay deserves to be listed as a co-author of the paper, and Mittleman does not deserve anything more than the brief acknowledgment, according to Phil B. Fontanarosa, executive editor at *JAMA*. "It is not apparent that [Mittleman's] activities included conception and design (of the study), acquisition of data, or analysis and interpretation of data," he wrote in an e-mail to me.

This use of an outside writing firm was not a one-shot deal. Kathleen Ohleth, then a writer for DesignWrite, helped Lindsay draft a 2009 article for the journal *Fertility and Sterility.* (After my initial interview with Lindsay, he declined to answer any more questions, including those about who paid Ohleth in 2009, and referred me to a press officer.) Two years later, in an article in *Osteoporosis International,* Lindsay also thanked Ohleth for "medical writing support" and acknowledged that it was funded by Pfizer (which acquired Wyeth in 2009) but said that he "was the sole contributor to the concept and content direction of the paper." The article declared that a set of hormones in Pfizer's pipeline presented a "new paradigm for menopausal therapy."

At the same time that Lindsay was accepting writing support from Pfizer, he was accumulating a number of financial arrangements that posed a potential conflict of interest. According to a database compiled by the investigative journalism group ProPublica, in 2009 and 2010 Eli Lilly paid Lindsay more than $124,000, much of it for speaking fees.

Most peer-reviewed journals have rules about disclosure of financial relationships. Precisely what a scientist has to disclose depends on the subject matter and on the journal, so it is hard to pin down exactly when a researcher is breaking those rules. In a number of publications, Lindsay did disclose his relationship with Lilly, but he did not do so uniformly. For example, in a September 2010 article in the *Mayo Clinic Proceedings* about an osteoporosis study, many of the authors declared that they were on Lilly's speakers bureau or had other entanglements with the company, although Lindsay, also a co-author, did not. He subsequently told me that he had changed his mind about declaring this kind of relationship: "Up until fairly recently, my declarations included any

pharmaceutical company whose products were in my talk" or article, he told me. "I've changed that philosophy a bit because now, to make sure that there's real clarity, I would declare all contacts."

Even when the subject of a study was a Lilly product, Lindsay did not always reveal his financial relationship with the firm. His 2008 study in the *Journal of Clinical Endocrinology and Metabolism* on whether teriparatide, the basis of Lilly's drug Forteo, is affected by other osteoporosis drugs had no announcement that Lindsay had in recent years acted as a consultant and lecturer for Forteo's maker. "Since everyone in that study was treated with teriparatide, there was no capability to create a conflict," Lindsay says. "And, of course, [the study] wasn't supported in any way by Eli Lilly."

Lindsay's inconsistent disclosure practice goes beyond research articles. As a prominent investigator, Lindsay has been instrumental in publishing guidelines that other physicians use to treat osteoporosis. For instance, he helped to develop and write the National Osteoporosis Foundation's 2008 *Clinician's Guide to Prevention and Treatment of Osteoporosis*. The guide, which has been endorsed by numerous physicians associations, talks about treatment choices, including teriparatide. ("Teriparatide is generally well tolerated, although some patients experience leg cramps and dizziness," it says.) In a section marked "Disclosure," the guide states that of the authors, including Lindsay, none of them has "a relevant financial relationship with any commercial interest."

What is more, Lindsay apparently failed to mention these potential conflicts when applying for federal grants. Although he was a consultant for Lilly at least as far back as 2004, in 2005 he applied to the NIH, the agency in charge of most of the nation's federally supported medical research, to fund a study of Forteo: Lindsay wished to biopsy patients' bones to see how the drug was affecting their skeletal structure. He got the grant. Over the next few years the NIH gave Lindsay $3.4 million to study the drug. In 2010 he applied for a new grant to compare two methods of administering Forteo. Again, he received the grant, this time for $364,000, in 2010, and another, for $346,000, in 2011.

Federal regulations about potential conflicts of interest in NIH grants stipulate that a grantee has to identify any real or apparent conflicts of interest and report how any such conflicts have been managed, reduced or eliminated. Failure to do so is a violation of the law. It seems clear enough, but in practice it is not at all clear. Responsibility for enforcement gets shifted from one institution to the other to such an extent that conflicts such as Lindsay's often fall through the cracks.

FOLLOW THE CASH FLOW

THE NIH IS RESPONSIBLE for giving medical researchers tens of billions of dollars every year. With that much money at stake, there is tremendous potential for corruption. The NIH is not very good at stopping it because the agency is not aggressive about ferreting out conflicts of interest in its scientists' work. When approached for this story about potential breaches of ethics rules, NIH officials closed ranks.

Asked about possible conflicts of interest in Lindsay's grants to study teriparatide, Faye Chen, an NIH official, refused to provide copies of written assurances from Helen Hayes, Lindsay's employer—paperwork required by federal law—that conflicts of interest had been properly dealt with. She insisted that everything was in order. "The NIH is committed to preserving the public's trust that the research supported by the NIH is conducted without bias and with the highest scientific and ethical standards," she wrote in an e-mail to me. She added, "I can assure you that Dr. Lindsay's institution provided the required certification and assurance prior to receiving the award, and they will be required to provide this certification every year prior to award." Documents obtained through a Freedom of Information Act (FOIA) request contained no mention of any potential conflict of interest—nothing to indicate that Lindsay was taking money from the manufacturer of the drug being studied. NIH officials would not comment on whether or not they have followed up on the matter.

The NIH gives medical researchers tens of billions of dollars every year. With that much money at stake, there is tremendous potential for corruption. The NIH is not aggressive about ferreting out conflicts of interest.

The NIH's actions should come as no surprise. A few years ago the Department of Health and Human Services's Office of Inspector General got its hands on internal NIH communications that show that management discourages investigations into conflicts of interest among NIH-sponsored researchers. (In the interest of transparency: my wife works for the Office of Inspector General but did not have anything to do with these studies or this article.) For example, one memorandum stated, "We should not follow up for additional details about the nature of the conflict or how it was managed unless there is sufficient programmatic concern to do so."

Lindsay's case does not appear to be an isolated one. Scientists around the country are pursuing government-funded research at the same time that they are taking money from pharmaceutical companies, which often poses a potential conflict of interest. To get a sense of how much money is flowing from drug companies to NIH grantees, my students and I used a database that contains all NIH grants from 2009 and 2010 and used the ProPublica database of drug company payments to identify which ones were on a pharmaceutical manufacturer's payroll. We were able to identify $1.8 million in payments from a handful of drug companies to NIH grant recipients in New York State alone—payments for speakers bureau appearances, consulting jobs and other services. (The total payouts in New York are likely to be much higher.) Many of these payments might not pose actual conflicts of interest.

Grantees are not the only ones taking cash from drug companies—so are the people at the NIH who help to decide which researchers get the grants. Just as we used the ProPublica database to identify pharmaceutical industry payments to NIH-sponsored researchers, we used it to spot drug company money flowing to members of the NIH's advisory and review committees. All told, we found nearly 70 advisory committee members taking a total of more than $1 million for speakers bureau appearances, con-

sulting and other services to the drug companies. Some of these payments may be violations of federal ethics rules, which prohibit advisory committee members from participating in decisions that might affect an organization from which they are receiving substantial remunerations.

The problem, then, goes much deeper than NIH grantees. Drug company money has seeped into the NIH itself. If the agency knew about its employees' potential conflicts and failed to ensure that those conflicts did not affect their decisions on the committees, the agency itself is violating the law. To find out, I filed a Freedom of Information Act request for documentation that would indicate whether or not the NIH knew about drug company payments to its advisory committee members and, if so, whether it allowed the payees to perform their duties despite being on a pharmaceutical manufacturer's payroll. The NIH refused to turn those documents over; I sued. After a nine-month-long lawsuit, a federal judge forced the NIH to release what it had tried to keep hidden.

Some of the documents revealed by the lawsuit imply that the NIH's internal conflict-of-interest policing is largely devoted to finding missing forms. Further, they show that a number of NIH institutes appear to not have taken a single conflict-of-interest enforcement action against their employees since 2008. Yet the most revealing documents—ones that the NIH fought to keep hidden—have to do with what are known as waivers.

Under limited circumstances, the NIH can grant a waiver, which exempts a conflicted government employee (such as an advisory committee member) from ethics laws. I requested information about waivers that had been granted to several individuals sitting on NIH advisory committees, each of whom, I knew from the ProPublica database and other sources, had taken thousands of dollars from drug companies. I wanted to find out why the NIH was allowing these people to sit on committees despite a potential conflict—and, just as important, what the nature of those conflicts were.

The vast majority of the payments from drug companies were nowhere to be found in those waivers. For example, Louis Ptáček, who was then on the National Advisory Neurological Disorders and Stroke Council, was granted permission to take part in a number of meetings despite his numerous stock holdings in drug companies, but the waiver did not mention that he had received more than $50,000 as a consultant for Pfizer. (Ptáček did not respond to a request for comment.) Similarly, a waiver for Arul Chinnaiyan, who sits on the National Cancer Institute's Board of Scientific Advisors, did not indicate that he had received, from GlaxoSmithKline, $9,000 in 2009 and $21,000 in 2010. But Chinnaiyan said that he had disclosed these arrangements with the NIH. Why, then, did they not appear on his waiver?

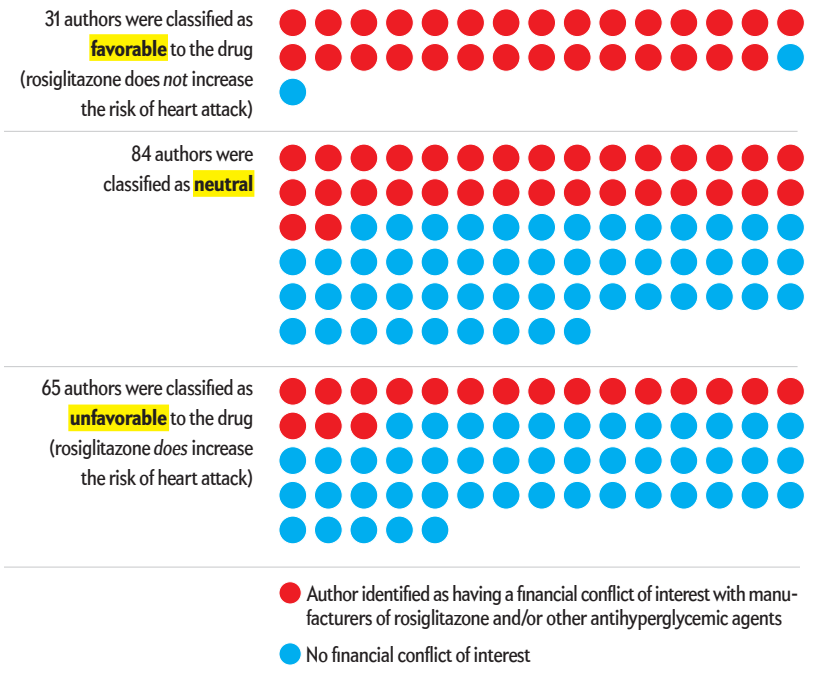
The NIH would not comment on individual cases. An NIH official agreed to speak on general policy but only under the condition that she not be named. Consulting fees and speakers bureau arrangements, she said, generally would not be listed on a waiver but instead on a separate document that deals with specific issues about which committee members must recuse themselves. As this article went to press, Susan Cornell, a FOIA officer at NIH, confirmed that the agency had failed to hand over certain recusal documents in response to my FOIA request, as it was supposed to do.

The NIH's inconsistent disclosure of documents and the secrecy behind them make it impossible to say with absolute certainty what is going on. At the very least, the NIH is doing a sloppy job of policing potential conflicts. For example, if consulting arrangements belong on a recusal document, why do Lawrence R. Stanberry's consulting arrangements with GlaxoSmithKline and Starpharma appear on his waiver? (Stanberry, chair of the pediatrics department at Columbia University's College of Physicians and Surgeons, sits on the National Institute of Allergy and Infectious

DRUG SAFETY

Case Study: Conflicting Interests

To what degree do financial entanglements influence the judgment of scientists? To find out, researchers at the Mayo Clinic in Rochester, Minn., focused on the diabetes drug rosiglitazone, which a meta-analysis had linked to increased risk of heart attacks. They examined articles that cited the meta-analysis or a subsequently released report on a large trial of rosiglitazone and found that scientists with a conflict of interest were more likely to view the drug favorably. "There was a clear and strong link between the orientation of authors' expressed views on the rosiglitazone controversy and their financial conflicts of interest with pharmaceutical companies," the report determined.



SOURCE: "ASSOCIATION BETWEEN INDUSTRY AFFILIATION AND POSITION ON CARDIOVASCULAR RISK WITH ROSIGLITAZONE: CROSS SECTIONAL SYSTEMATIC REVIEW," BY AMY T. WANG, CHRISTOPHER P. MCCOY, MOHAMMAD HASSAN MURAD AND VICTOR M. MONTORI, IN *BMJ*, VOL. 340, NO. 7750; APRIL 10, 2010

Graphic by Jen Christiansen

Diseases's Board of Scientific Counselors.) And why does the waiver not include the consulting work he has done for Sanofi Pasteur? "I don't know why the consulting at Sanofi did not appear to be on the waiver," Stanberry wrote to me in an e-mail. Perhaps the officers in charge of producing waivers made mistakes.

THE ENFORCEMENT SHELL GAME

INFORMATION obtained by another Freedom of Information Act request—this time to the Office of Government Ethics (OGE), the agency that is in charge of ensuring that government agencies such as the NIH are following ethics rules—implies that the NIH is not complying with federal regulations about waivers.

From the government's point of view, granting a waiver is a serious matter; it is essentially granting immunity from a law, and it is supposed to be done only rarely and with a good deal of oversight. Federal regulations dictate that the NIH must check in with the OGE before making such grants. The NIH has issued dozens of such waivers for advisory committee members in recent years, but since 2005 the ethics office had documented only three times where the NIH consulted with the office as required, and none of the waivers in question had to do with a member of an advisory committee. When I asked NIH officials about this issue, they insisted that the agency was fully in compliance with federal regulations when it comes to issuing waivers but did not provide any evidence that the NIH was consulting with the OGE when issuing waivers as required by law.

The institutions that administer grants are supposed to provide another check on conflict of interest, but they do not. Historically, the NIH has not taken responsibility for policing conflicts of interest in the research it funds. In 2007, responding to the Office of Inspector General's complaint that the NIH's handling of financial conflicts of interest was woefully inadequate, Elias Zerhouni, then director of the agency, maintained that it was not the NIH's job to figure out whether its grantees were obeying ethics laws. "We believe it is vital to maintain objectivity in research," he wrote in a letter to the Office of Inspector General, "however, responsibilities for identifying … FCOIs [financial conflicts of interest] must remain with grantee institutions." NIH officials say that current policy on the matter has not changed.

Yet grantee institutions also have a record of failing to address ethical issues involving their researchers. A 2009 report by the Office of Inspector General looked at how organizations that receive NIH grants find potential conflicts of interest. Ninety percent of them left it up to the researcher's discretion to identify any problems. Even institutions that publicly take a hard line against conflicts of interest are often lax in enforcing their policies. In late 2010 ProPublica developed a drug company database and started checking up on Stanford University and several other universities with strong anti-conflict-of-interest policies. They found dozens of faculty members who were taking pharmaceutical money in violation of those institutions' rules.

Researchers cannot stop the influence of drug company money. Hospitals and universities will not do it. The NIH will not do it. As a result, millions of taxpayer dollars fund research whose objectivity is being undermined.

Helen Hayes, where Lindsay works, does not seem to rigorously enforce its own rules. To be sure, the organization is complex—it is a state facility, so the New York State Department of Health has an interest, and all its grants are administered through Health Research, Inc. (HRI), a nonprofit organization that helps the state health department get external funding for medical research. HRI administers half a billion dollars a year in grants. With so many grants and so much money at stake, however, it is surprising that HRI is not identifying scores of conflict-of-interest cases every year. "I've been director of sponsored programs here for 11 years, and I've been employed by Health Research doing grant administration for 17 years. I've never seen a conflict of interest," Terry Dehm of HRI told me. "Not a single conflict of interest on any grant that we've applied for.… We've just never seen it."

When I told her that Lindsay's NIH grant to study Forteo, which was administered by HRI, draws income from the manufacturer of the drug he is using federal funds to study, Dehm said that HRI's then executive director, Michael Nazarko, would call that afternoon or the next day. He never did so, nor did he respond to repeated attempts to follow up. Through a New York State Department of Health press officer, Nazarko eventually declined to answer any questions, as did Val Gray, the CEO of Helen Hayes. Felicia Cosman, Helen Hayes's clinical research director, also declined. Cosman took NIH money to study Forteo even though Lilly paid her more than $135,000 for speaking and consulting, according to ProPublica. When asked for comment, Helen Hayes and HRI e-mailed a copy of their conflict-of-interest policies and a statement that insisted that "the procedures outlined in this policy have been followed" with Lindsay's and Cosman's grants.

A few days after I called Helen Hayes to inquire about Lindsay's work and potential conflicts of interest, hospital officials called for an ethics review of that work. Initially, the hospital sought to find an independent panel to review whether or not Lindsay's work was conflicted because of his relationship with Lilly. Failing to find an independent panel, however, the hospital asked the Helen Hayes Hospital Institutional Review Board (IRB) to take a look. (Lindsay was then a member of the board, but he sat out of the deliberations.) The board found that Lindsay had taken significant payments from Lilly but that the payments did not pose a conflict of interest. I found out about these proceedings months later, after using New York State's Freedom of Information Law for documents related to the grants.

Unfortunately, an IRB—which is set up to approve research protocols in a clinical trial and ensures that patients are treated properly—is ill equipped for answering questions about financial conflicts of interest. "The composition of an IRB was never designed to handle [conflict of interest] in today's world," notes Arthur Caplan, a bioethicist at New York University Langone Medical Center (and a member of the board of advisers for *Scientific American*). "It's pretty clear to me that this guy at Helen

Hayes has a pretty serious conflict," Caplan says. Carl Elliott, a bioethicist at the University of Minnesota, agrees. "The IRB was the wrong body to ask for an opinion," he told me in an e-mail.

In any case, Helen Hayes is not geared to rooting out conflicts. Lawyers there adapted the boilerplate language from NIH grant guidelines requiring that a researcher report, among other things, "anything of monetary value, in cash or in kind, *from a research sponsor* (e.g., consulting fees, honoraria, or travel, meals or entertainment)." (Italics added for emphasis.) The inserted clause narrows the scope of what needs to be disclosed. Because Lilly is not the sponsor of Lindsay's research—the NIH is—payments from Lilly would not seem to be a conflict of interest under these guidelines. Indeed, it is difficult to conjure a circumstance in which an NIH grantee would have a conflict of interest under Helen Hayes's rules. There is no reason to think that Helen Hayes is special in this regard. Institutions that administer grants have no real incentive to worry about conflicts. The more grant money their employees get, the better for the employer. Why kick up a fuss?

FIXING THE SYSTEM

RESEARCHERS cannot stop the influence of drug company money. Hospitals and universities will not do it. The NIH refuses to do it. And as a result, millions of taxpayer dollars fund research whose objectivity is being undermined. Congress, which holds the purse strings, is hopping mad.

Most of its wrath is directed at the NIH, which it has called to task for not following ethics guidelines. "I am well acquainted, from my years as chairman of this subcommittee, with the attitude often found at the NIH: the rules don't apply to us," said Representative Joe Barton of Texas, then chair of the House Energy and Commerce Committee, at a hearing in 2004 about ethical lapses at the NIH. "One can only wonder: if the NIH can be so permissive about the most basic ethical rules in the federal government, what does this say about the NIH's ability to manage taxpayer dollars and, most important, ensure that taxpayer-supported research gets translated into cures?" he added. Yet the attitude persists even after Congress has put increasing pressure on the NIH to mend its ways.

Starting in 2008, Senator Charles Grassley of Iowa led a set of congressional inquiries into several incidents in which NIH grantees failed to reveal payments from drug companies and universities failed to discipline the researchers involved properly. The most prominent example was the case of Charles Nemeroff, who, until recently, was chair of Emory University's psychiatry department. Emory documents showed that as early as 2000, there were questions about the propriety of Nemeroff's ties to industry—such as money he was taking from drugmaker SmithKline Beecham, which later became GlaxoSmithKline. (The company also had donated money to endow a chair in Nemeroff's department.) In 2003 researchers accused Nemeroff of not disclosing his ties to the manufacturers of three treatments covered in a *Nature Neuroscience* article. (*Scientific American* is part of Nature Publishing Group.)

Emory's response was to hold an investigation. In 2004 the university determined that Nemeroff had, in fact, committed "many violations of the Conflict of Interest, Consulting, and other policies." Confronted with these findings, Nemeroff agreed to limit his consulting with GlaxoSmithKline because of the implications it might have for an NIH grant he was working on, as well as to reduce his involvement with various other firms. After a congressional inquiry in 2008 revealed numerous undisclosed payments, Nemeroff stepped down as chair of Emory's psychiatry department, and Emory prohibited him from applying for NIH-sponsored grants for two years. Nemeroff has since left Emory for the University of Miami, where he is now chair of the department of psychiatry and behavioral sciences and the principal investigator on a new $400,000 NIH grant.

After these congressional inquiries, the NIH adopted revised regulations that require grantees to disclose all financial entanglements greater than $5,000 to their home institutions. In addition, the rules compel those institutions to make a public accounting, in broad terms, of any conflicts of interest of personnel involved in NIH-sponsored research. These changes mean that the public will have access to more information about the targets of pharmaceutical industry money.

NIH director Francis Collins trumpeted the new regulations as "a clear message that the NIH is committed to promoting objectivity in the research it funds." Yet there was no language in the new regulation that changed who is responsible for spotting such conflicts or how ethical problems are managed. "Because the institutions themselves know the context in which their employees work and because these are employees of the institution and not employees of the federal government, the management responsibility resides with them," says Sally Rockey, the NIH's deputy director for extramural research. "The institutions are in the best position to manage the financial interests of their own employees."

The only hope of solving the problem of conflicted science rests with the researchers themselves. The culture of science can change. Through the agency of peer-reviewed journals (whose reputations suffer as a result of biased research) and via learned societies (which set the ethical standards that scientists are supposed to abide by), scientists can exert pressure on their peers to forgo drug company money. At the very least, they might convince their fellow scientists that it is in their long-term interest to be completely open about the payments they are taking from pharmaceutical firms.

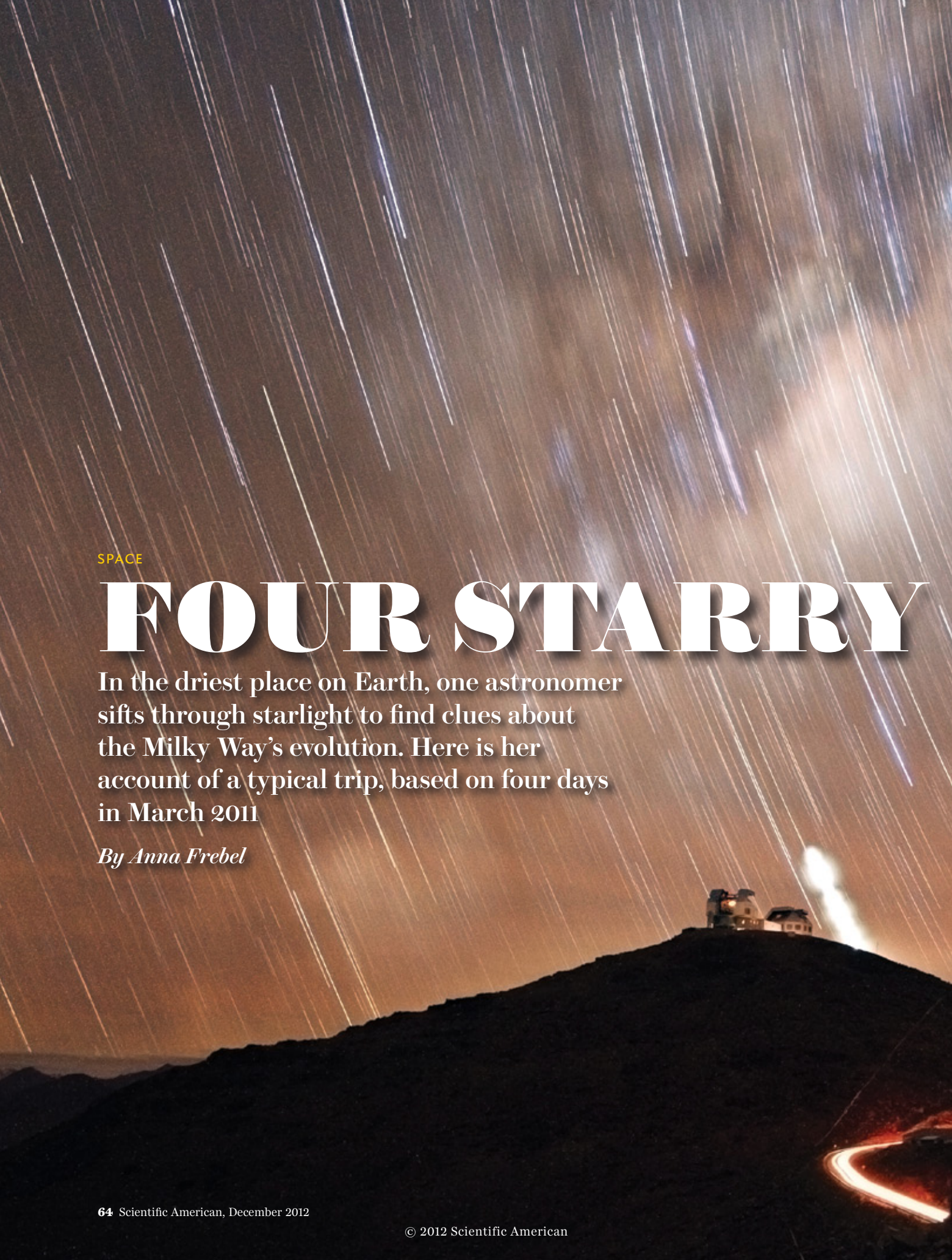
The best hope to provide ethical guidance and to exert peer pressure lies in the professional organizations and peer-reviewed journals. In Lindsay's field, those would be the National Osteoporosis Foundation and *Osteoporosis International*. Would these organizations be willing and able to take the lead in rooting out conflicts of interest? One person to ask might be the former president of the National Osteoporosis Foundation and the current editor in chief of *Osteoporosis International*—Robert Lindsay. SA

MORE TO EXPLORE

ProPublica database cited in this article: http://projects.propublica.org/docdollars
University of California, San Francisco, database of drug-industry documents: http://dida.library.ucsf.edu
NIH database of research grants: http://projectreporter.nih.gov/reporter.cfm?icde=
Report from Grassley-Baucus Senate hearings: www.finance.senate.gov/hearings/hearing/?id=dc6efa3a-e47a-86db-2281-bf16970558e6

SCIENTIFIC AMERICAN ONLINE

Links to the documents and studies that Seife used to research this article are available at ScientificAmerican.com/dec2012/drug-research



SPACE

FOUR STARRY

In the driest place on Earth, one astronomer sifts through starlight to find clues about the Milky Way's evolution. Here is her account of a typical trip, based on four days in March 2011

By Anna Frebel

NIGHTS

STARGAZERS: The twin 6.5-meter Magellan telescopes, Baade and Clay, sit atop Cerro Manqui peak in Chile's Atacama Desert.

Anna Frebel is an assistant professor of physics at the Massachusetts Institute of Technology. She won the 2010 Annie J. Cannon Award in Astronomy from the American Astronomical Society.

Arrival

ONCE WE ARE SETTLED IN A RED PICKUP TRUCK, MY DRIVER AND I leave the airport behind and make our way through Chile's Atacama Desert toward an isolated peak known as Cerro Manqui. Two hours later, as the car hugs a curve of the winding road that summits the mountain, I welcome a familiar sight: sunlight bouncing off the silver shells of the twin Magellan telescopes, Baade and Clay. My heart beats a little faster. Starting tomorrow night, the Clay telescope is all mine.

I travel from Boston to Las Campanas Observatory about three times every year to help unravel some of the remaining mysteries of the Milky Way's evolution. Astronomers are intimately familiar with the anatomy of our galaxy, but we still do not know all the details of its birth and development. Computer simulations of the early universe suggest that thousands of small galaxies once surrounded the young Milky Way, which grew larger by consuming many of its smaller brethren. To help determine whether these simulations are correct, I compare the chemical composition of ancient stars in the outskirts of our galaxy—a region known as the halo—with that of ancient stars in dwarf galaxies that still orbit the Milky Way today. If the simulations are right, then ancient halo stars and dwarf galaxy stars should be made from the same stuff.

Over the past several years that is exactly what chemical analysis has revealed. In all likelihood, the Milky Way has expanded by gobbling up dwarf galaxies and incorporating their stars into its halo. Even now our galaxy seems to be fattening itself with stellar streams torn from galactic neighbors. Astronomers, however, have not yet collected enough data to write these ideas into the textbooks. Like every good observer, I am always in search of more evidence. Every now and then an astronomer needs to leave the office and university behind, travel somewhere remote, away from any urban hullabaloo—preferably, somewhere with high elevation—and confront the night sky in all its naked beauty. On journeys like this, I remember why I fell in love with science in the first place. That is what I would like to show you.

Preparations

AS USUAL, I HAVE ARRIVED at the observatory a day before my turn with the telescope so that I have time to adopt the nocturnal schedule my research requires. At this time of year, a typical workday lasts from 3 P.M. to 6 A.M., with the night's observations starting around 6 P.M. I rest for an hour before having dinner with other astronomers in the lodge, where the geekiness is palpable. We talk about recent studies we have found interesting, any technical problems people have had with the telescopes, and the weather forecast—everyone dreads cloudy skies.

After dinner, I visit the operators and technical staff who

IN BRIEF

Even though astronomers know a lot about the structure of the Milky Way, its origins and development remain somewhat mysterious.
The author routinely travels to a remote observatory in Chile's Atacama Desert, where she studies ancient stars in dwarf galaxies that orbit the Milky Way, as well as stars in our galaxy's halo.
Chemical analysis suggests that dwarf galaxy stars and halo stars formed from similar kinds of gaseous clouds, which in turn supports the idea that the Milky Way expanded by gobbling up small satellite galaxies—a habit that continues to this day.

PRECEDING PAGES: ALEX TUDORICA

maintain the Clay optical telescope and its impressive 21-foot-diameter mirror. Only relatively large telescopes like this one are capable of collecting sufficient light from the dim and distant stars I study. Even though I am not observing tonight, I like to talk with the staff and the current observer and learn what has happened at Las Campanas since my last visit.

Around 2 A.M.—having stayed awake long enough to begin shifting my sleep cycle—I leave the telescope and step into the cool night air, where I find my way among shrubs and stones. The Atacama, the driest desert in the world, is the ideal place to study stars: there is almost no water in the air to bend beams of starlight away from the telescopes. The Southern Hemisphere offers unparalleled views of the Milky Way even without a telescope. I tilt my head back and stare into the center of our galaxy, where countless stars are scattered like flecks of diamond in molasses.

If you were to peer at the Milky Way edgewise, it would look like an egg, sunny-side up: a bright, dense yolk of stars called the galactic center, around which the galaxy's spirals form a thin saucer known as the galactic disk. An evanescent halo of old stars envelops the entire galactic disk. About 30 known dwarf galaxies spin through the outermost regions of the halo. On average, typical dwarf galaxies contain only a few billion stars, far fewer than the 200 billion to 400 billion stars in the comparatively gigantic Milky Way. Some particularly dim dwarf galaxies may contain only thousands of stars, although it is difficult to count stars in such faint clusters.

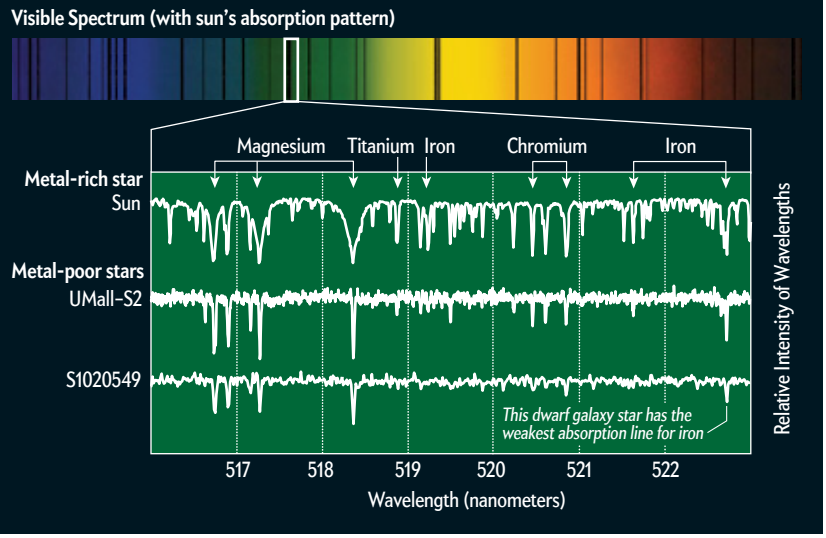
My research primarily focuses on stars in ultrafaint dwarf galaxies that astronomers spotted only in the past 10 years. Stars in these galaxies seem to be some of the oldest ever discovered. We know these stars are old because of the proportions of chemical elements they contain. After the big bang, the first stars in the universe formed from gaseous clouds of hydrogen, helium and tiny traces of lithium—the lightest of all elements and the only ones that existed at the time. As those first stars aged, the nuclear reactions in their cores produced heavier elements such as carbon, oxygen, nitrogen and iron, which spewed into space when these stars exploded as supernovae. A new generation of stars formed from gaseous clouds enriched by these heavier elements, which, along with lithium, astronomers call "metals" for convenience. Only stars that formed in later generations contain substantial amounts of metals. I study metal-poor stars that were born in the universe's infancy. Ultrafaint dwarf galaxies have fewer stars than their more luminous peers, but they have a higher proportion of metal-deficient stars—they are most likely relics from a time long past.

I walk from the telescope to the lodge guided by starlight alone—no need for a flashlight. Just me and the stars.

EVIDENCE

A Star's Chemical Bar Code

Starlight contains plenty of useful information, but astronomers have to decode it. In a technique known as spectroscopy, a telescope equipped with a spectrograph splits starlight into a rainbow spectrum of different wavelengths. The dark lines that appear along the spectrum, known as absorption lines, represent how much starlight was absorbed by different chemical elements in the star's outer atmosphere. The thinner the line, the less abundant the element. Below, arrows indicate absorption lines for iron and other heavy elements in the sun and two stars in dwarf galaxies that orbit the Milky Way. The dwarf galaxy stars have much weaker absorption lines and therefore smaller portions of heavy elements than our relatively young sun, which makes sense because dwarf galaxies formed long before the sun when the heavier elements were still scarce.



SOURCE: ANNA FREBEL

All in a Night's Work

AFTER SLEEPING THROUGH most of my second day, I prepare for my first night of observation with the telescope. I take my seat at the observer's workplace—a desk on which are a few computer screens that tell me about the condition of the telescope, the weather and the positions of stars. The telescope operator, who maneuvers the instrument on my command, sits in front of a wall of 15 screens arranged in several rows.

The week before I arrived in Chile, I made a "target list" of dwarf galaxy stars, ordered by priority. After reviewing the weather conditions, I choose the first star on the list, ask the operator to move the telescope into position and begin collecting starlight.

The ribbons of starlight that travel from dwarf galaxies some 130,000 light-years away carry the stars' chemical DNA—but the code must be deciphered. The Clay telescope is equipped with a high-resolution spectrograph that stretches the beam of starlight into a rainbow of different wavelengths, which I view on a small computer screen. Slicing through the rainbow at different points are black vertical bars known as absorption lines, which correspond to the abundances of different chemical elements in the outer shell of the star. The thinner the absorption line, the less of that particular element exists in the star. In fact, high-resolution spectroscopy is precise enough to tell me how

TIMELINE

Evolution of the Milky Way

Our galaxy might be a cannibal 1. Long ago the Milky Way was one of many small galaxies. Over time it may have consumed its even smaller neighbors 2, growing into the galaxy we know today 3. In support of this scenario, astronomers have discovered that stars in surviving dwarf galaxies orbiting the Milky Way today (*detail*) have a highly similar chemical composition to stars in the Milky Way's outskirts, a region known as the halo. This, in turn, suggests that halo stars were once part of dwarf galaxies that the Milky Way absorbed. Even now our galaxy continues to eat its brethren.

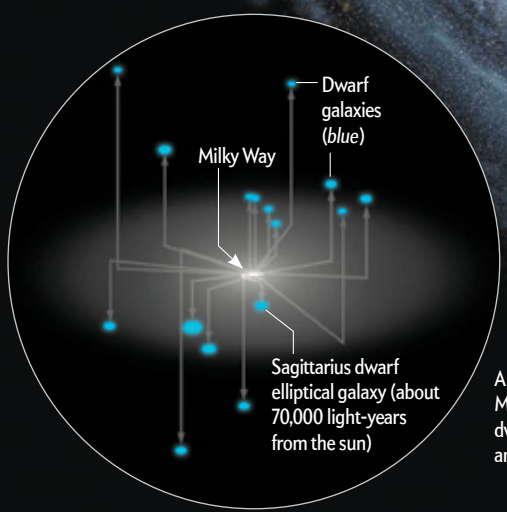
1

2

Halo

Milky Way today

3



A snapshot of the modern Milky Way and surviving dwarf galaxies orbiting in and around the galaxy's halo

SOURCE: MARLA GEHA IN "DARK, BUT LIGHT: SMALLEST GALAXIES EVER SEEN SOLVE A BIG PROBLEM," FOR KECKOBSERVATORY.ORG; SEPTEMBER 12, 2007 (*modern dwarf galaxy configuration*)

Illustration by Ron Miller

many individual atoms of each chemical element a star contains.

All the starlight I have collected and analyzed in the past several years shows me that both halo stars and dim dwarf galaxy stars have very weak absorption lines corresponding to heavy elements such as iron. In the Milk Way's halo, for example, I discovered the most iron-deficient star in the universe, which has only 1 percent as much iron as Earth's core. For comparison's sake, consider that this star is about 60 percent as massive as the sun, which is 300,000 times more massive than our planet.

Such metal-poor halo stars could not have been born in the Milky Way among relatively recent generations of stars. Rather they must have formed from the same kinds of gaseous clouds that birthed ancient dwarf galaxy stars—clouds that existed only in the universe's infancy, before stellar furnaces churned out the heavier elements. The evidence suggests that ancient halo stars are chemically similar to dwarf galaxy stars because they were once part of dwarf galaxies, too. Over time the Milky Way ingested these nearby dwarf galaxies, stealing their stars and growing larger all the while. Yet chemical analysis is not the only evidence of our galaxy's cannibalism. Astronomers have also found what we think are the stains of former meals—stellar streams in the halo, which were likely unspooled from satellite galaxies caught in the Milky Way's gravitational field. Right now the Milky Way is eating up the Sagittarius dwarf elliptical galaxy bit by bit as the satellite zips in arcs around our galaxy. With every turn, stars are torn away from Sagittarius and flung into our galaxy's halo.

Around 7 A.M., more than 12 hours since I first entered the telescope observation room, I am satisfied with the data I have collected on the first stars in my target list. Time to call it a night. I gather my notes, leave the telescope and make the short journey down the mountain to my bedroom in the lodge. Already I am imagining myself drawing the thick, sun-proof shades on my window and resting my head against my pillow. The morning twilight cloaks the stars overhead, but I know they are there—burning as they have for billions of years.

Further Observations

I DRAG MYSELF out of bed at 3 P.M. and, after some dinner, prepare to make more observations with the telescope. I cannot afford to waste a single minute, especially considering that each evening of observation costs more than $50,000, so I plan my nights carefully.

Whenever I observe a star, I need to collect a sufficient number of photons to later make a meaningful analysis of that star's chemical composition. The fainter the star, the more time I need to collect enough photons. Ideally, I want to observe each dwarf galaxy star on my target list for a total of 10 hours because these stars are so faint—halo stars, in contrast, require only one to three hours of exposure. As Earth rotates around its own axis, however, Las Campanas turns away from the region of space I am studying, making it impossible to observe any of my target dwarf galaxy stars for more than four or five hours a night. To compensate, I observe the same set of stars over the course of several nights. There is another complication: high-energy cosmic rays constantly bombard the planet—hitting the telescope's detector and degrading the data. I have found that an efficient way to strike the right balance between collecting enough starlight but not too many cosmic rays is to break up my observations into 55-minute chunks. Shorter than 55 minutes, and I will have not collected enough photons; too much longer than 55 minutes, and the instruments will have been hit by too many cosmic rays. I usually observe one star for four or five 55-minute chunks and move on to the next star in a different part of the sky.

When it is time to switch from observing one star to another, I must carefully review all the data available to me: the number of photons I have collected so far, the positions of my target stars in the night sky, and the weather forecast. The telescope operator is waiting for my decision. Let's say, for example, that I have not collected as many photons as I would like from the first star I was observing but that this star will soon disappear below the horizon. I need to decide whether to stick with the star a little while longer or move on to another and hope that the skies will be clear enough to observe the first star again another night. If I am lucky, I am able to scamper downstairs to the kitchen to make myself a sandwich, but for most of the time I am glued to my computer screens until I have collected enough photons to call it a night.

A Change in the Weather

AROUND 6:30 P.M., I step onto the catwalk outside the Clay telescope before a new night of observation. Watching the sunset at Las Campanas is something of a ritual. The sun sinks slowly below the horizon, draping the hilltops in veils of pink and peach. Each sunset marks a new night of observation—as long as the weather obliges. My third night in the telescope begins well enough, but before long I am frowning at the weather reports on the monitors in front of me. I open the telescope door and stick my head into the night air. Clouds thicker than clotted cream have crowded the Cerro Manqui peak. There is not much that can be done. I won't be observing any more stars tonight. I sit at my laptop and answer e-mails I have ignored for too long, sort through data from previous studies, and write—in fact, I wrote most of this article that cloudy night.

When I take a break from my writing, images of yet undiscovered dwarf galaxies swim through my mind. Computer simulations of our galaxy's birth suggest there are many more dwarf galaxies orbiting the Milky Way than we have discovered so far. We have mapped all the bright dwarf galaxies. The ones we do not know about yet are either much fainter or farther away, which means we need an especially keen eye to find them. The Carnegie Institution for Science plans to build a new telescope at Las Campanas, on a hill that neighbors the Cerro Manqui peak—an instrument boasting an 82-foot-diameter mirror. That is nearly four times the diameter of the mirror I use now. With its giant mirror and accompanying spectrograph, the new telescope will let me gaze into far-flung regions of the Milky Way's halo, where I hope to find more metal-deficient stars. The more observations we make, the closer we get to filling in all the gaps in the story of our galaxy and of how the Milky Way became what it is today. SA

MORE TO EXPLORE

Linking Dwarf Galaxies to Halo Building Blocks with the Most Metal-Poor Star in Sculptor. Anna Frebel, Evan N. Kirby and Joshua D. Simon in *Nature, Vol.* 464, pages 72–75; March 4, 2010.

Precious Fossils of the Infant Universe. Anna Frebel and Volker Bromm in *Physics Today,* Vol. 65, No. 4, page 49; April 2012.

SCIENTIFIC AMERICAN ONLINE
Learn more about how spectrographs manipulate starlight at
ScientificAmerican.com/dec2012/ancient-stars

Daniel Grushkin writes about science and technology for *Businessweek*, *Nature Medicine* and other publications. He also co-founded Genspace, a community laboratory in New York City focused on biotech education and innovation.

ART CONSERVATION

The Case of the Disappearing Daguerreotypes

As priceless images from the earliest days of photography were dissolving in front of museumgoers' eyes, an unlikely team set out to save them

By Daniel Grushkin

In the theaterlike darkness of the International Center of Photography in New York City, black-and-white ghosts of New England's mid-19th-century Boston Brahmins stared out from behind the glass-and-rosewood frames. These were the works of Albert Sands Southworth and Josiah Johnson Hawes, the Rembrandts of daguerreotypy—the first practical form of photography. A demure bride in white silk crepe fingered her ribbons; the stern and haughty statesman Daniel Webster glared from behind his brow. When the "Young America" exhibit opened in 2005, its 150-year-old images captured American icons at a time when the nation was transitioning from adolescence into a world power. "Each picture glows on the wall like a stone in a mood ring," the *New York Times* raved in its review.

Yet after a month on exhibit, the silver plate–bound images

IN BRIEF

Curators monitoring an exhibition of 150-year-old daguerreotypes noticed the images clouding before their eyes. The exhibition's lights appeared to be bleaching them out, and no one knew why.

The conservator in charge of the images teamed up with a physicist who typically works with Bose-Einstein condensates to investigate the nanoscale chemistry at the heart of the destruction.

The results of their investigations affect not just the storage and display of priceless art, they also illuminate fundamental physical processes that could be used in nanoscale engineering.

COURTESY OF GEORGE EASTMAN HOUSE

DISAPPEARING SITTER: **The daguerreotype of this unnamed woman represents one of the earliest forms of photography. Within a month of its 2005 exhibition, a haze began to obscure the image (*above*).**

began to degrade. White spots overtook half the portrait of a woman in a curtain-length skirt. Iridescent halos formed on abolitionist Henry Ingersoll Bowditch. Other images blistered. By the end of the two-and-a-half-month show, 25 daguerreotypes had been damaged, five of them critically.

The sudden decay created a panic within the small world of daguerreotypy. Unlike photography, where a single negative can make multiple prints, each daguerreotype is one of a kind. Once the image fades, it is forever lost. The vanishing images suggested that any daguerreotype could spontaneously crumble. Collectors feared they would lose their million-dollar collections. Conservators feared these windows into the 19th century might simply cloud over.

At the time, art conservators and daguerreotype experts had no idea what could be happening. Although most of the images had spent their existence in dark lockers at the George Eastman House International Museum of Photography and Film in Rochester, N.Y., occasional past exhibitions appeared to do no harm. This time the very act of displaying the images seemed to be destroying them as well. The Eastman House decided to take its daguerreotypes off display. The Metropolitan Museum of Art in New York City now displays only one but does so under a curtain. And the Yale Center for British Art, which had intended to stage a major exhibition of daguerreotypes, postponed it until conservators could find a safe way to put them on view.

That job fell to Ralph Wiegandt, a conservator at Eastman House who had designed the lighting and cases for the "Young America" exhibit. Wiegandt, a friendly man with shaggy hair and a tinker's inquisitiveness, found himself confronted with chemical questions beyond his conservator's expertise. "I've been a conservator for nearly 30 years, and this object stands apart," he says. "Its entire meaning is in a molecular layer or two." Because of the complex physics on the silver surface of daguerreotypes, the crisis called for an unlikely collaboration.

Wiegandt needed to partner with physicists. And in the course of their quest to understand the fading images, he and his partners would uncover surprising new molecular effects at the nanoscale. In doing so, the accidental relics of a 150-year-old technology may perhaps inspire the future of engineering.

FIXED IMAGES

NICHOLAS BIGELOW heads the physics department at the University of Rochester, located just down the road from Eastman House. He had heard about the original exhibit and in 2009 invited Wiegandt to talk about his unique problem at a physics meeting to be held in Rochester. Bigelow typically works on Bose-Einstein condensates, clouds of atoms at temperatures near absolute zero—an abstract quantum state in unimaginable conditions. Yet he was captivated by Wiegandt's talk and volunteered his services, explaining that he wanted to help with "something that has an impact on the human side of life."

Daguerreotypes, Bigelow figured, had changed the way we see the world. Louis-Jacques-Mandé Daguerre, a Parisian artist and showman, introduced the medium in 1839, after a decade of searching for a way to fix an image on a silver plate. One day, the story goes, he accidentally broke a thermometer and absently put it in a cabinet with his silver plates. The following day he found that the mercury vapor had somehow made the image permanent. Daguerre had discovered the chemistry of image making. "What was really going on was self-assembling nanostructures," Bigelow says. "Whether or not he meant to, he was doing nanoengineering."

Bigelow and Wiegandt would have to reconstruct the nanoengineering that Daguerre had stumbled on (and remained oblivious to), but to do that, they first would have to do some macroengineering. On an unseasonably warm day in February, Wiegandt, Bigelow and Brian McIntyre, a microscopist at University of Rochester, knelt on the floor of the physics department, where they poked at the insides of an electron microscope with the handle of a hammer. The airlock on the vacuum chamber was being testy and required a couple of taps. When it did kick in, the computer displayed a centimeters-long rectangle of silver inside the chamber, a section of a daguerreotype Wiegandt had bought on eBay for $60 and cut into squares. On its surface was half the face of a man with shadowy eyes. "I know I cut this gentleman up. I'll take the heat for that," Wiegandt told me.

Magnified 32 times, the man's face began to look like a 19th-century map—the corrosion by his hair an oceanic oil slick, the blisters an archipelago. Magnified 20,000 times, the silver surface looked ridged along the grain in which it was polished. Highlights such as the whites of the man's eyes revealed a hidden nanostructure that resembled tiny clusters of white eggs—uniform silver-mercury crystals whose distribution determined the image's whites and grays.

Making a daguerreotype requires three steps. First, the artist exposes silver to the vapor of iodine or bromine, both highly reactive elements called halogens. The vapor bonds to the silver to create a uniformly light-sensitive surface of silver halide. When a photographer exposes the plate, photons knock off the halides and leave pure silver. Where the image was dark, the silver halide remains. Next, the artist exposes the plate to mercury vapor. The mercury atoms bond with the pure silver and form silver-mercury crystals. As a last step, the artist washes the plate in sodium thiosulfate—film photographers call it "hypo"—which removes the halogen from the surface of the plate to leave a pure silver surface speckled with silver-mercury crystals. The bare silver reflects back as black, and the silver-mercury crystals refract light as white to create an eerie effect—the subject radiates just behind the silver's mirrorlike surface.

Because of the severely reactive silver, daguerreotypes have always been plagued by tarnish. For that reason, portrait makers would seal the plates immediately in glass cases to protect them. This method appeared to work for 150 years, until "Young America" showed them to be susceptible to light alone.

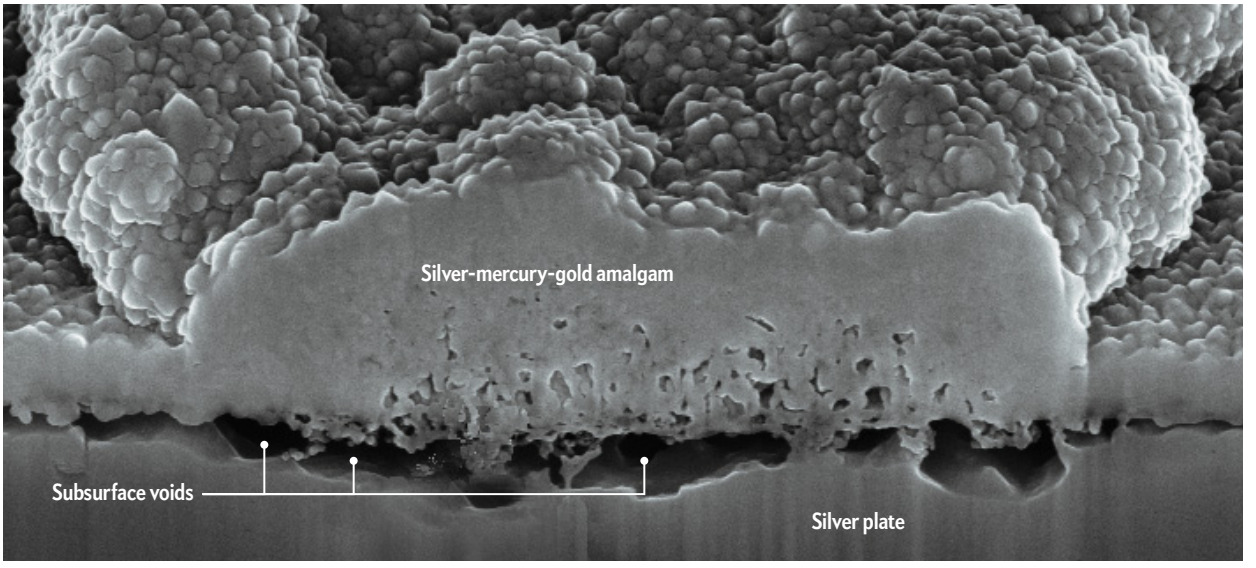
BRIGHT SPOTS

WIEGANDT AND BIGELOW were working on the problem along with conservators from the Metropolitan Museum, who found traces of chlorine in the corrosive white spots of the images. Because the plates were originally exposed to Boston's salty air, chlorides had permeated the plates. Chlorine is a halogen, like iodine, and reacts with silver. A spotlight focused on the daguerreotype at an exhibition would reexpose the plate and create silver-chloride crystals that would cloud over the original image.

Yet sea air was not the only culprit. Wiegandt and Patrick Ravines, now director of the art conservation department at Buffalo State University, found that the integrity of the daguerreotypes was also being undermined from below the surface of the

Trouble under the Surface

This cross section of a daguerreotype reveals the tiny subsurface voids that could be responsible for its deterioration. When a daguerreotype is developed, silver from the plate below combines with mercury and gold vapor on its surface. Scientists theorize that the process draws silver to the surface to form subsurface voids. In the case of the Southworth and Hawes images, these voids may have trapped chlorine from Boston's salty air. Light would then reexpose the sensitive silver chloride and form a haze that mars the image.



plates. In collaboration with researchers at Kodak, Wiegandt's team punched a 30-micron-long rectangle through the surface of sample daguerreotypes using a focused ion beam. They then examined the layers in cross section. To their surprise, they saw 300-nanometer-wide voids just under the surface—a network of tunnels running just beneath the image.

The team believes this light-induced version results from something called the Kirkendall effect, which usually happens in alloying metals. When two different metals fuse into each other at different rates, small voids, or imperfections, form at their interface. The daguerreotype's voids must have formed when they were first exposed, when the silver-mercury crystals drew silver from under the plate's surface.

The voids could explain why some of the daguerreotypes in the exhibit showed damage. Over the course of 150 years chlorine or other contaminants might have seeped into these voids. When the pictures went on display, light may have triggered subsurface reactions between the chlorine and silver, causing the images to sprout spots from below.

Yet on a positive note, the team's discovery might help other industries. Many researchers are looking to produce uniform hollow particles for, say, drug delivery. Bigelow believes that if they learn how to control the Kirkendall effect to create a single, uniform hole in a metal particle, such a technique might be used to engineer nanocapsules for medicine.

CLOSED CASES

WIEGANDT CANNOT reverse the damage already suffered, but he can use what he has learned to protect the remaining images in the Southworth and Hawes collection. At his laboratory at Eastman House, he has built prototype frames out of aluminum and Pyrex with a valve that can seal the plates in an argon atmosphere. Argon, a noble gas, protects the daguerreotype from oxygen and contaminants in the air that can cause reactions on the silver surface. He says he has managed to bring the costs for each argon case down to $50 by using off-the-shelf materials.

He is currently in the process of producing argon cases for the museum's entire Southworth and Hawes collection. Still, that does not necessarily mean they will be going back on display. "I don't know if I'd say go ahead, let's do it," he says. As a man who has spent the past seven years analyzing and enumerating the ways the world—from photons to fungi—can destroy the daguerreotypes' delicate surfaces, Wiegandt is understandably skittish: "I will say that daguerreotypes, whether in storage or on exhibit, should go in an argon atmosphere."

Museumgoers may not realize what conservators never forget—every artifact, whether paint, stone or silver, has a life span. Even in pristine museum conditions, the image fades, the stone breaks, the silver nanoparticles come loose. The conservator cannot save them forever. "The two pillars of a museum are preservation and access," Wiegandt says. Rarely have they been set so directly at odds. SA

MORE TO EXPLORE

Young America: The Daguerreotypes of Southworth and Hawes. www.eastmanhouse.org/icp/pages/young_america.html

SCIENTIFIC AMERICAN ONLINE
See more clouding daguerreotypes from the Southworth and Hawes collection at ScientificAmerican.com/dec2012/dags

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NEUROSCIENCE

Mind Theorist

Knowledge of how the brain intuits what someone else is thinking helps Rebecca Saxe devise possible solutions to seemingly intractable political and social conflict

Interview by Gareth Cook

IN BRIEF

WHO
REBECCA SAXE

VOCATION | AVOCATION
Cognitive neuroscientist

WHERE
Massachusetts Institute of Technology

RESEARCH FOCUS
Understanding how the ability to deduce what someone else is thinking or feeling can help conflict resolution.

BIG PICTURE
"Theory of mind" equips societies with the tools needed to peacefully resolve their differences.

HAVE YOU EVER STOPPED TO CONSIDER WHAT A BRILLIANT MIND READER you are? If someone in your field of view experiences a sudden happy thought or a wave of anger, you do not need to be told. You just seem to know. Of course, this ability is not based on psychic powers but on the reading of small clues: a distinctive curl of the lips for joy, a clenching of the jaw for pique. Think of how a mime, working without words, can evoke an entire story, with multiple characters, each with their own intentions, beliefs and desires—all because we are remarkably skilled at imagining the mental lives of others.

At the Massachusetts Institute of Technology, Rebecca Saxe, 33, is part of a scientific movement to better understand this ability, known as theory of mind. Saxe established that there is a single location in the brain, the right temporoparietal junction, where this thinking is centered. The finding surprised neuroscientists because theory of mind is an abstract and involved ability, the kind they would have expected to involve large swaths of the cortex. Yet, according to Saxe, this little section of brain, just behind the right ear, drives much of what we associate with humanity—conversation, friendship, love, empathy, morality. And art: theory of mind is why humans write novels and why they read them.

Although Saxe's curriculum vitae lists her credentials as a neuroscientist, she might just as easily be called a philosopher. After growing up in Ontario, she

Photograph by Jared Leeds

went to the University of Oxford to study, unsure of which career path to follow. Today her tools include computers and brain scanners, but the questions are enduring. What is the relation between our ability to deduce what others think and the three-pound mass we call the brain? How do ideas relate to experience?

Saxe's laboratory has undertaken broad-ranging investigations into language, moral reasoning, autism, causal reasoning and the development of the brain. But she has a particular passion for conflict resolution. She and her colleague, Emile Bruneau, hope to discover how our theory of mind skills fail us when considering an enemy and how understanding these failures might help mend divided societies. The world would be a better place, Saxe says, if our mind-reading skills, good as they are, could be improved. Excerpts follow.

SCIENTIFIC AMERICAN: How did your passion for science lead you to study the brain?

SAXE: For as long as I can remember, I've been fascinated with the idea that the things that matter most to us are built out of simple, tiny parts you can understand. When I was a kid, I was interested in the way atoms and molecules make up all the stuff around us. I wanted to be a chemist. Then I became interested in all the chemical and cellular parts that make up our bodies; I wanted to be a biologist.

By the time I was 16 or 17, what most blew my mind was the brain. From one cell sending one electrical signal to another cell, you can build up our minds, our thoughts, our conscious experiences. People sometimes say the two fundamental problems in science are the origins of the universe and the structure of the mind. You can fall in love with either one for the same reason.

How did you choose your current area of study within neuroscience?

I use neuroscience to study in humans what you can't study in other animals—things like language and morality.

The parts of our brains that we understand best are those that are shared with animals and most connected to the input and output. For example, how do we parse a visual scene into the dark parts and the white parts or into sofas and tables? Our visual system has a lot in common with cats and monkeys, and we have decent theories about how this works. The same thing goes for motor control, which neuroscientists have been studying since the late 19th century.

All of that is incredibly important, and sometimes I find it tempting to work in a part of neuroscience where there is a lot of knowledge. There is something very satisfying about knowing a lot about a system and adding to it in a cumulative program. But I was seduced the other way, toward the parts of the mind and brain that we know the least about.

Is that what drew you to trying to understand "theory of mind"?

Yes, it's a deep, fundamental, wide-open problem. But I am also drawn to theory of mind because it has so many potential applications. There are clinical applications for people with disorders of social cognition such as autism and social anxiety. Many of the neurodevelopment disorders about which we know the least are the ones that have social components.

To run our society well, we need to understand the way minds work. We need to understand one another and ourselves and how we think about others. We have to coordinate societies to function together. We won't ever be able to do that well if we are systematically wrong about what other people are thinking.

For example, there are huge efforts being devoted toward conflict resolution in the world. Yet these efforts are largely based on intuitive theories of mind—on commonsense notions about how other people work, what will change their thinking and behavior, what causes conflict, and what will diffuse it.

These intuitive theories of mind are pretty good, just as our intuitive physics is pretty good. With our intuitive physics, we can catch baseballs. But for some applications, pretty good is not good enough. If you tried to go to the moon using intuitive physics, you would miss. With conflict resolution, I sometimes feel that we are trying to go to the moon and missing.

How did you become involved in conflict resolution?

When I was first starting up my lab, I got an e-mail from Emile Bruneau, a graduate student at the University of Michigan. He told me he was passionate about understanding how people change their minds about one another and how conflicts get resolved. He said, "I think this is the deep problem, I think it's desperately in need of a science, and I think neuroscience could help." I wrote back to him and said, "You're crazy. What you are suggesting is probably not possible."

But after talking to him, I concluded that this was in fact a very important problem and that this was a person with a vision. Honestly, we're five years in, and I still don't know how useful neuroscience is going to be. But Emile thinks about these problems waking and sleeping, 24 hours a day, whether he's working or not. This is the thing he wants to do in the world—and that's the person you want to work with.

What can neuroscience bring to conflict resolution?

Think about something like bias. There are many reasons for people to tell you they're not biased. They don't want to be biased; they know the right answer is not to be biased. Often people are not even aware of their own biases. So there is a big problem: How do you measure and change something that people are not entirely aware of, that they don't want to admit and that they have a motivation to cover up?

It would be much better if you could find a way to measure something like bias directly, and this is where neuroscience comes in. If we can figure out the bias mechanism in the brain, we can measure bias, instead of asking people to tell us if they are biased. Then, if we could measure bias, we would have a more accurate way to test different approaches to conflict resolution. We could simply test people's level of bias before

JAAFAR ASHTIYEH Getty Images

MIND MATTERS: Saxe and her team study how different approaches to dialogue can affect the resolution of conflict, such as the one between Israelis and Palestinians.

and after different types of intervention and see which one's best.

These goals are a long way off. But I suspect that what is happening in conflicts is a complex, insidious set of biases in how one side thinks about the emotions and motivations of the other side. Each thinks that the other is driven by ideology, not reasons, or that the other side only understands the language of violence. These elements of theory of mind are critical and relatively neglected.

Can you explain your study on what you call "perspective giving"?

Our objective was to use a scientific approach to study dialogue: what happens when two people from opposite sides of a conflict get a chance to talk to each other about their views and experiences. Many conflict resolution programs rely on dialogue, but there are very few scientific studies about whether it works.

We had the idea that dialogue has two sides. In one, perspective taking, you're hearing someone else's perspective. In the other, you're the one who is really being heard—we call that perspective giving. Also, in many conflicts, one group has relatively more power. We suspected the effects of dialogue might not be symmetric.

We studied two pairs in conflict—Palestinians and Israelis, as well as Mexican immigrants and white Arizonans—and the people from the relatively less empowered group show positive improvements in their attitudes only if they're in the perspective-giving role, if they are the ones who are explaining their side. For them, there is no benefit to being asked to take the perspective of the relatively dominant person. But for the dominant group, the strongest benefits of dialogue came from perspective taking, from listening to the other side.

We are not suggesting that dialogue programs should be completely asymmetric with only one side talking and one side listening. But it's important to understand that talking and listening can accomplish different things for different groups. For example, I recently heard about [an unpublished study by Phillip Hammack of the University of California, Santa Cruz, describing] what happens in dialogues between Arabs and Israelis. They found the Israelis talk a lot more than Arabs. If everybody benefits when the Arabs are talking, then at least there should be mechanisms in place to try to increase the probability that they're talking.

Might these same insights also apply in personal relationships?

Yes, to the extent that you are the empowered person in the situation, you should work extra hard to listen, to get new information and to hear where the other person is coming from. For the disempowered person, the experience of being heard can help open barriers and unblock bad situations.

Are there other ways this work might apply on a more personal level?

Another thing that we are working on is how people reason about arguments they disagree with. The goal of conflict resolution programs is not necessarily to change what people think. We just want people to see the potential validity of the other side.

This is what we want to understand better—the difference between disagreeing with something because you have this reaction that tells you it's crazy versus disagreeing while understanding where it's coming from.

This would certainly seem to be an issue in the U.S.

Yes, this is something we are examining now. America has reached a particularly partisan moment in its history. We're interested in how people think about the arguments—and the people—on the other side of major issues such as the environment or gay marriage.

We're not trying to figure out why people are for or against gay marriage. We want to see if we can change their minds about why anyone would ever have a different opinion. A lot of people seem to be saying the only reason anyone would hold a different opinion is if they're immoral or crazy. It's the sense that you must be crazy if you disagree with me that may be worth trying to change.

Gareth Cook is a Pulitzer Prize–winning journalist, a Boston Globe columnist and Scientific American's Mind Matters editor. For more, follow Cook on Twitter @garethideas

MORE TO EXPLORE

Looking for Empathy in a Conflict-Ridden World. Kristina Bjoran. May 18, 2011. http://blogs.scientificamerican/comguest-blog/2011/05/18/looking-for-empathy-in-a-conflict-ridden-world

Live Webcast: Xenophobia—Why Do We Fear Others? Editors of *Scientific American*. March 31, 2012. www.scientificamerican.com/article.cfm?id=live-webcast-xenophobia-

SCIENTIFIC AMERICAN ONLINE

Read more about Saxe's research at ScientificAmerican.com/dec2012/conflict-resolution

SCIENTIFIC AMERICAN Travel

BRIGHT HORIZONS™ 16

FEBRUARY 20–MARCH 5, 2013 ✷ PATAGONIA ✷ www.InsightCruises.com/sciam16

Explore the far horizons of science while living the dream of rounding Cape Horn. Gather indelible images of the uttermost ends of the Earth in the company of fellow citizens of science. Venture about South America's uniquely beautiful terrain with Scientific American Travel on the Bright Horizons 16 cruise conference on Holland America's Veendam from Santiago, Chile to Buenos Aires, Argentina, February 20 – March 5, 2013. An abundance of cultural, natural, and scientific riches await you.

Embrace the elemental suspense of Patagonia. Absorb the latest on neutrinos with Dr. Lawrence Krauss. Immerse yourself in oceanography with Dr. Gary Lagerloef. Survey South America's deep origins with Dr. Victor A. Ramos. Take a scientific look at beliefs, ethics, and morals with Dr. Michael Shermer. Ponder key questions about extraterrestrial life with Dr. Seth Shostak. See the world in a grain of soot and the future in nanotechnology with Dr. Christopher Sorenson.

You have pre- and post-cruise options to peer into the Devil's Throat at Iguazu Falls (a great wonder of the natural world), visit Easter Island or the Galapagos, or ascend Machu Picchu.

Savor South America with a friend. The potential of science beckons, and adventure calls on Bright Horizons 16. Please join us! We take care of the arrangements so you can relax and enjoy the natural and cultural splendor of South America. For the full details, email Concierge@insightcruises.com, or call 650-787-5665.

Cruise prices vary from $1,599 for an Interior Stateroom to $5,599 for a Deluxe Suite, per person. For those attending our SEMINARS, there is a $1,575 fee. Taxes, Port Charges, and an Insight Cruises fee are $336 per person. Program subject to change. **For more info please call 650-787-5665 or email us at Concierge@InsightCruises.com**

THE EARTH FROM SPACE

Gary Lagerloef, Ph.D.

Earth From Space: A Dynamic Planet

The world's space programs have long focused on measurements of Earth. NASA has more than a dozen satellites collecting data on weather, climate change, the land, ocean and polar regions. They reveal Earth's dynamic biosphere, atmosphere, oceans and ice. Get a guided tour of an active and dynamic Earth with amazing and astonishing images and videos.

The Oceans Defined

Satellites have greatly enhanced the exploration & understanding of our oceans. From early weather satellite images detailing ocean currents to views of the marine biosphere, new satellite technologies have revolutionized our scientific understanding of the oceans. Find out what we can measure from space today, objectives of measurement, the amazing technology behind these abilities, and the latest compelling discoveries.

Climate Science in the Space Age

Climate variability and change are among the most important societal issues of our time. Signs of rising global temperatures are obvious in meteorology and oceanography. We'll discuss short, medium and long-term climate variability & change. You'll gain perspectives to effectively sort through contemporary debate about climate change.

The Aquarius/SAC-D Satellite Mission

Take an in-depth look at the Aquarius/SAC-D mission, an oceanographic partnership between the United States and Argentina. Get a behind-the-scenes look at the process of developing and launching a new satellite mission, a briefing on the core scientific mission, and a look at initial findings. Dive into a session that ties together mission, data, and applied science.

GEOLOGY

Speaker: Victor A. Ramos, Ph.D.

The Patagonia Terrain's Exotic Origins

Did Patagonia evolve as an independent microcontinent that fused with South America 265 million years ago? Dr. Ramos will give you the latest theory on the complex development of Patagonia. We'll look at the geologic evidence of Patagonia's close relationships with Antarctica, Africa, and South America, plus archaeological evidence suggestive of Patagonia's origins.

The Islands of the Scotia Arc

Delve into the dynamic nature of South Georgia and the South Sandwich and South Orkney Islands on the Scotia Plate, one of the youngest, and most active tectonic plates. Deepen your understanding of the geology, ecosystems, and history of the Scotia Arc, part of the backbone of the Americas.

The Andes: A History of Earthquakes and Volcanoes

Unfold deep time and learn how South America took shape. Get the details on how the Andes formed, how active Andean volcanoes are, the Andes as a unique climate change laboratory, and lessons learned from the Chilean earthquakes of 1960 and 2011. All certain to give you geologic food for thought on your voyage around the Horn.

Darwin in Southern South America

Darwin's voyage on the Beagle is an incredibly rich scientific and human adventure. Learn the highlights of HMS Beagle's mission in South America in 1833–1835, including Darwin's geological and biological observations. Gain a sense of South America's role in Darwin's life work, and an understanding of his contribution in the context of contemporary science.

PHYSICS

Speaker: Lawrence Krauss, Ph.D.

The Elusive Neutrino

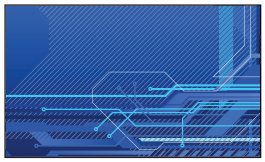
Neutrinos are the most remarkable elementary particles we know about. They are remarkable probes of the Universe, revealing information about everything from exploding stars to the fundamental structure of matter. Dr. Krauss will present a historical review of these elusive and exciting objects, and leave you with some of the most remarkable unsolved mysteries in physics.

The Physics of Star Trek

Join Lawrence Krauss for a whirlwind tour of the Star Trek Universe and the Real Universe — find out why the latter is even more exotic than the former. Dr. Krauss, the author of The Physics of Star Trek, will guide you through the Star Trek universe, which he uses as a launching pad to the fascinating world of modern physics.

Space Travel: Why Humans Aren't Meant for Space

The stars have beckoned humans since we first looked at the night sky. Humans set foot on the Moon over 40 years ago, so why aren't we now roaming our solar system or the galaxy in spacecraft? Dr. Krauss describes the daunting challenges facing human space exploration, and explores the realities surrounding our hopes for reaching the stars.



NANOSCIENCE

Chris Sorensen, Ph.D.

Fire, Fractals and the Divine Proportion

Physicist Chris Sorenson discusses the mysteries, beauties, and curiosities of soot. Take an unlikely journey of discovery of soot to find fractal structures with non-Euclidian dimensionality, networks that tenuously span space and commonalities among spirals, sunflowers and soot. Gain an appreciation for the unity of Nature, and the profound lessons in the commonplace as well as the sublime through soot!

Light Scattering

Take a *particle* physics perspective and ask: how do particles scatter light and why does light scatter in the first place? What are the effects of scattering on the polarization? How do rainbows, glories and sundogs work? How do light scattering and absorption effect the environment? Get the latest on scattering and see your universe in a new light.

Nanoparticles: The Technology.

Nanoscience has spawned a significant nanotechnology. Explore new nanomaterials such as self cleaning surfaces and fibers stronger yet lighter than steel. Then we'll do some informed daydreaming about far reaching possibilities like nanobots that could take a "fantastic voyage" inside your body or stealth materials for the invisible man. Enjoy reality science fiction at its best!

Nanoparticles: The Science.

What makes "nano" so special? Why does nano hold such great promise? Take a look at the clever chemistry that creates the nanoparticle building blocks of the new nanomaterials. Find out why physical properties of nanoparticles differ from larger particles. When this session is over, you'll understand why small can be better.

ASTROBIOLOGY

Speaker: Seth Shostak, Ph.D.

Hunting for Life Beyond Earth

Is Earth the only planet to sport life? Researchers are hot on the trail of biology beyond Earth, and there's good reason to think that we might find it within a decade or two. How will we find alien biology, and what would it mean to learn that life is not a miracle, but as common as cheap motels?

Finding E.T.

Life might be commonplace, but what about intelligent life? What's being done to find our cosmic confreres, and what are the chances we'll discover them soon? While most people expect that the cosmos is populated with anthropomorphic aliens aka "little gray guys with large eyes and no hair" you'll hear that the truth could be enormously different.

What Happens If We Find the Aliens?

One-third of the public believes that aliens are visiting Earth, pirouetting across the skies in their saucers. Few scientists agree, but researchers may soon discover intelligent beings sharing our part of the galaxy. Could we handle the news? What facts could be gleaned

immediately, and what would be the long-term effects such a discovery would have on us and our institutions, such as religion?

The Entire History of the Universe

Where and when did the cosmos begin, and what's our deep, deep future? The book of Genesis gives only a short description of the birth of the cosmos, but modern science can tell a more complex tale. How did the universe get started, and could there be other universes? And how does it all end, or does it end at all?

SKEPTICISM

Speaker: Michael Shermer, Ph.D.

The Believing Brain: From Ghosts and Gods to Politics and Conspiracies — How We Construct Beliefs and Reinforce Them as Truths

The brain as a "belief engine"? Learn how our brains' pattern-recognition and confirmation bias help form and reinforce beliefs. Dr. Shermer provides real-world examples of the process from politics, economics, and religion to conspiracy theories, the supernatural, and the paranormal. This discussion will leave you confident that science is the best tool to determine whether beliefs match reality.

Skepticism 101: How to Think Like a Scientist

Harvest decades of insights for skeptical thinking and brush up on critical analysis skills in a lively session that addresses the most mysterious, controversial, and contentious issues in science and skepticism. Learn how to think scientifically and skeptically. You'll see how to be open-minded enough to accept new ideas without being *too* open-minded.

The Science of Good and Evil: The Origins of Morality and How to be Good Without God

Tackle two challenging questions of our age with Michael Shermer: (1) The origins of morality and (2) the foundations of ethics. Dr. Shermer peels back the inner layers covering our core being to reveal complex human motives — good and evil. Gain an understanding of the evolutionary and cultural underpinnings of morality and ethics and how these motives came into being.

The Mind of the Market: Compassionate Apes, Competitive Humans, and Other Lessons from Evolutionary Economics

How did we evolve from ancient hunter-gatherers to modern consumer-traders? Why are people so irrational when it comes to money and business? Michael Shermer argues that evolution provides an answer to both of these questions through the new science of evolutionary economics. Learn how evolution and economics are both examples of complex adaptive systems. Get your evolutionary economics tools together.

SCIENTIFIC AMERICAN Travel HIGHLIGHTS

IGUAZU FALLS

March 5–7, 2013 — Surround yourself with 260 degrees of 240 foot-high walls of water at Iguazu Falls. Straddling the Argentinian-Brazilian border, Iguazu Falls is split into about 270 discrete falls and at peak flow has a surface area of 1.3 million square feet. (By comparison, Niagara Falls has a surface area of under 600,000 square feet.) Iguazu is famous for its panoramic views and breath-taking vistas of huge sprays of water, lush rainforest, and diverse wildlife.

You'll walk Iguazu National Park's extensive and well-engineered circuit paths over the Falls, go on a boat ride under the Falls, be bowled over by the massiveness and eco-beauty, and take a bazillion pictures.

MACHU PICCHU

February 15–20, 2013 — Scale the Andes and absorb Machu Picchu's aura. Visit this legendary site of the Inca World, draped over the Eastern slopes of the Peruvian, wrapped in mystery. Whether it was an estate for the Inca emperor Pachacuti or a site for astronomical calculations, it captures the imagination. Visit Machu Picchu, and see for yourself the massive polished dry-stone structures, the Intihuatana ("Hitching Post of the Sun"), the Temple of the Sun, and the Room of the Three Windows. Iconic ruins, rich flora and fauna, and incomparable views await your eye (and your lens).

EASTER ISLAND

Febrruary 16–20, 2013 — The moai of Easter Island linger in many a mind's eye, monumental statues gazing inland, away from the South Pacific. Join Bright Horizons on a four-day pre-cruise excursion to explore the mysteries of Rapa Nui. Visit archaeological sites, learn about the complex cultural and natural history of the island, and absorb the ambiance of one of the most remote communities on Earth. Come along on an adventure where archaeology and environment create memories and food for thought.

GALAPAGOS

February 12–20, 2013 — Enter an unearthly natural world in an eight-day pre-cruise excursion to the Galapagos Islands. "See the world in a grain of sand" and hone your knowledge of evolution with your observations in the Galapagos, a self-contained natural history laboratory. We'll tour Santiago, Chile, and straddle the Equator at the "Middle of the World" complex in Quito, Ecuador. Then off to the Galapagos for a four-day expedition on the mv Galapagos Legend. Accompanied by certified naturalists see the incredibly diverse flora and fauna up close. You'll have the opportunity to swim and snorkel, and photograph legendary wildlife and wild landscapes. Join Bright Horizons in the Galapagos for all the intangibles that communing with nature provides.

SCIENTIFIC AMERICAN™ Travel

BRIGHT HORIZONS™ 17

NORWEGIAN FJORDS, JULY 5–15, 2013

For information on more trips like this, please log onto **www.ScientificAmerican.com/Travel**

Are you restless? Seeking new science horizons? Slake your thirst for the latest in science, Viking style, on Bright Horizons 17 cruise conference aboard Celebrity Cruises' Infinity, round-trip Harwich, England to the Norwegian fjords, July 5–15, 2013. Pack your curiosity and join a floating community of keen minds and quick wits voyaging into a landscape of epic beauty.

Top off your fund of knowledge about chemical bonds. Venture into the weird, weird world of quantum mechanics. Go deep into the neurobiology of stress and aggression. Site the Vikings in a context of ingenuity and adaptation. As we travel, you can visit the UNESCO World Heritage sites of Geiranger Fjord and Bryggen, enjoy scenic and noteworthy rail trips, and view glaciers and waterfalls.

Powered by the midnight sun, immerse yourself in essential Norway. Bring a friend and relax amidst scenic beauty from sky to fjord. Refresh the spirit, share downtime with near and dear, savor Nordic cuisine. Absorb new views and innovative thinking from the experts while enjoying the delights of Scandinavia. Join the fun on Bright Horizons 17. Visit www.InsightCruises.com/SciAm-17, contact concierge@insightcruises.com, or call (650) 787-5665.

Cruise prices vary from $2,169 for an Interior Stateroom to $7,499 for a Royal Suite, per person. For those attending our Program, there is a $1,575 fee. Port charges are $235. Government taxes and an Insight Cruises service fee are $215 per person. Gratuities are $150 per person. Program subject to change.

Neurobiology

Speaker: Robert Sapolsky, Ph.D.

The Biology of Memory

Consider the biology of memory. We'll start with the neurobiology of different types of memory, from the pertinent regions of the brain down to the pertinent molecules and genes. Learn about memory's impressive features, wild inaccuracies, and failings in neurological diseases. Examine individual differences in memory skills and find out how to improve your own memory capacities.

Sushi and Middle Age

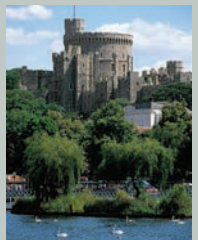
When was the last time you tried a really different, strange type of food, explored the work of a new composer, or made a substantial change in appearance? As we age, we get less interested in novelty and increasingly crave the familiar. Examine the neurobiology and psychology underlying this age-related effect.

Humans: Are We Just Another Primate? Are We Just a Bunch of Neurons?

Dr. Sapolsky both does neurobiology research in the lab and research on wild baboons in East Africa. He'll consider human nature from these two perspectives. Are we just another primate on a continuum with all the others, or are we intrinsically special? Find out a biologist's answer.

The Biology of Aggression and Violence

Examine the biology of violence, dealing with a single fact that makes this one of the most complicated subjects in behavioral biology — we don't hate violence, just violence in the wrong context. Looking at neurobiology, Us/Them dichotomies, hormones, evolutionary biology, and game theory, put the phenomenon of violence in a scientific context.



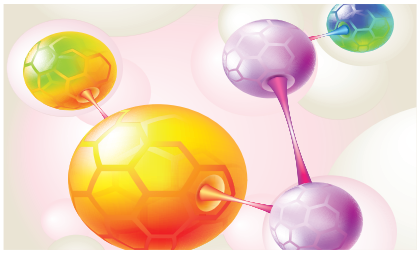
Hampton Court and Windsor Castle (July 2)

Join us visiting two timeless treasures in a day designed to bring British history to life. Enhance your knowledge of Britain's history with an idyllic day trip to Windsor Castle (left) and Hampton Court Palace. They are related yet differing demonstrations of British monarchy, nationhood, and domesticity.

It's good to be Queen, and the evidence is all about you at 1,000 year old Windsor Castle. Rubens, Rembrandt, and a remarkable collection of fine art envelope you in history. Go behind the scenes at the legendary seat of the House of Windsor.

Hampton Court (also known as King Henry VIII's summer palace) is a place of royal passions and competing interests. Pomp and consequence, subterfuge and service inform the history of the palace. Our visit will put the juxtaposed Tudor and Baroque architecture, larger than life personalities, exquisite Chapel Royal, and magnificent gardens in historical context for you.

For more info please call 650-787-5665 or log on to ScientificAmerican.com/Travel



Chemistry

Speaker: Robert Hazen, Ph.D.

Genesis: The Scientific Quest for Life's Origins

— Is life's origin an inevitable process throughout the cosmos, or is it an improbable accident, restricted to a few planets (or only one)? How does a lifeless geochemical world of oceans, atmosphere, and rocks transform into a living planet? Find out how scientists use experimental and theoretical frameworks to deduce the origin of life.

The Diamond Makers

Diamond forms deep in Earth when carbon experiences searing heat and crushing pressure. Decades ago General Electric scientists learned how to mimic those extreme conditions of Earth's interior in the laboratory to make synthetic diamonds. Learn the human drama and technological advances involved in producing this coveted gem and industrial tool from carbon-rich substances.

The Story of Earth: How the Geosphere and Biosphere Co-evolved

Earth is a planet of frequent, extravagant change. Its near-surface environment has transformed over and over again across 4.5 billion years of history. Learn about the work of Dr. Hazen and colleagues that suggests that Earth's living and nonliving spheres have co-evolved over the past four billion years.

Chemical Bonding

— The solid, liquid, and gaseous materials around us depend on the specific elements involved and the chemical bonds that hold those atoms together. By looking at the nature and significance of ionic, metallic, and covalent bonds you'll gain a new understanding of the workings of the world around you.

Quantum Physics

Speaker: Benjamin Schumacher, Ph.D.

Private Lives of Quantum Particles

Quantum systems can exhibit all sorts of bizarre behavior. But many of these phenomena can only be observed under conditions of the strictest privacy, where systems are "informationally isolated" from the world. These are not accidental features of quantum theory. They are inescapable facts about the microscopic world: Quantum physics is what happens when nobody is looking.

2π Is Not Zero (But 4π Is)

— If you rotate any geometrical shape by 360 degrees (2π radians) about any axis, you will end up with exactly the same shape. But this fact, seemingly obvious, is not true for quantum particles with spin. Learn how a rotation by 2π makes a big difference, and how it all comes down to a simple minus sign — probably the most important minus sign in all of physics. Enjoy quantum fun, demystified by Dr. Schumacher.

The Physics of Impossible Things

Physicists find it surprising useful to ponder the impossible. Using the laws of nature, assess the possibility of science fiction's favorite phenomena and explore seemingly impossible things, which while odd, are possible. Venture into the study of impossible things and come away with an affirmation of the consistent logic of nature, and renewed wonder at real phenomena.

The Force That Isn't a Force

— What makes a rubber band elastic? It's entropy, the microscopic disorder of its molecules. Now, entropy may provide a clue to the most familiar and mysterious of the basic forces of nature: gravity. Explore the link between entropy and gravity, and gain fascinating and unexpected insights of contemporary theoretical physics.

Archaeology

Speaker: Kenneth Harl, Ph.D.

From Old Europe to Roman Provinces

Explore the prehistoric foundations of Scandinavia and the Viking Age from ca. 3000 B.C. to 400 A.D. From Megalithic cultures to the arrival of Indo-Europeans, to Northern Bronze Age innovations and Celtic and Roman contributions, learn the unique environmental, cultural, and social factors that create a context for the Vikings.

Great Halls and Market Towns in Viking Age Scandinavia

— Using archaeology and literary sources (especially saga and Eddas), learn how the "great halls" emerged as the main focus of Scandinavia civilization. Find out how the development of towns facilitated trade and were vital for the transformation and technological advance of Scandinavian society.

Ships and Ship Building in the Viking Age

— European history records the effectiveness of the fearsome Viking longship; find out the features and technologies that made it so. Based on archaeological finds, learn about the multi-millennial evolution of the longship, from linden to oak, dugout to mast and sail. Gain an appreciation for the form and function, as well as the wider implications of Norse naval mastery for three hundred years.

Warfare in the Viking Age

— The Viking's applied technologies led to three centuries of robust military and economic power for Scandinavia. Discover what factors made the Vikings accomplished warriors and learn what archaeological finds tell us about Viking exploration, settlement, and development of kingdoms.

SCIENTIFIC AMERICAN Travel HIGHLIGHTS

NORWEGIAN FJORDS JULY 5–15, 2013

The Royal Observatory and the Churchill War Room/Museum (July 4)

Take the road less traveled in London, visiting two less well known gems of the City, both uniquely fascinating and inspiring.

Courage, duty, shared sacrifice, and conviction are the foundation of the Churchill Cabinet War Rooms. Hidden in plain sight in the heart of London, a scant 600 miles from Berlin. Step back in time and discover how Churchill and Britain's government functioned in secrecy in these quarters, from the Blitz to VE Day. The furnishings, maps, and ephemera are as they were on VE day, May 8, 1945. Hear the stories and imagine life under bombardment in the simple and inspiring environment of the Cabinet War Rooms.

Are you the precise type? Are you a fan of Google maps or GPS? Or Cutty Sark? Join us on a tour of maritime Greenwich, where our prime objective is visiting the Royal Observatory, Greenwich, home of the Prime Meridian of the World and Greenwich Mean Time. Stroll a deeply historic corner of London significant in local, national, and international culture. See the Royal Observatory, the National Maritime Museum, the tea clipper Cutty Sark, and the Royal Naval College. Master the lingo of time — UT0, UT1, UTC, and GMT. Stand astride two hemispheres on the Prime Meridian, a moment sure to be recorded on your timeline.

Stonehenge and Bath (July 3)

Pass a day on the Salisbury Plains and Somerset Hills, absorbing the history of two spots with ancient cultural roots.

Mute, mysterious, and megalithic, Stonehenge calls to us across the millennia. We'll respond, and walk the site in its details. Learn the significant geography, the archaeological and astronomical background, and the key stone names. But those are just the facts — the memories and true meaning of Stonehenge will be up to you.

Bath beckons the seasoned traveler. People are drawn to Bath to see its honey-colored Bath limestone buildings, and to explore its 2,000 year history as a place of relaxation and restoration. Plumb the details and nuances of Bath's fusion of architecture, culture, and history in a city with many echoes of and homages to the ancient world, while embodying the Georgian worldview.

For more info please call 650-787-5665 or log on to ScientificAmerican.com/Travel

Recommended by Anna Kuchment

CAMEL caravans in the Sahara

Desert Air

by George Steinmetz. Abrams, 2012 ($60)

Shooting from his one-seat motorized paraglider, geophysicist-turned-photographer Steinmetz spent 15 years documenting the world's "hyperarid regions"—areas that get fewer than four inches of precipitation a year. The result is a coffee-table book of stunning images that also serves as a sober scientific exploration of the nature of these extreme environments.

Wind Wizard: Alan G. Davenport and the Art of Wind Engineering

by Siobhan Roberts. Princeton University Press, 2012 ($29.95)

The dramatic undulations and final collapse of the Tacoma Narrows Bridge in 1940 demonstrated the power of wind and impelled a new discipline of wind engineering. Alan G. Davenport led the field with his meticulous science and innovative wind tunnel. Journalist Roberts delves into Davenport's portfolio of superlatives, which includes the world's tallest bridge, France's Millau Viaduct. —*Marissa Fessenden*

Chasing Doctor Dolittle: Learning the Language of Animals

by Con Slobodchikoff. St. Martin's Press, 2012 ($25.99)

A biologist at the University of Northern Arizona, Slobodchikoff has been interested in language from the time he arrived in the U.S. as a Russian-speaking boy. In this book, he takes readers through fascinating studies of how honeybees, prairie dogs, squid and many other species communicate and makes the case that humans' language abilities are no exception in the animal world.

FROM OUR EDITORS

The Best Science Writing Online 2012

Bora Zivkovic, series editor. Jennifer Ouellette, guest editor. Scientific American/Farrar Straus and Giroux, 2012 ($16)

Online science writing has come into its own since Zivkovic, *Scientific American*'s blog editor, first compiled this series six years ago. The new volume features a rich mix of writing styles and tackles subjects as varied as the limits of rocketry and the effect of neuroticism on sex drive.

STATEMENT OF OWNERSHIP, MANAGEMENT, AND CIRCULATION *1.* Publication title: Scientific American. *2.* Publication number: 509-530. *3.* Filing date: 10/1/2012. *4.* Issue frequency: monthly. *5.* Number of issues published annually: 12. *6.* Annual subscription price: U.S. and its possessions, 1 year, $39.97; Canada, 1 year, $49.97; all other countries, 1 year, $61. *7.* Complete mailing address of known office of publication: Scientific American, 75 Varick Street, 9th Floor, New York, NY 10013-1917, USA. *7a.* Contact person: Karen Dawson; telephone: 212-726-9369. *8.* Complete mailing address of the headquarters or general business office of the publisher: Scientific American, a division of Nature America, Inc., 75 Varick Street, 9th Floor, New York, NY 10013-1917, USA. *9.* Full names and complete mailing address of publisher, editor and managing editor: Publisher, Michael Florek, Scientific American, 75 Varick Street, 9th Floor, New York, NY 10013-1917, USA. Editor, Mariette DiChristina, Scientific American, 75 Varick Street, 9th Floor, New York, NY 10013-1917, USA. Managing Editor, Ricki L. Rusting, Scientific American, 75 Varick Street, 9th Floor, New York, NY 10013-1917, USA. *10.* Owner: Scientific American, a division of Nature America, Inc., 75 Varick Street, 9th Floor, New York, NY 10013-1917, USA. *11.* Known bondholders, mortgagees and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages or other securities: none. *12.* Tax status: has not changed during preceding 12 months *13.* Publication title: Scientific American. *14.* Issue date for circulation data below: September 2012. *15.* Extent and nature of circulation: *a.* Total number of copies (net press run): average number of copies of each issue during preceding 12 months: 747,530; number of copies of single issue published nearest to filing date: 731,913. *b.* Paid circulation (by mail and outside the mail): *(1)* mailed outside-county paid subscriptions stated on PS Form 3541 (include paid above nominal, advertiser's proof and exchange copies): average number of copies of each issue during preceding 12 months: 343,872; number of copies of single issue published nearest to filing date: 343,118. *(2)* mailed in-county paid subscriptions stated on PS Form 3541 (include paid distribution above nominal rate, advertiser's proof copies and exchange copies): average number of copies of each issue during preceding 12 months: 0; number of copies of single issue published nearest to filing date: 0. *(3)* paid outside mail through dealers and carriers, street vendors, counter sales and other paid distribution outside USPS: average number of copies of each issue during preceding 12 months: 148,421; number of copies of single issue published nearest to filing date: 136,104. *(4)* paid distribution by other classes mailed through the USPS (e.g., First-Class Mail): average number of copies of each issue during preceding 12 months: 0; number of copies of single issue published nearest to filing date: 0. *c.* Total paid circulation (sum of *15b (1), (2), (3)* and *(4)*): average number of copies of each issue during preceding 12 months: 492,293; number of copies of single issue published nearest to filing date: 479,222. *d.* Free distribution by mail (samples, complimentary, and other free): *(1)* free or nominal rate outside-county included on PS Form 3541: average number of copies of each issue during preceding 12 months: 16,540; number of copies of single issue published nearest to filing date: 16,590. *(2)* free or nominal rate in-county copies included on PS Form 3541: average number of copies of each issue during preceding 12 months: 0; number of copies of single issue published nearest to filing date: 0. *(3)* free or nominal rate copies mailed at other classes through the USPS (e.g., First-Class Mail): average number of copies of each issue during preceding 12 months: 0; number of copies of single issue published nearest to filing date: 0. *(4)* free or nominal rate distribution outside the mail (carriers or other means): average number of copies of each issue during preceding 12 months: 8,098; number of copies of single issue published nearest to filing date: 8,103. *e.* Total free or nominal rate distribution (sum of *15d (1), (2), (3)* and *(4)*): average number of copies of each issue during preceding 12 months: 24,638; number of copies of single issue published nearest to filing date: 24,693. *f.* Total distribution (sum of *15c* and *15e*): average number of copies of each issue during preceding 12 months: 516,931; number of copies of single issue published nearest to filing date: 503,915. *g.* Copies not distributed (see instructions to publishers #4 (page #3)): average number of copies of each issue during preceding 12 months: 230,599; number of copies of single issue published nearest to filing date: 227,998. *h.* Total (sum of *15f* and *15g*): average number of copies of each issue during preceding 12 months: 747,530; number of copies of single issue published nearest to filing date: 731,913. *i.* Percent paid (*15c* divided by *15f* times 100): average number of copies of each issue during preceding 12 months: 95.2%; number of copies of single issue published nearest to filing date: 95.1%. *16.* Publication of statement of ownership is required. Will be printed in the December 2012 issue of this publication. *17.* I certify that all information furnished above is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties). Signature and title of Editor, Publisher, Business Manager, or Owner: (signed) Michael Florek, Executive Vice President. Date: 9/17/2012.

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Michael Shermer is publisher of *Skeptic* magazine (www.skeptic.com). His new book is *The Believing Brain*. Follow him on Twitter @michaelshermer

The Alpinists of Evil

Nazis did not just blindly follow orders

In last month's column I recounted how my replication of Stanley Milgram's shock experiments revealed that although most people can be inveigled to obey authorities if they are asked to hurt others, they do so reluctantly and with much moral conflict. Milgram's explanation was an "agentic state," or "the condition a person is in when he sees himself as an agent for carrying out another person's wishes." As agents in an experiment, subjects shift from being moral agents in society to obedient agents in a hierarchy. "I am forever astonished that when lecturing on the obedience experiments in colleges across the country, I faced young men who were aghast at the behavior of experimental subjects and proclaimed they would never behave in such a way but who, in a matter of months, were brought into the military and performed without compunction actions that made shocking the victim seem pallid."

This is an astute observation because research on the motivation of soldiers during combat—well summarized by Lt. Col. Dave Grossman in his deeply insightful book *On Killing* (Little, Brown, 2009)—reveals that a soldier's primary motivation is not politics and ideology but devotion to his band of brothers. "Among men who are bonded together so intensely," Grossman explains, "there is a powerful process of peer pressure in which the individual cares so deeply about his comrades and what they think about him that he would rather die than let them down."

As a social primate species, we modulate our morals with signals from family, friends and social groups with whom we identify because in our evolutionary past those attributes helped individuals to survive and reproduce. We do not just blindly concede control to authorities; instead we follow the cues provided by our moral communities on how best to behave.

The power of identification is emphasized in a reinterpretation of Milgram in a 2012 article in *Perspectives on Psychological Science* by University of St. Andrews psychologist Stephen D. Reicher, University of Queensland psychologist S. Alexander Haslam and University of Exeter psychologist Joanne R. Smith. They call their paradigm "identification-based followership," noting that "participants' identification with either the experimenter and the scientific community that he represents or the learner and the general community that he represents" better explains the willingness of subjects to shock (or not) learners at the bidding of an authority. At the start of the experiment, subjects identify with the experimenter and his worthy scientific research program, but at 150 volts the subjects' identification begins to shift to the learner, who cries out "Ugh!!! Experimenter! That's all. Get me out of here, please. My heart's starting to bother me. I refuse to go on. Let me out."

It is, in fact, at 150 volts that subjects are most likely to quit or protest. "In effect," Reicher and his colleagues postulate, "they become torn between two competing voices that are vying for their attention and making contradictory demands on them." This hypothesis better explains subjects' overt moral struggles after 150 volts far better than Milgram's agentic state because the latter encompasses only the subject-authority tie at the exclusion of the obvious subject-victim empathetic bond.

The other shortcoming of Milgram's model is that it lets Nazi bureaucrats off the hook as mere agentic apparatuses in an extermination engine run by Adolf Eichmann, whose actions were famously described by Hannah Arendt as the "banality of evil." Where is the moral accountability? As historian Yaacov Lozowick noted in his 2002 book *Hitler's Bureaucrats,* "Eichmann and his ilk did not come to murder Jews by accident, or in a fit of absent-mindedness, nor by blindly obeying orders or by being small cogs in a big machine. They worked hard, thought hard, took the lead over many years. They were the alpinists of evil."

Examples of Nazi climbers ascending into the thin air of evil abound in a 1992 book entitled *The Good Old Days.* As explained by one such alpinist, SS Lt. Col. Karl Kretschmer: "It is a weakness not to be able to stand the sight of dead people; the best way of overcoming it is to do it more often. Then it becomes a habit."

Providentially, learned habits can be unlearned, especially in the context of moral groups. SA

SCIENTIFIC AMERICAN ONLINE
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Illustration by Mario Wagner

The ongoing search for fundamental farces

Steve Mirsky has been writing the Anti Gravity column since Derek Jeter had a total of 12 base hits in the major leagues. He also hosts the *Scientific American* podcast Science Talk.

Tongue Twisters

Some unusual things have been entering and exiting human mouths

Journalists are always on the lookout for what's called the man-bites-dog story, that is, a reversal of the ordinary order of things. Now, you're correct if you think this theme seems familiar because we also discussed the man-bites-dog concept in this space in the February issue. Back then, the subject was animals that got the upper hand—well, hoof, paw or claw, really—on humans who were hunting them.

I am compelled to revisit man-bites-dog now because on September 26, police in Pembroke, Ontario, arrested a man for biting a dog. An eyewitness summed up the scene thusly to the Canadian Broadcasting Corporation: "It was messed up." Despite the man's apparently best efforts, the dog—a pit bull, no less—suffered only minor injuries.

When I last checked, both the man and the dog were in the custody of the relevant health care experts. In the unlikely event that the biter was found to be in full possession of his faculties, he could wind up in court on animal cruelty charges. While the innocent dog, as it were, walks.

Legal cases involving humans and animals have a long history. As was also mentioned in my earlier column, animals were routinely brought up on charges back in the Middle Ages—a concept prefaced by the line, "Sure, charging an animal with a crime seems loony now." Nevertheless, in January 2009 police in Nigeria did hold a goat "on suspicion of attempted armed robbery," according to a Reuters report.

The goat was ratted out to the police by people who said it was really a human "armed robber who had used black magic to transform himself into a goat to escape arrest after trying to steal a Mazda 323." This therianthropy (hey, we're a science magazine) turned out not to be much of a plan, seeing as he/it wound up under arrest anyway.

If one reads between the lines of the published account, however, one suspects that the cops were really protecting the goat from some citizens who maintain a belief in witchcraft. As police spokesman Tunde Mohammed told Reuters, "We cannot confirm the story, but the goat is in our custody. We cannot base our information on something mystical. It is something that has to be proved scientifically, that a human being turned into a goat."

Tunde Mohammed thus stands in shining contrast to one Paul Broun. Just one day after the Ontario dog biter made his case to receive free Canadian government mental health care, Broun, a medical doctor, also started foaming at the mouth. On September 27, Broun told the attendees of a sportsman's banquet at the Liberty Baptist Church in Hartwell, Ga.: "All that stuff I was taught about evolution and embryology and big bang theory, all that is lies straight from the pit of hell. And it's lies to try to keep me and all the folks who are taught that from understanding that they need a savior."

Broun also put forth the notion that Earth is 9,000 years old. But that is just silly—in the 1600s Bishop James Ussher figured out that Earth was created the night before October 23, 4004 B.C. None of this would be any of my possibly literally damned business if not for the fact that Broun serves in the U.S. Congress and sits on the House Committee on Science, Space, and Technology—where he presumably interprets climate data from ice core samples that date back more than 9,000 years as a trick by Satan. To which I would respond, well, how can you get ice from the pit of hell, huh? QED.

By the time you read this, the representative from Georgia will have been reelected to his seat, since he was running unopposed. I am confident Broun cannot be turned into a goat, but can he at least be moved to a committee where his antediluvian, ahem, views are less likely to impede progress? I tell you, this stuff makes me biting mad. SA

SCIENTIFIC AMERICAN ONLINE
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Illustration by Matt Collins

Thanks to business aviation, we're bringing cancer patients closer to their cure.

"After her cancer treatment, she could not fly commercially. What a relief she could fly with Corporate Angel Network."


PHOTO BY GABE PALACIO

Through the generosity of corporations flying business aircraft, Corporate Angel Network arranges free travel for cancer patients using the empty seats on corporate jets.

This service is vitally important to cancer patients. Some simply can't afford the cost to fly commercially. Others can't handle the stress of navigating airports. Still others can't risk the exposure of crowded airports because of immune system deficiencies.

Since 1981, Corporate Angel Network, a not-for-profit organization, has worked with U.S. corporations to schedule more than 31,000 cancer-patient flights and currently transports nearly 250 patients a month to and from treatment. The process is simple. Corporate Angel Network's staff does all the work. After all, patients and their families have enough to worry about.

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50, 100 & 150 Years Ago compiled by Daniel C. Schlenoff

Innovation and discovery as chronicled in *Scientific American*

December 1962

Silent Spring

"Book Review, by LaMont C. Cole: *Silent Spring,* by Rachel Carson. Houghton Mifflin Company ($5). As an ecologist I am glad this provocative book has been written. That is not to say I consider it a fair and impartial appraisal of all the evidence. On the contrary, it is a highly partisan selection of examples and interpretations that support the author's thesis. The fact remains that the extreme opposite has been impressed on the public by skilled professional molders of public opinion. It is surely time for laymen to take an objective interest in what man is doing to alter his environment, and *Silent Spring* provides many dreadful examples of how the environment has been damaged by the indiscriminate application of chemicals."

December 1912

Pavlov's Hungry Dogs

"The brilliant Russian physiologist, Pawlow [Pavlov], has for some years been conducting an exhaustive investigation by scientific laboratory methods of the reflex action of animals. The *Deutsche Revue* says: 'Pawlow now no longer speaks of psycho-reflexes, but of conditioned and unconditioned reflexes. The latter are those which invariably occur when the appropriate stimulus finds a sensory path, as when food is put in the mouth, and a flow of saliva follows. "Artificial conditioned stimuli" have the same effect. If a given musical note be repeatedly sounded at the same time that a given article of food is offered to a dog, after a certain lapse of time the mere sounding of the note will produce a corresponding flow of saliva. But the saliva will fail to flow if there be even a minimal variation in the tone.'"

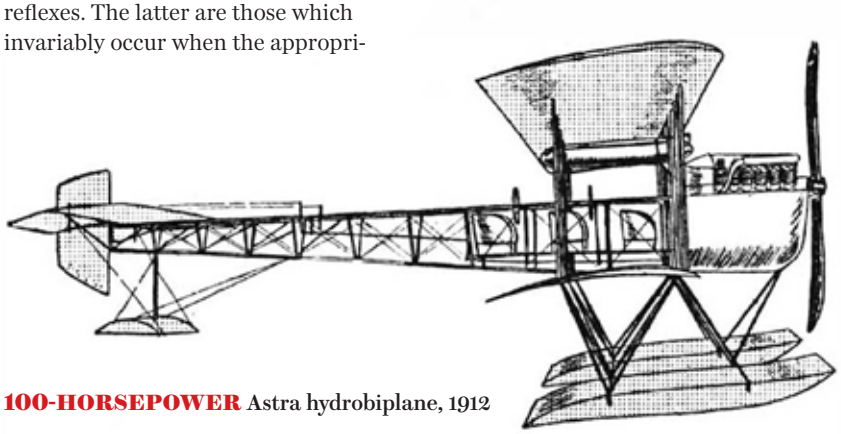
Grand Central Terminal, New York

"Among the great terminal stations of the world, we know of none that surpasses this in the conformity of its architecture to the purposes of the building. The general effect is one of great dignity and beauty. As forming the commercial gateway for a great system of railways to the heart of the country's greatest city, the Forty-Second Street facade, crowned by its imposing statuary, must be pronounced a notable architectural success."

For a slide show on the 1912 coverage of the new Grand Central Terminal, see www.ScientificAmerican.com/dec2012/railroad

Paris Air Show

"This year the number of flying machines has sprung up to 77. The Astra machine [*see illustration*] is equipped for water-flying, and steel has been employed largely in its construction. The old system of Wright wing flexing and strut attachment is retained. There are seats for three. Fitted with a 12-cylinder Renault engine of 100 horsepower, it looks a machine for serious work."



100-HORSEPOWER Astra hydrobiplane, 1912

SCIENTIFIC AMERICAN SUPPLEMENT, VOL. LXXIV, NO. 1926, DECEMBER 14, 1912

December 1862

Otis Safer Elevators

"A very neatly arranged and practical elevating apparatus is made by Messrs. Otis Brothers, of Yonkers, N.Y. It is intended especially for stores and warehouses. Just above the head to which the rope is fastened, there may be seen a ratchet secured to the timbers which guide the platform; this is a very important feature, as it secures the safety of goods and the lives of persons who may be near in case any accident should happen to the hoisting machinery or rope."

In 2012 the Otis Elevator Company has 2.4 million lifting devices operating worldwide.

End of Slavery?

"The President [Abraham Lincoln] urges at great length, what he terms 'compensated emancipation' of slavery. He proposes to inaugurate the great jubilee with the year 1900, by payment of the owners of slaves as a mutual concession on both sides, and as a matter of justice to those who are owners of this species of property. It being quite evident that the war between slavery and freedom will continue to be waged with increased vigor, the President hopes to modify its intensity, by fixing upon a certain period, when the institution shall forever cease. He thinks this policy will shorten the war, and secure justice to all concerned; while, at the same, the country will be saved from the effects of violent and sudden changes in its domestic arrangements. This view of the case strikes us as humane, and if the more radical portion of the two sections would but accept it, as a ground of settlement, peace would again bless us; but so intensely bitter have these contending elements become, that we fear no such compromise would be acceptable or satisfactory."

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in association with
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5 short films on physics

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and on iTunes and the *Nature Video* channel on YouTube

This summer, Nobel laureates and young physicists from around the world gathered in Germany for the annual Lindau Meeting. We filmed five debates on issues that matter to the current generation of researchers. Is dark matter real? How can we solve the looming energy crisis? How is physics perceived by the public? Watch the films to uncover the discussions and disagreements that emerged.

Access the Lindau Video site on your smartphone

*Published weekly from the 19th Sept – 10th Oct 2012
Image: NASA

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MEETINGS OF NOBEL LAUREATES LINDAU

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Planets Everywhere

Systematic searches are revealing a plenitude of alien worlds

- **Host stars** (exact positions shown on chart)

Confirmed exoplanets, as of Sept. 9, 2012 (orbits on chart stylized for legibility)

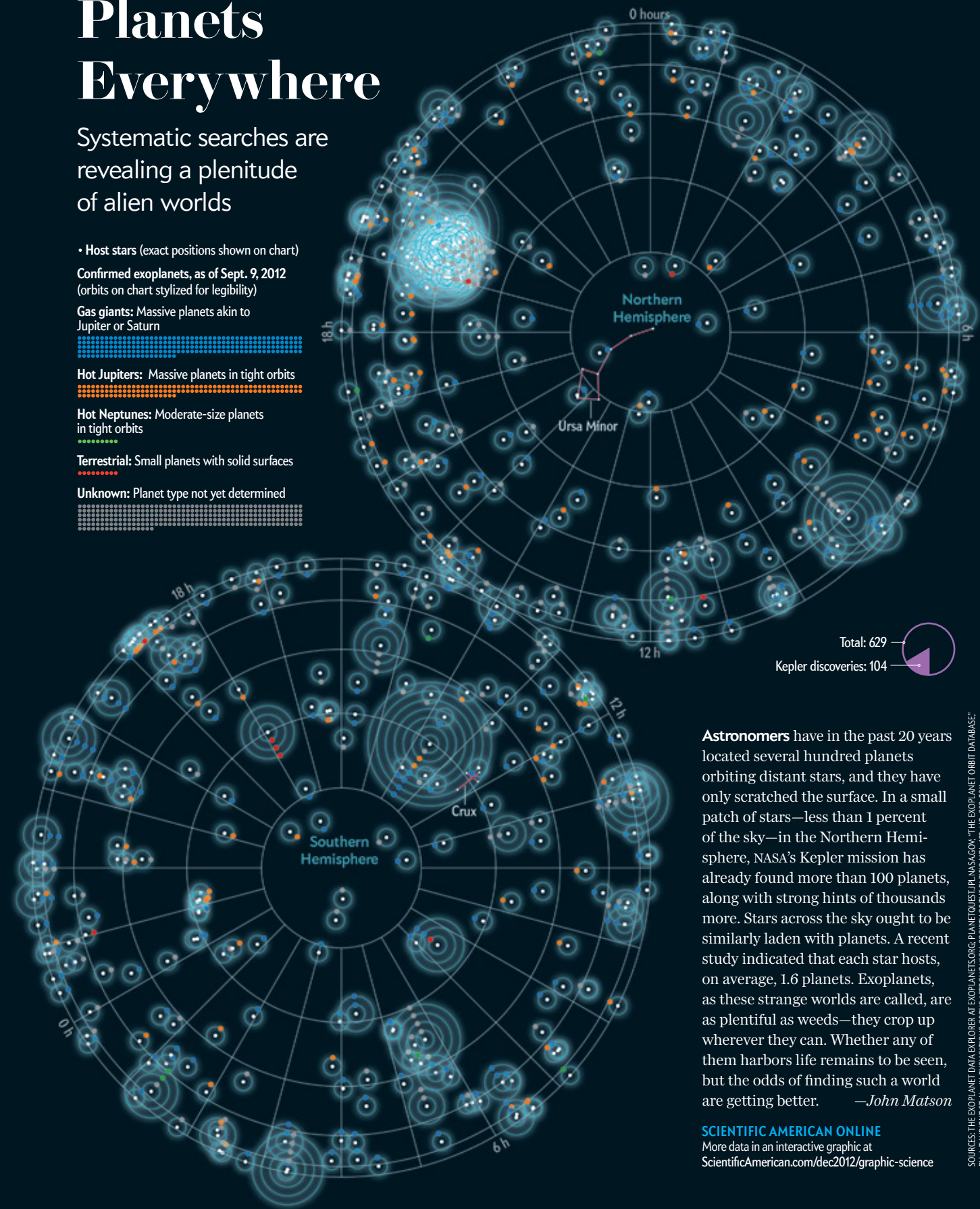
Gas giants: Massive planets akin to Jupiter or Saturn

Hot Jupiters: Massive planets in tight orbits

Hot Neptunes: Moderate-size planets in tight orbits

Terrestrial: Small planets with solid surfaces

Unknown: Planet type not yet determined



Astronomers have in the past 20 years located several hundred planets orbiting distant stars, and they have only scratched the surface. In a small patch of stars—less than 1 percent of the sky—in the Northern Hemisphere, NASA's Kepler mission has already found more than 100 planets, along with strong hints of thousands more. Stars across the sky ought to be similarly laden with planets. A recent study indicated that each star hosts, on average, 1.6 planets. Exoplanets, as these strange worlds are called, are as plentiful as weeds—they crop up wherever they can. Whether any of them harbors life remains to be seen, but the odds of finding such a world are getting better. —*John Matson*

SCIENTIFIC AMERICAN ONLINE
More data in an interactive graphic at ScientificAmerican.com/dec2012/graphic-science

SOURCES: THE EXOPLANET DATA EXPLORER AT EXOPLANETS.ORG; PLANETQUEST.JPL.NASA.GOV; "THE EXOPLANET ORBIT DATABASE," BY J. T. WRIGHT ET AL., IN *PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC*, VOL. 123, NO. 902, 2011

Graphic by Jan Willem Tulp

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