SPECIAL REPORT 35 PAGES THAT WILL HEAL THE WORLD

DISCOVER®

Science, Technology, and The Future

HOW TO CURE EVERYTHING

SCIENCE DELIVERS SOLUTIONS TO LIFE'S MOST VEXING PROBLEMS

Obesity * Addiction * Diabetes * Heart Attacks * Cancer * Traffic * Unsolved Murders
Mosquitoes * Nuclear Fallout * Information Overload * The End of AIDS (At Last)
Biohackers: The Self-Made Experts Who Are Reinventing Medicine

+

What's Beyond the Edge of the Universe?
America's Secret Earthquake Zone
20 Things You Didn't Know About Fire

OCTOBER 2011
$5.99 U.S.
10
0 74470 01372 3
DISCOVERMAGAZINE.COM

We are proud to have America's

#1 cash rewards program:*

Because when you're talking about rewards, who wants the #2 program?

It pays to switch. It pays to

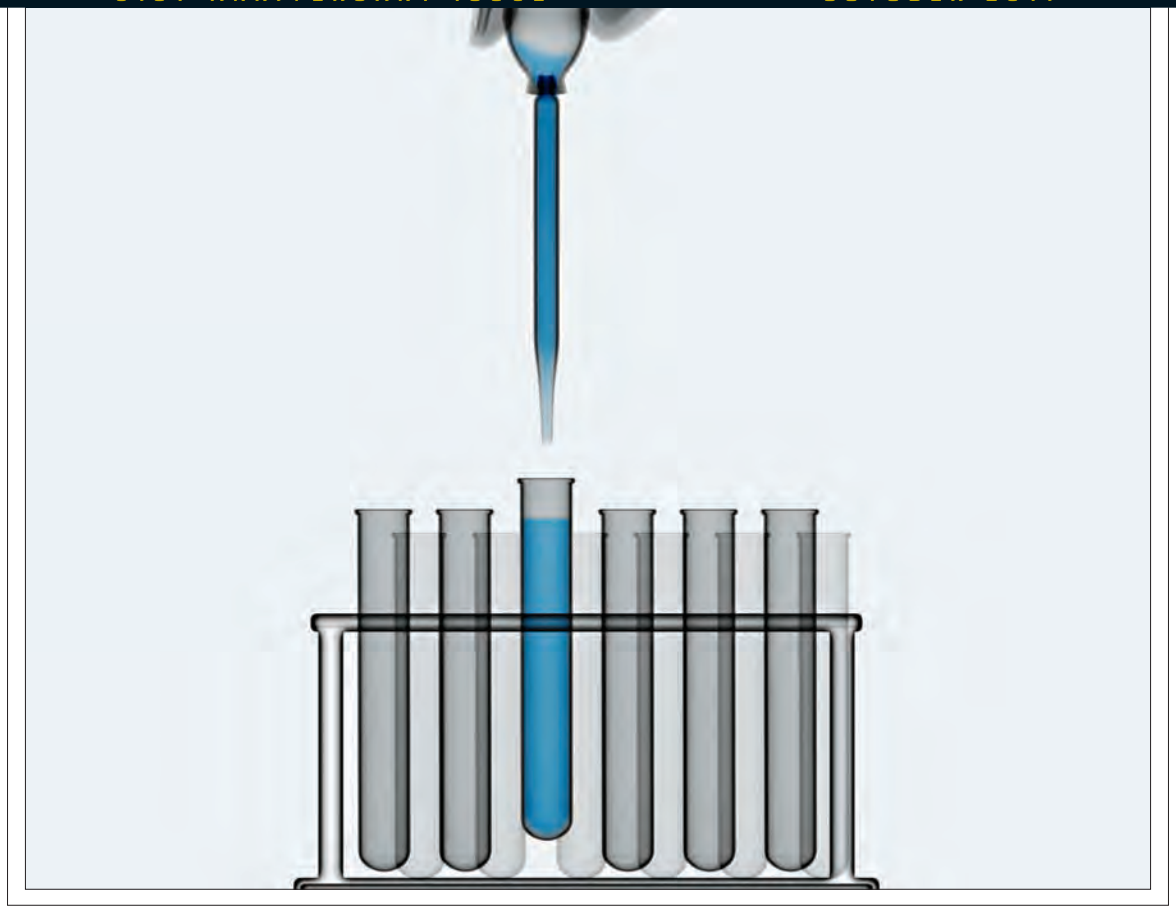
1-800-DISCOVER
discover.com

*More U.S. households have a Discover® card than any other cash rewards card. (TNS 2009 Consumer Card Strategies Research)

DISCOVER

contents

31ST-ANNIVERSARY ISSUE OCTOBER 2011



The world is full of problems. Science has solutions.

DAVID ARKY

contents /// october 2011

31ST-ANNIVERSARY ISSUE **SPECIAL SECTION: THE CURE FOR EVERYTHING**

DISCOVER MAGAZINE .COM **SEE IT RIGHT NOW AT DISCOVERMAGAZINE.COM**

"The lead-up to the last space shuttle flight provoked a great outpouring of misplaced nostalgia, awe, admiration, and trepidation. While it's nice to see that people care so much about space and putting humans up into it, they're missing the fact that we needed to drop the shuttle to make any real progress—the sooner the better."

–Amos Zeeberg, DISCOVER's online managing editor, "How to Avoid Repeating the Debacle That Was the Space Shuttle"

Scientists Pinpoint a Genetic Mutation That Makes Sperm Poor Swimmers–and It Appears to Be Widespread
discovermagazine.com/web/sperm

From Body Lice to Cocoa Trees, a Look at 8 Surprising Genomes Scientists Have Sequenced
discovermagazine.com/web/genomes

The Science of Food: A Photo Gallery of How We Smoke, Sizzle, and Sauté
discovermagazine.com/web/food

ethical dilemmas

Questioning Moral Science

"The End of Morality" (July/August, page 32) described the work of cognitive scientists who are exploring the neurobiological underpinnings of morality.

People are rarely confronted with situations in which they can predetermine with certainty the results of their actions. It's easy to say that pushing the man off the bridge would stop the trolley and save the people on the track, but the trolley could just roll over him, in which case he becomes an unnecessary casualty.

Donn L. Calkins
Wellington, CO

A flaw in the trolley experiment was not specifying the cultural identities of the potential pusher and pushee on the bridge. Details like the pushee's age, gender, race, and health shape the pusher's emotional reaction. In some cultures, age is venerated. In others, it is denigrated. Likewise, some cultures value female life while others consider it expendable.

Aviva Cantor
New York, NY

If you really believe that it is morally right to murder a man so that some of his organs could save five patients, would it not then be more moral for you to kill yourself for those parts rather than murder someone else?

John W. Foster
Perrysburg, OH

Time Travel

In "What You Don't Know Can Kill You" (page 50), Jason Daley examined common misconceptions of risk in the modern world.

With an average of only 48 casualties in the country each year, airline travel is considered far safer than auto travel with its 30,000 deaths. But Americans travel a lot more miles by car than by plane. A more valid comparison would measure the two modes of travel using the same basis, namely, deaths per passenger-mile.

Roger Floyd
Albuquerque, NM

The editors respond: *Air travel still wins by a large margin, although your measure does even the playing field. Using the simple measure of deaths per year, it is 625 times as safe to travel by air than by car; using deaths per passenger-mile, air travel is a little more than 100 times as safe.*

Keep Your Pants On

DISCOVER's "Impatient Futurist," David H. Freedman (page 22), described the plausibility of a network that keeps tabs on all his possessions.

When I read David Freedman pining for an "Internet of Things" in his home, I was nonplussed. I kept thinking, "Why would anyone want a network to help keep track of pants, Advil, and beer?" And then it dawned on me: He's a man! Like most wives, I already have a network that tracks the status of everything in my home: my brain.

Chelsea Crawford
Mountain View, CA

Skewed Sample

In "A Billion Wicked Thoughts" (page 46), neuroscientists Ogi Ogas and Sai Gaddam delved into the naughty side of the mind by examining sexual-themed Web searches of millions of people.

The study is flawed. It only samples people who actually choose to search on the Internet, which is adverse selection. Should we really care what all the deviants around the world are searching for?

Chris Sesler
Plantation, FL

I cannot believe that DISCOVER has been reduced to printing an article about the statistics of online porn viewers. Spanking, Paris Hilton, hot mothers, GG-cup breasts? Please do not tell me this is science!

Christina Brundage
Raleigh, NC

Clarification

"What You Don't Know Can Kill You" states on page 56 that during the year following the terrorist attacks of September 11, 2001, airlines recorded no fatalities. We were referring to the year 2002, not the period from September 2001 to September 2002. Many readers correctly noted that in November 2001, the crash of an American Airlines flight killed 265 people.

Send email to
editorial@discovermagazine.com

Address letters to
DISCOVER
275 Seventh Ave.
21st Floor
New York, NY 10001

Include your full name, address, and daytime phone number.

Science With a Common Touch

ANDREW CUTRARO

THERE'S AN OLD JOKE: IF YOU TELL SOMEONE THE UNIVERSE IS expanding, he'll believe you. If you tell him there's wet paint on the park bench, he'll want to touch it to make sure.

The joke is usually told as a commentary on how the ideas of science are far removed from the concerns of ordinary people, but I see a more encouraging lesson embedded in this wry little observation. Anyone who has the impulse to check whether the paint is wet has exactly the right kind of instincts for doing science: a ready curiosity, a desire to gather empirical evidence, a willingness to get dirty in order to put a theory to the test. Those instincts are reassuringly widespread. I recently spent an enlightening day with my wife and two young daughters at the Carnegie Science Center in Pittsburgh (a wonderful spot, in case you are ever in town). All around, kids were playing with weighted balls and air jets and floppy rockets, all looking fairly happy. But their parents were looking even happier, running the intended science experiments with those toys and reading up on Bernoulli's Principle, turbulent flow, and the like.

The inquisitive souls who have made it into the academic science world will find no shortage of practical ends for even esoteric types of research—the curative applications celebrated in this month's issue starting on page 33. Laboratory studies of magnetic flux leakage turned out to be crucial for repairing broken gas pipelines. The CCR5 receptor, a protein found on the surface of CD4 T-cell lymphocytes in the immune system (try saying that quickly), may hold the key to ending the AIDS pandemic.

> "Anyone inclined to check wet paint has the right stuff for doing science."

But those who stand outside of the research world have a growing number of ways to contribute as well. A generation ago, chemistry sets and Heathkit build-it-yourself electronic devices were the entry points for amateurs. These days the door is open much wider. Anyone can sign up for a public laboratory like Genspace in Brooklyn and learn genetic sequencing (see page 58). Even science-minded people with no patience or ability for hands-on study have plenty of opportunities. Online projects like Galaxy Zoo (**www.galaxyzoo.org**) let amateurs participate in high-level astronomical research.

In short, the gap between the park bench and the expanding universe—always smaller than it seemed—is getting smaller. And this month, in our new Out There column (page 30), physicist Sean Carroll does his part to bring one of the most remote ideas in cosmology back down to Earth. Other universes and other dimensions? In his view, it's not so far from a walk in the park.

Corey S. Powell, EDITOR IN CHIEF

DISCOVER MAGAZINE

Corey S. Powell
EDITOR IN CHIEF

Michael F. Di Ioia
CREATIVE DIRECTOR

EDITORIAL
Nicole Dyer EXECUTIVE EDITOR
Tina Wooden MANAGING EDITOR
Pamela Weintraub FEATURES EDITOR
Eric A. Powell SENIOR EDITOR
Jennifer Barone SENIOR ASSOCIATE EDITOR
Amy Barth ASSOCIATE EDITOR
Andrew Grant ASSOCIATE EDITOR
Valerie Ross REPORTER/RESEARCHER
Debi Allen EXECUTIVE ASSISTANT
INTERNS
Gillian Conahan, Katie M. Palmer, Caroline Spivack
CONTRIBUTING EDITORS
Sean Carroll, Tim Folger, Susan Kruglinski, Michael Lemonick, Bruno Maddox, Linda Marsa, Kathleen McAuliffe, Kat McGowan, Jill Neimark, Phil Plait, Dava Sobel, Gary Taubes, Carl Zimmer

ART
Erik Basil Spooner ART DIRECTOR
Randi Slatken PHOTO EDITOR
Katie Hausenbauer ASSISTANT PHOTO EDITOR
Aine Duffy INTERN
CONTRIBUTING ARTISTS
Douglas Adesko, Timothy Archibald, C. J. Burton, Caleb Charland, Ann Elliott Cutting, Joshua Darden, J. Henry Fair, Derek Lea, Spencer Lowell, Tim O'Brien, Jonathon Rosen, Mackenzie Stroh, Shannon Taggart, Nathaniel Welch

DISCOVERMAGAZINE.COM
Amos Zeeberg MANAGING EDITOR, ONLINE
Gemma Shusterman WEB PRODUCER
Veronique Greenwood STAFF WRITER
Joseph Castro INTERN

ADVERTISING SALES OFFICES
NEW YORK
Robert D. Vitriol ACCOUNT MANAGER
917 421 9048
DETROIT
Joy Gariepy ACCOUNT MANAGER
248 530 0300 x1401
CHICAGO
Keith Bainbridge ACCOUNT MANAGER
312 236 4900 x1106
LOS ANGELES
Craig Miller ACCOUNT MANAGER
213 624 0900 x1228
DIRECT RESPONSE
Ilyssa Somer EAST COAST 917 421 9055
Reina Miller EAST COAST 917 421 9052
Joe Wholley MIDWEST 312 236 4900 x1102
Kim McGraw WEST COAST 213 596 7215
Glenne Belton MARKETPLACE & CLASSIFIEDS 213 596 7212

June C. Lough MARKETING DIRECTOR
Susan Weiss RESEARCH DIRECTOR
Sara Everts ADVERTISING SERVICES MANAGER
262 798 6474

KALMBACH PUBLISHING CO.
Gerald B. Boettcher PRESIDENT
Charles R. Croft EXECUTIVE VICE PRESIDENT
Kevin P. Keefe VICE PRESIDENT, EDITORIAL, PUBLISHER
Scott Stollberg VICE PRESIDENT, ADVERTISING
Scott Bong CORPORATE ADVERTISING DIRECTOR
Daniel R. Lance VICE PRESIDENT, MARKETING
Michael Barbee CORPORATE CIRCULATION DIRECTOR
Ken Meisinger GROUP CIRCULATION MANAGER
Brian Schmidt DIRECTOR OF OPERATIONS

SUBSCRIPTIONS
In the U.S., $29.95 for one year; in Canada, $39.95 for one year (U.S. funds only), includes GST, BN 12271 3209RT; other foreign countries, $44.95 for one year (U.S. funds only).

SUBSCRIBER INQUIRIES
800 829 9132, DCRcustserv@cdsfulfillment.com
P.O. Box 37807, Boone, IA 50037. Back issues available.

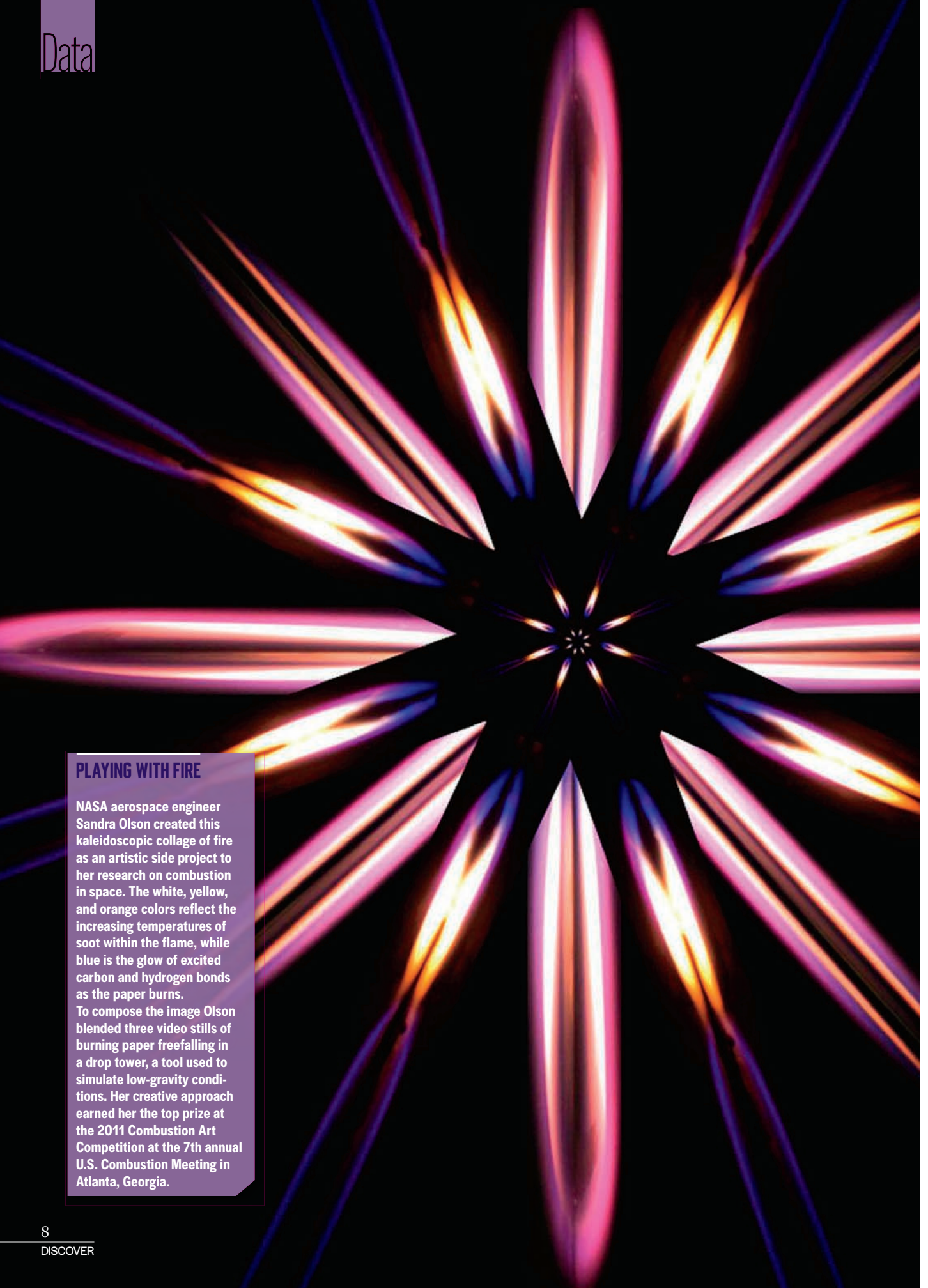
EDITORIAL INQUIRIES
editorial@discovermagazine.com
275 Seventh Avenue, New York, NY 10001

The Audit Bureau
KALMBACH PUBLISHING CO.

Data

POLAR EXPRESS

ARTIFICIAL SNOW pelts the lead car of the 460-passenger Velaro D, Germany's newest high-speed train, during extreme weather testing at the Rail Tec Arsenal research facility in Vienna. As part of its safety tests, Siemens, the train's manufacturer, purchased 1,000 hours in a 300-foot-long wind tunnel, where independent inspectors exposed a prototype to rain, sleet, and snow in temperatures ranging from below zero to more than 110 degrees Fahrenheit. Concerns over high-speed rail safety emerged in July after two bullet trains collided in China, killing 39 people and injuring 210. Bad weather may have played a role in the crash.



PLAYING WITH FIRE

NASA aerospace engineer Sandra Olson created this kaleidoscopic collage of fire as an artistic side project to her research on combustion in space. The white, yellow, and orange colors reflect the increasing temperatures of soot within the flame, while blue is the glow of excited carbon and hydrogen bonds as the paper burns.
To compose the image Olson blended three video stills of burning paper freefalling in a drop tower, a tool used to simulate low-gravity conditions. Her creative approach earned her the top prize at the 2011 Combustion Art Competition at the 7th annual U.S. Combustion Meeting in Atlanta, Georgia.

COURTESY NASA. PREVIOUS PAGE: COURTESY SIEMENS

CHANGE YOUR EXPIRATION DATE.

TRY POMx FREE

The Antioxidant Superpill.™

A healthy history.

For thousands of years, pomegranates have been recognized for their contributions to health and well-being. To the ancient Persians, they offered the promise of invincibility. To the Greeks, pomegranates symbolized fertility. In ancient Egypt, King Tut was entombed with a pomegranate-shaped vase. So why did so many civilizations hold the pomegranate in such high esteem?

The antioxidant power of our 8oz juice.

For the answer, we can look to modern science. Chemical analysis has revealed that pomegranates contain uniquely high levels of several different polyphenol antioxidants. Two of them, punicalagin and punicalin, are not found in any other food.

POMx is pure pomegranate.

POMx is an all-natural antioxidant supplement extracted from the same California-grown, Wonderful variety pomegranates we use to make POM Wonderful® 100% Pomegranate Juice. Containing a full spectrum of pomegranate polyphenols, POMx is so concentrated that just one 1000 mg capsule has the antioxidant power of a full glass of POM Wonderful juice.

The power of POMx.

It seems that every day some new "superfood" makes the news with a flurry of hype and hope. However, independent laboratory studies comparing POMx to other antioxidant supplements found the free radical fighting power of POMx superior to all the supplements tested. These include green tea, grape seed, goji berry, lutein, lycopene – even heavily hyped newcomers like resveratrol and açai. In addition, 30 studies have been published on POMx by leading researchers at major universities, and more are in progress. Visit www.pompills.com/dcv and sign up for our special limited offer. Don't wait. Like you, it won't last forever.

Try POMx Pills FREE for ONE MONTH.

We'll even pay for the shipping.*

Cancel anytime.

Order Now: 888-766-7455 or pompills.com/dcv

Use discount code: DCV30

*SIGN UP FOR POMx MONTHLY, AND WE'LL SEND YOUR FIRST BOTTLE FREE. AFTER THAT, YOU'LL CONTINUE TO RECEIVE MONTHLY SHIPMENTS FOR $29.95 WITH COMPLIMENTARY SHIPPING.

Offer expires 10/31/11 and applies only to the purchase price for the first bottle of POMx Monthly. Following months will be $29.95 per bottle. One discount per customer. Cannot be combined with other offers. No substitutions, transfer rights or cash equivalents. We reserve the right to modify or discontinue this promotion, change the product price or change the shipping charge at any time. Valid only at pompills.com or 1-888-766-7455. Not valid on POMx Trial or other POM products. Credit or debit card required.

POM WONDERFUL®

A Shock to the Heartland

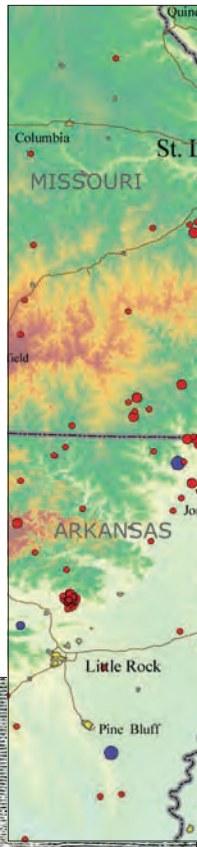
Anticipating a Killer Quake in the Central United States

THE DISASTROUS WINTER OF 1811–12 is the stuff of legend in the Midwest. In the span of a few months, three major earthquakes rocked Missouri, Tennessee, and Arkansas, violently shaking 230,000 square miles stretching from St. Louis to Memphis. Witnesses claimed that the ground rolled in waves several feet high and the Mississippi River flowed backward. Some reports described buckling sidewalks in Charleston, South Carolina, and tremors that reached as far as Quebec. Had seismographs been available at the time, scientists believe those tremors would have registered magnitudes at least as great as the 7.0 quake that devastated Haiti in 2010 and possibly as high as 8.0. These would place them among the worst in U.S. history.

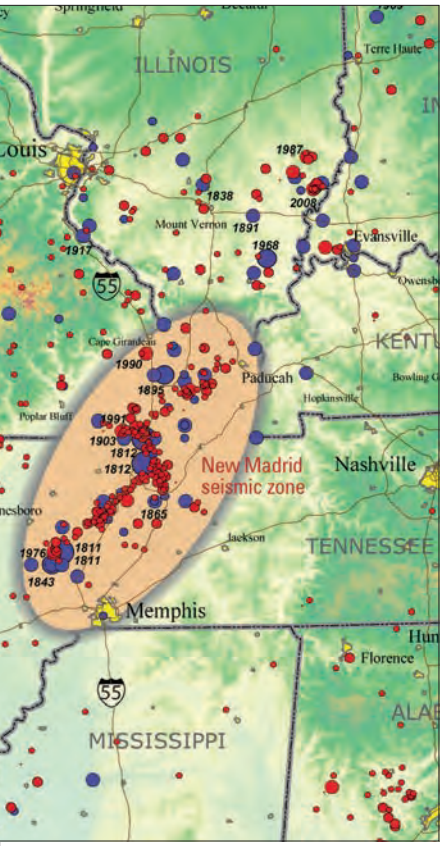
Two centuries later, the set of faults responsible for the tumult in the Midwest, known collectively as the New Madrid Seismic Zone, continue to rumble—only now they do so beneath millions of homes and some of the biggest ports along the Mississippi. In April an independent panel of geologists, seismologists, and engineers commissioned by an advisory group to the United States Geological Survey (USGS) published a report disputing earlier claims that the seismic strain in the area had dissipated, concluding instead that the New Madrid Seismic Zone is "at significant risk for damaging earthquakes." According to the USGS, the chances of a quake of magnitude 6 or higher within the next half-century are between 25 and 40 percent. "That must be accounted for in urban planning and development," the panelists wrote.

That directive has gone ignored. In an area that does not fit the prototype of a seismic hotbed, efforts to implement meaningful policy changes have stalled, leaving the area vulnerable to tremendous damage. "There are no dedicated programs to strengthen facilities or infrastructure in the Midwest in order to resist New Madrid–type earthquakes," says Amr Elnashai, a structural engineer at the University of Illinois. "Politicians are worried about floods, hurricanes, and tornadoes—things that happen frequently." Earthquakes are different, he notes. "They are low probability and high consequence, and politicians only hope they don't happen on their watch."

Assessing the risk of any seismic zone is difficult, but in New Madrid it is particularly challenging. Most earthquakes occur along the edges of continental plates, often near a coastline, where plates scrape and



collide. In those regions, such as California, the faults that can result from that rock movement usually lie close to the surface, making them relatively easy to study. The New Madrid Seismic Zone, in contrast, sits in the center of the North American Plate, and most of the fault system lies four to nine miles beneath the surface. When ancient geologic forces failed to rip the continent apart, the pressure left behind deep rifts that can shift and shove against each other and trigger earthquakes. In 2009 a Purdue University geophysicist grabbed headlines when he published a paper suggesting that the seismic pressure in those rocks had dissipated to the point that the fault system could no longer produce intense tremors. The recent USGS report overwhelmingly rejected that notion, and most scientists agree that powerful quakes are still possible—though how large and when, exactly, are subject to debate. "The less we know, the more we have to guard against," says USGS seismologist Michael Blanpied, who advised on the April panel report.



Above: A map of the New Madrid Seismic Zone shows quakes greater than magnitude 2.5. Red circles represent quakes since 1973; blue shows those recorded earlier. Yellow denotes towns with populations greater than 10,000. Left: An engraving depicts the aftermath of the 1811 and 1812 quakes.

COURTESY U.S. GEOLOGICAL SURVEY, OPPOSITE: THE GRANGER COLLECTION, NEW YORK / THE GRANGER COLLECTION

Embracing a similar philosophy, the Federal Emergency Management Agency (FEMA) commissioned a study in 2006 to estimate the cost and casualties of a hypothetical magnitude 7.7 quake in the Mississippi Valley. That job went to Elnashai, who began by creating a detailed database pinpointing the location of 603,756 structures, including all the hospitals, bridges, schools, and fire stations in the region. He attached corresponding information about the type of rock and soil beneath each structure, details of the structure itself, the amount of shaking anticipated in the area, and the expected population nearby. Elnashai then plugged all the data into a computer model designed to simulate a 7.7 quake—a magnitude approved by the USGS—and let it rip.

The results were sobering: Some 715,000 buildings would be seriously damaged, 425,000 pipelines would be broken, and some 15 major bridges would fail. By Elnashai's calculation, such a quake would injure 86,000 people, displace 7.2 million, and force 2 million into temporary shelters. The direct economic losses would total nearly $300 billion. "Everybody was surprised by the numbers," he says.

Elnashai never got to take his study further. In 2009 the project was cut short when a new FEMA administration took over and reshuffled the agency's funding priorities. The decision scuttled his plans to highlight those structures most in need of shoring up to help officials prioritize their investments in seismic retrofits. "The bottom line is that there is increased awareness, and not much else," Elnashai says. "Our task was to run the numbers and simulate the effects, and that's what we've been doing. The results are haunting, but they are just pushed aside."

As the 200th anniversary of the New Madrid quakes approaches, the local population is arguably no better prepared than it was in 1811, when Missouri and Arkansas were not yet even states. "An earthquake in New Madrid is a matter of when, not if," Elnashai says. "I'm a resident of this area, and I'm not too happy with what is happening."

AMY BARTH

NOT YOUR AVERAGE EARTHQUAKE ZONES

Earthquakes are not restricted to tectonic plate boundaries. New Madrid is just one of several regions that have been struck by major tremors despite a seemingly safe location at the center of a plate.

ST. LAWRENCE VALLEY, QUEBEC The North American plate builds up tremendous pressure as it runs into neighboring plates. It releases most of that strain along its edges, but every now and then it de-stresses through ancient fault lines at its center. Southeastern Canada contains one such fault system and has suffered quakes as strong as magnitude 7.0 as a result.

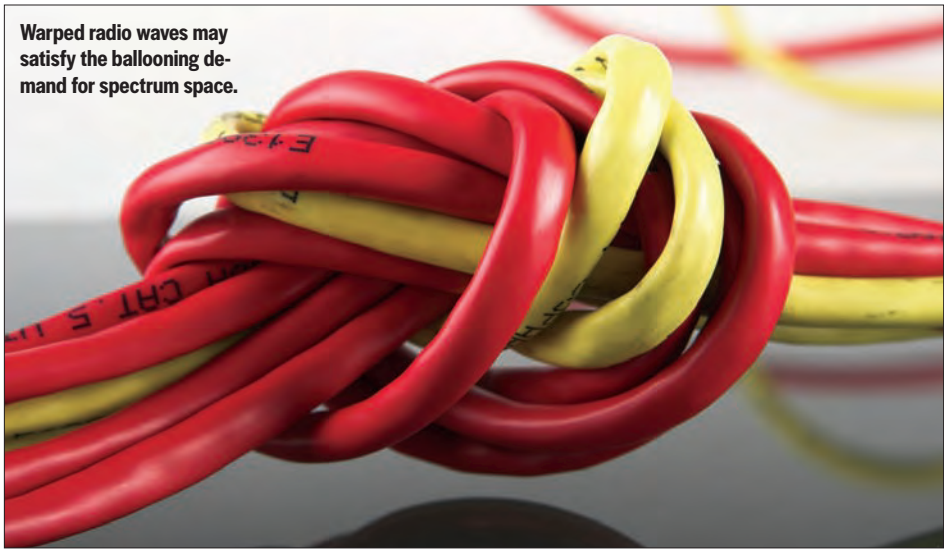
CHARLESTON, SOUTH CAROLINA Deep beneath the South Carolina coastline lie fault lines dating back 150 million years. The area experiences about 20 small quakes a year, plus the occasional monster, such as the magnitude 7.3 shake in 1886 that killed 60 people.

BHUJ, INDIA Most seismic activity in India occurs near the Himalayas, where two plates are slamming into each other. But in 2001, a huge burst of pressure was released through Jurassic-era fault lines near the center of the Indian plate, triggering a magnitude 7.7 quake that took 20,000 lives.

GILLIAN CONAHAN

SPECTRUM CRUNCH

Giving Waves a Twist to Increase Bandwidth



Warped radio waves may satisfy the ballooning demand for spectrum space.

AS MORE PEOPLE STREAM VIDEO to their mobile devices, wireless bandwidth is becoming an increasingly precious commodity. Data traffic increased 8,000 percent in the past four years on AT&T's network alone. In trying to avoid what the Federal Communications Commission calls a "looming spectrum crisis," telecommunications companies are lobbying the government to assign them more spectrum space in the 300- to 3,000-megahertz range, the sweet spot for wireless communication. But Italian astrophysicist Fabrizio Tamburini says a solution may lie in making better use of the frequencies already in use. In a recent paper, he demonstrated a potential way to squeeze 100 times more bandwidth out of existing frequencies.

The idea is to twist radio waves like corkscrews and create multiple subfrequencies, distinguished by their degree of twistedness. Each subchannel carries discrete data sets. "You can tune the wave with a given frequency as you normally do, but there is also a fingerprint left by the twist," Tamburini says. He and Swedish colleague Bo Thidé hit upon the approach while studying waves warped by the immense gravity of black holes. This past June, the scientists set up a custom dish in Venice and successfully broadcast video encoded in both twisted and normal radio waves across St. Mark's Basin.

The next step is to design small, cheap smartphone antennas that can transmit and receive the warped signals. If the industry's appetite for bandwidth is any indication, it may not be long before twisted-radio technology shows up in your new gadgets. EDWIN CARTLIDGE

Plants may lose their carbon-capturing prowess as temperatures rise.

CLIMATE CONUNDRUM

Can Trees Offset Our Carbon Fumes?

FORESTS ARE THE PLANET'S BIGGEST TERRESTRIAL carbon sinks, soaking up and storing a quarter of the world's annual emissions. Forests are also vulnerable to changes in climate, leading scientists to explore whether they can continue their sequestering magic in a warming world. A new large-scale study provides a worrisome answer, suggesting that while forests are very resilient, they may not be able to shoulder the load in the long run.

As global temperatures rise, forests face a pair of counteracting carbon processes. Warming causes dead plants to decompose more quickly, which releases carbon dioxide. But decomposition also releases ammonium—essentially fertilizer—into the soil, allowing trees to grow faster and store more carbon.

To find out which process wins out, ecologist Jerry Melillo of the Marine Biological Laboratory in Woods Hole, Massachusetts, tracked two 10,000-square-foot plots of deciduous forest for seven years. On one plot, he installed underground cables to warm the soil by 9 degrees Fahrenheit. He found that the hotter soil, rife with decaying plants, released significantly more carbon than did its cooler counterpart. That carbon burst was short-lived, however. As ammonium levels in the heated soil increased, trees grew faster and absorbed more carbon. By the study's end, trees on the warm plot were sequestering carbon at the same rate the soil was pumping it out.

That's good news, but there is a catch: The growth rate of trees is limited, unlike the rise in temperatures. Once that growth rate tails off, additional carbon released from the ground will enter the atmosphere and make the planet even warmer. "If we continue with business as usual," Melillo says, "plants' ability to store carbon will be maxed out." VALERIE ROSS

The Scatological Hitchhiker Snail

IF YOU HAVE EVER COMPLAINED about flying on a budget airline, spare a thought for the Japanese snail *Tornatellides boeningi.* The only way for this laggard gastropod to rack up its air miles is to be eaten by a bird and excreted out the other end. And even though the stowaways are slathered in digestive fluids and feces, many of them survive, enabling them to colonize a much larger area than their slow-lane pace would seem to allow. "This could help explain why the snails are so widespread," says biologist Shinichiro Wada of Tohoku University, who found that snails at one end of Hahajima Island are as genetically similar to those from the opposite corner as to their neighbors.

Some snail species can survive trips through fish guts, but this is the first one known to pass through birds. Wada discovered the snails' odd means of travel after finding undamaged shells in bird droppings. When he fed 174 live snails to Japanese white-eyes and brown-eared bulbuls, around 15 percent of them lived. "One snail even gave birth just after passing through the gut," Wada says.

The snails probably survive because of their small size (less than a tenth of an inch long, on average) and compact shells. Wada suspects that they shield themselves with mucus or seal the gap between their body and shell to prevent digestive fluids from seeping inside.

Escargot, anyone? ED YONG

Some snails embark on bile-filled flights.

CLOCKWISE FROM TOP: ISTOCK(2); LENA CLARA/GETTY IMAGES

Data Special Report

9/11 Ten Years Later

Towering Feats of Engineering

One World Trade Center rises with a bomb-resistant fortified base, a superstrong mix of concrete, and a fleet of elevators that can really move.

WHEN ARCHITECT MINORU YAMASAKI BEGAN DESIGNING two 1,360-foot towers for the World Trade Center in 1962, he gave little thought to terrorism. The same cannot be said for Kenneth Lewis, project manager of the 1,776-foot skyscraper at One World Trade Center, slated for completion in 2013. "At a site in downtown Manhattan that's been attacked twice, people are thinking about their personal safety," he acknowledges. Future occupants may take comfort knowing that Lewis and his colleagues have employed the latest materials and engineering techniques to design a building that, despite its soaring height, will be stubbornly resistant to explosions and other violent attacks. "It's designed to be as secure as a foreign embassy," he says.

Security measures begin at ground level with a 186-foot base built to withstand a blast more powerful than the 1993 car bombing, which, according to the NYPD, was equivalent to 900 pounds of TNT. While the frame of the Twin Towers was erected entirely of steel, the base of the new building, as well as a core running up its center, will be forged from 5.4 million cubic feet of concrete, enough to fill 60 Olympic-size swimming pools. The concrete mix can withstand pressure of up to 15,000 pounds per square inch and is the toughest ever used for a New York City building. Its strength comes from a combination of reinforcing steel rods, a newly developed mix of materials, and a high-tech curing process. The chemical reactions that bolster concrete as it hardens are very sensitive to temperature, so as the mix is poured, engineers drop in microchip thermometers that wirelessly relay temperature readings.

The building's surrounding steel frame will be just as tough. When planes struck the Twin Towers in 2001, the floors located just below the impact buckled beneath the weight above, setting off a domino effect that led to a total collapse. One World Trade will feature beams and columns welded and bolted together to distribute the weight, so that if any two columns fail, the rest can pick up the slack.

But Lewis insists these numerous safeguards will not define the tower. "It's iconic, but not because it looks like a bunker," he says. "It's iconic because it's a beautiful building."

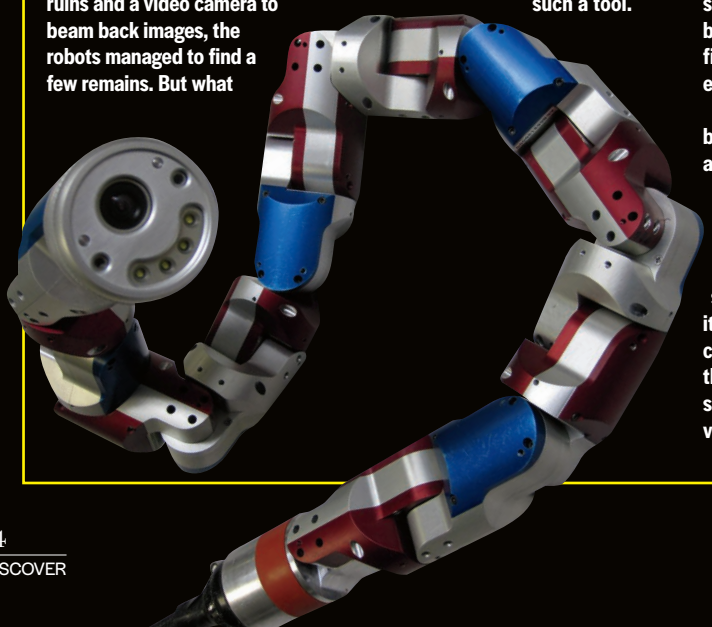
MARA GRUNBAUM

TOOLS OF THE TRADE

Lesson Learned: A Better Rescue Bot

AFTER THE WORLD TRADE TOWERS collapsed in 2001, rescuers dispatched shoe box-size robots to explore the debris for trapped victims. Using two miniature bulldozer treads to muscle over the ruins and a video camera to beam back images, the robots managed to find a few remains. But what they really needed was a way to peer inside all the openings and crevices dammed up by curtains, paper, and loose materials.

Daniel Goldman, a biophysicist at Georgia Tech, is building just such a tool.



His latest robot behaves less like an ATV and more like a sandfish lizard, relying on a chain of six motors encased in slick spandex to mimic that animal's undulating motion. Last June a prototype version managed to crawl through a box of plastic beads, a significant first step toward more challenging environments such as rubble.

Goldman began the project by learning everything he could about reptile physics. To start, he placed a sandfish lizard in a vat of sand and snapped 1,000 X-ray images each second as it wiggled its way beneath the surface. He then broke down its motion frame by frame to characterize the movement of the lizard's body in relation to the sand around it. He also calculated variations in the density and size of the sand particles affecting the lizard's friction, drag, and thrust. When Goldman fed this torrent of data into a computer model, he discovered that the main mechanism underlying sand swimming was a wave that passed from head to tail, pushing off from the sand and generating enough thrust to propel the lizard forward. His robot now uses the same motion to move steadily at about three and a half inches per second.

This May, Goldman upgraded the design with a wedge that can be tilted up or down to allow the robot to burrow deeper or snake its way back to the surface. Robin Murphy, the Texas A&M computer scientist behind the 9/11 robots, calls Goldman's work "very exciting," but we hope the tool sees little use.

ADAM PIORE

COURTESY HOWIE CHOSET/CARNEGIE MELLON UNIVERSITY. OPPOSITE: JOE WOOLHEAD (2)

23

Speed, in miles per hour, of 5 of the 70 elevators planned for One World Trade Center. They will be the fastest in North America; an express ride to the top of the 105-story skyscraper will take one minute. In the United States, most elevators run between 1 and 6 mph. Taiwan's Taipei 101 financial center is home to the world's fastest lift, which tops out at 38 mph.

One World Trade Center's 186-foot-high base is made of the strongest concrete ever used in New York City architecture.

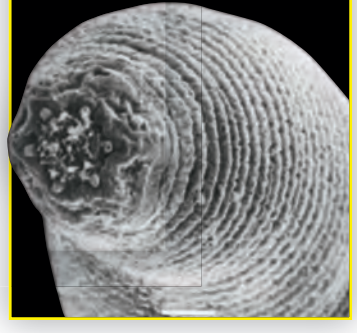
OFF THE CHARTS

Deepest Animal Unearthed

When it comes to indestructible species, the cockroach is a kitten compared with the nematode. Nematode worms thrive in desert, mountain, and ocean environments. Nematodes aboard the space shuttle *Columbia* even survived after the spacecraft disintegrated during reentry in 2003. Now Belgian biologist Gaetan Borgonie has discovered a new species of nematode nearly a mile underground, where no other animal has ever been found.

Earth's first few miles of bedrock teem with life, but scientists had long assumed that only simple, single-celled organisms could survive there. Borgonie teamed with Tullis Onstott of Princeton University to prove that assumption wrong. For a year they made intermittent descents to sample the Beatrix gold mine in South Africa, funded by their own savings. Finally, in late 2008, Borgonie looked into a microscope and saw a worm with a broken tail squirming across the slide. "I became an ICU nurse, looking every few hours to make sure she was still alive," he says. "She laid 12 eggs before dying."

In a recent paper, Borgonie and Onstott named the species *Halicephalobus mephisto* (below), from the Greek for "he who loves not the light." Now they plan to expand their expedition to find other animals lurking in the depths. CAROLINE SPIVACK



LITTLE GREEN MEN

The Square Kilometre Array will listen for aliens living halfway across the galaxy.

Recession-Proof Alien Hunting

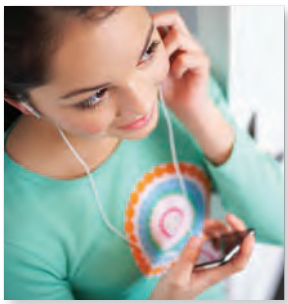
THIS SPRING, THE ALLEN TELESCOPE ARRAY, or ATA, a cluster of 42 radio astronomy dishes about 300 miles north of San Francisco, became the latest science casualty of California's budget crisis. The ATA, a joint project of the Search for Extraterrestrial Intelligence Institute and the University of California, Berkeley, scoured the radio spectrum for distant galaxies and nearby satellites, but it was best known as a listening station for greetings from little green men. The mothballing is unfortunate, says astronomer Joseph Lazio of the Jet Propulsion Laboratory, "but the ATA was never going to be the only way to search for extraterrestrial civilizations."

Lazio is helping to develop the next-generation radio telescope planned for construction in 2016: the $2.1 billion Square Kilometre Array, or SKA, a collaboration among 70 organizations in 20 countries. The SKA is essentially a bigger, more advanced version of the ATA. The site is undecided, but the blueprints call for thousands of dishes—each wider and more powerful than those of the ATA—to be spread over an area more than 1,800 miles wide. The dishes can point and turn in unison, picking up radio waves from vast tracts of sky and relaying the data to computing facilities with the processing power of 1 billion PCs. The SKA will be 50 times as sensitive as its predecessor, capable of registering booming "we are here" broadcasts from civilizations halfway across the Milky Way. It could also detect faint alien signals leaking into space, akin to those from airport radar or TV broadcast towers. In other words, the SKA could hear ETs even when they are not trying to call us.

All this for aliens? Not exactly. Unlike the ATA, which was devoted primarily to finding intelligent life, the SKA will help study general relativity, star and planet formation, and more. The ET hunt is just one of many aims. Lazio, the SKA chief project scientist, explains that the varied goals do not conflict: The same signals gathered while studying stars can be parsed for alien messages. "Anytime you point dishes at the sky, you get data that you might as well scan for ET civilizations," he says. The SKA is also protected against penny-pinching. "The money is coming from many countries," Lazio says, "so it's less likely to just disappear." GREGORY MONE

FROM TOP: SPDO/TDP/DRAO/SWINBURNE ASTRONOMY PRODUCTIONS; G. BORGONIE/GHENT UNIVERSITY, BELGIUM

With APC Back-UPS, your digital life goes on...




even when the power goes off.

Preserve what's most important to you.

Reliable power backup for 24/7 availability

Whether DVRing your favorite show, updating your Facebook® status, or playing a live networked game, you depend on your home electronics every day, all day. That's why APC by Schneider Electric™ has designed battery backup solutions that protect the constant availability and connectivity you expect…and depend on.

Peace-of-mind protection on two levels

When the power goes out, our popular Back-UPS™ units go to work. They instantly switch your home technologies to emergency power, allowing you to work through brief power outages or safely shut down your systems so you won't lose valuable files—such as digital photos and media libraries. They also feature surge outlets to guard your electronics and data from "dirty" power and damaging power surges—even lightning. So you get two levels of protection in every APC Back-UPS unit!

Energy-saving insurance for what matters most

Our Back-UPS units protect your home office, digital living and home media applications, notebook computers, DVRs, and gaming applications. And since we now offer energy-efficient models that reduce electricity costs through unique power-saving outlets, you can realize true energy savings regardless of the applications you're backing up. Throughout your home, the APC Back-UPS is the cost-saving insurance you need to stay up and running and reliably safeguarded from both unpredictable power and wasteful energy drains.

Keep your electronics up and your energy use down!

ES Series

The ever-popular ES models are priced affordably yet provide enough extended runtime to allow you to work through short and medium power outages. Some power-saving models have been designed to actively reduce energy costs.

The energy-efficient ES 750G

The ES 750G boasts innovative power-saving outlets, which automatically shut off power to unused devices when your electronics are turned off or asleep, eliminating wasteful electricity drains.

- 10 outlets
- 450 watts / 750 VA
- 70 minutes maximum runtime
- Telephone/network protection

The best-value ES 550G

The ES 550 uses an ultra-efficient design that consumes less power during normal operation than any other battery backup in its class, saving you money on your electricity bill.

- 8 outlets
- 330 watts / 550 VA
- 43 minutes maximum runtime
- Telephone/network nrotection

Power up to WIN 1 of 7 APC BR700G Battery Back-UPS units (a $130 value)!

Visit www.apc.com/promo Key Code f733v • Call 888-289-APCC x4018 • Fax 401-788-2797

APC™ by Schneider Electric

email: esupport@apc.com • 132 Fairgrounds Road, West Kingston, RI 02892 USA • 998-2508_GMA

HIDDEN SCIENCE

Pittsburgh Pirates catcher Ryan Doumit breaks his bat during a recent game. Since a 2008 study exposed a pivotal structural weakness in maple bats, the number of shattered bats has dropped 50 percent.

How the Forest Service Saved Baseball

IN APRIL 2008, A JAGGED PROJECTILE OF MAPLE wood hurtled into the stands at Dodger Stadium in Los Angeles and struck Susan Rhodes in the face. She left the ballpark with a concussion and a broken jaw. By June, Major League Baseball (MLB) had commissioned a $500,000 investigation into the alarming number of bats that had shattered that season, including more than 750 in just three months.

Fans attending the 2011 World Series should be relatively safe from impalement, owing to some sharp scientific sleuthing that has reduced the number of pulverized bats in the league by 50 percent and shed light on one of baseball's strangest mysteries.

In their 50-page report to MLB, the researchers, led by U.S. Forest Service engineer Dave Kretschmann, pinned blame squarely on two culprits: the type of wood (maple) and the cut of the grain. The conspicuous spike in shattered sticks, they discovered, coincided with a shift in preference from traditional ash bats to maple, a supposedly more durable wood that skyrocketed in popularity after Barry Bonds clobbered a record-breaking 73 home runs with maple bats in 2001. The researchers also found that in some bats the wood fibers ran along the handle at an angle, instead of straight up; parallel fibers create a solid foundation to absorb the force of the ball. Angled fibers are easy to spot in ash but are nearly invisible in maple, so manufacturers were unknowingly distributing bats that were sapped of up to three-quarters of their potential strength (although Bonds did not seem to notice). "That's the problem you have when you make something with wood," Kretschmann says. "There are so many variables."

MLB has since mandated that bat manufacturers place an inkblot on the handle of every maple bat they make. The ink bleeds along the grain of the wood, allowing a third-party agency contracted by the league to ensure that the fibers run at an angle of no more than 3 degrees from vertical. As a result, the number of splintered bats plunged by 30 percent in 2009 and continued a steady descent last season. For Kretschmann, watching baseball has never been more satisfying: "On a high-definition TV I can see the little black inkblots and say, 'Oh, I was involved in that.'" MADELINE BODIN

SAINTS + SINNERS

SAINT: WINDPIPE BUILDERS In June a dream team of doctors and researchers saved the life of a tracheal cancer patient by performing the first artificial windpipe transplant. Alexander Seifalian of University College London built a scaffold for the windpipe out of plastic and nanomaterials, Harvard Bioscience grew tissue on the scaffold using the patient's stem cells, and Swedish surgeon Paolo Macchiarini aced the transplant.

SINNER: EDWIN HUBBLE A new paper alleges that the astronomer credited with discovering the expansion of the universe censored the work of rival Georges Lemaître, who had come up with the same idea two years prior. Historian David Block argues for a Lemaître Space Telescope to finally give the Belgian astronomer his due.

SAINT: N.E.D. (NO EVIDENCE OF DISEASE) In June the rock band N.E.D., made up of six gynecologic oncologists, released its second album, *Six Degrees*. The band members use their music to raise awareness of the deadly cancers (ovarian, uterine, and cervical) that they treat in their day jobs.

SINNERS: 3 HARVARD PSYCHIATRISTS In July Harvard disciplined Joseph Biederman, Thomas Spencer, and Timothy Wilens for neglecting to mention that they had accepted more than $4.2 million from drug companies to support their research. The doctors said their mistakes were "honest ones."

CLOCKWISE FROM TOP RIGHT: COURTESY MAJOR LEAGUE BASEBALL; ISTOCK; JON BRENNEIS/GETTY IMAGES

HOT SCIENCE

What to read, view, and visit this month

Museums

The Open Sea

MONTEREY BAY AQUARIUM

Most of us have a hugely distorted view of the seas: We look mostly at the shore while the real action happens far out beyond the horizon, where hardy animals built for speed and endurance traverse the open waters. Three beautifully remodeled galleries here give landlubbers a rare glimpse of this sprawling oceanic wilderness, the world's largest habitat. Ten thousand sardines form an undulating river in the aquarium's million-gallon centerpiece tank, as tuna and barracuda zip past sharks, stingrays, and sea turtles. Clever design creates the illusion of endless depths, giving visitors a hint of the true vastness of the sea. Open now. GILLIAN CONAHAN

MONTEREY BAY AQUARIUM/RANDY WILDER

Books

The Beginning of Infinity: Explanations That Transform the World

By David Deutsch

Through the eyes of theoretical physicist David Deutsch, humanity's gravest problems become grist for the mill. People survive and thrive by solving problems, he argues, and good solutions demand good explanations. New explanations, in turn, create new problems, and so the wheel of progress spins indefinitely. Deutsch applies this ultrarational analysis to evolution, artificial intelligence, and many other fields. The result is a brilliant, brash, but strangely dehumanized manifesto for modern science. "A sick person is a physical object, and the task of transforming this object into the same person in good health is one that no law of physics rules out," the author writes. Then again, cheery bedside manner will never cure cancer. NICOLE DYER

A More Perfect Heaven

By Dava Sobel

Nicolaus Copernicus turned the universe inside out, theorizing that the sun, and not Earth, was the fixed point around which heavenly bodies moved. With her customary flair for charting the history of the heavens

through a human lens, Sobel chronicles Copernicus's life, from his celestial observations to his domestic disputes, and explores how his ideas shaped the subsequent astronomical breakthroughs of Tycho Brahe, Johannes Kepler, and Galileo. The book's surprise centerpiece is a play in which Sobel imagines a pivotal story largely lost to history: how a visiting scholar convinced Copernicus, who had kept his sun-centered model secret for decades, to reveal it to the world.

VALERIE ROSS

The Better Angels of Our Nature: Why Violence Has Declined

By Steven Pinker

At a time when shooting sprees play out in near-real time on the Internet, it often seems as if the world is becoming ever more violent. But experimental psychologist Steven Pinker has news for you: We are actually living in an era of unprecedented peace. Archaeological and historical data show violence was a miserable fact of daily life until the Middle Ages. To understand the dramatic decrease in bloody acts since then, Pinker explores the social and neurological roots of aggressive behavior, from the grotesque murders described in the Bible to the brain's "rage circuit."

Feynman

BOOK SNEAK PEEK

By Jim Ottaviani and Leland Myrick

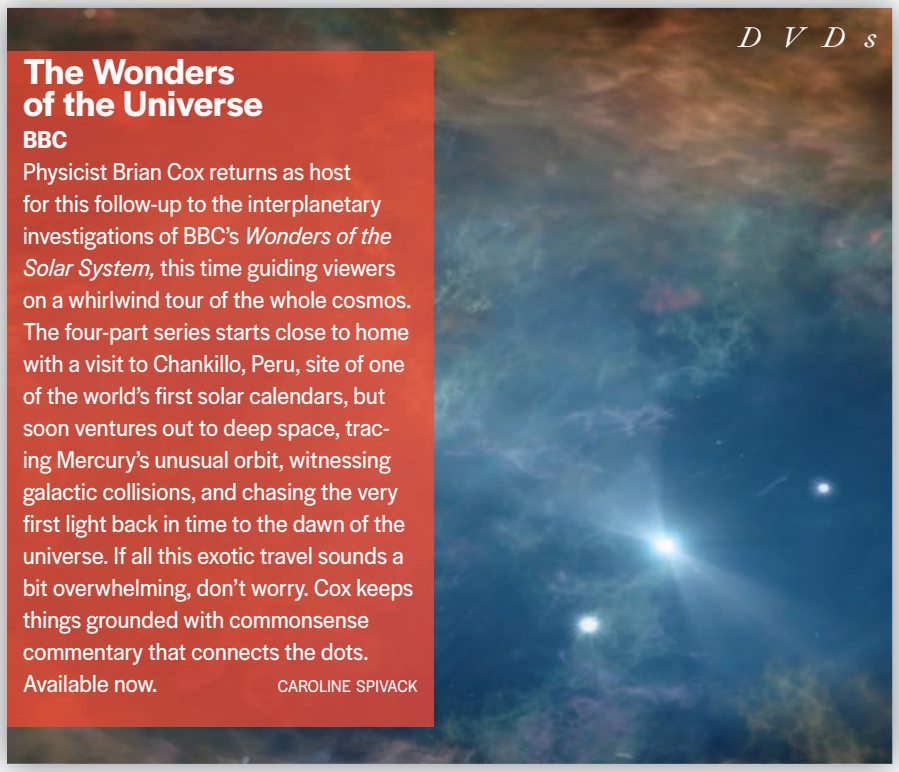
This writing and illustrating team offers a fresh look at the life of famed physicist Richard Feynman, framing his world within brightly colored panels and impressionistic lines. Their comic book-style biography follows its hero from his early job on the Manhattan Project through his role investigating the Challenger disaster. Much like Feynman himself, the book succeeds in making complicated science clear–and gladly takes detours from the cerebral side of physics to travel the globe, tell some jokes, and meet a few girls. In the excerpt below, Feynman attempts to decode his Nobel Prize-winning work on quantum electrodynamics. V. R.

Although there's no smoking gun, Pinker posits that a rise in IQs over the last century might be part of the explanation: A smarter world could be a less violent one. ERIC POWELL

America the Vulnerable

By Joel Brenner

A public service announcement of the most urgent sort, this engrossing book reveals how our lack of cyber savvy, both as individuals and as a nation, is exposing us to extraordinary risks, including viruses that could destroy the power grid, simple hacks that have harvested millions of credit card numbers from retailers, and security breaches that are hemorrhaging classified intelligence through the Net. It is thought-provoking reading from an expert witness: Brenner is the former inspector general of the National Security Agency. VERONIQUE GREENWOOD



The Wonders of the Universe

BBC

Physicist Brian Cox returns as host for this follow-up to the interplanetary investigations of BBC's *Wonders of the Solar System,* this time guiding viewers on a whirlwind tour of the whole cosmos. The four-part series starts close to home with a visit to Chankillo, Peru, site of one of the world's first solar calendars, but soon ventures out to deep space, tracing Mercury's unusual orbit, witnessing galactic collisions, and chasing the very first light back in time to the dawn of the universe. If all this exotic travel sounds a bit overwhelming, don't worry. Cox keeps things grounded with commonsense commentary that connects the dots. Available now. CAROLINE SPIVACK

Contagion

WARNER BROS.

A lethal new virus rampages across the globe, sending health officials and ordinary citizens scrambling to deal with both the deadly pandemic and the panic burgeoning in its wake. The high-profile cast includes Matt Damon and Kate Winslet, but *Contagion* isn't just another disaster thriller. It's an all-too-realistic glimpse at the kind of outbreak that could happen tomorrow.

According to the movie's science adviser, Columbia microbiologist Ian Lipkin, the film's pandemic scenario is spot-on, from the disease's sudden emergence to the struggles of developing a vaccine. The scenes of mass panic ring true as well, says Lipkin, who was in Beijing during the 2003 SARS outbreak: "I've seen this fear firsthand." Opens September 9. GILLIAN CONAHAN

BY CARL ZIMMER

A British family with a bizarre speech deficit has led linguists to *FOXP2*: a gene that may explain how our ancestors acquired language.

IT IS A SHAME THAT GRAMMAR LEAVES NO FOSSILS BEHIND. FEW things have been more important to our evolutionary history than language. Because our ancestors could talk to each other, they became a powerfully cooperative species. In modern society we are so submerged in words—spoken, written, signed, and texted—that they seem inseparable from human identity. And yet we cannot excavate some fossil from an Ethiopian hillside, point to a bone, and declare, "This is where language began."

Human speech requires complex, rapid movement of the lips, tongue, and vocal cords. A gene called *FOXP2* may explain how we evolved those capabilities.

Lacking hard evidence, scholars of the past speculated broadly about the origin of language. Some claimed that it started out as cries of pain, which gradually crystallized into distinct words. Others traced it back to music, to the imitation of animal grunts, or to birdsong. In 1866 the Linguistic Society of Paris got so exasperated by these unmoored musings that it banned all communication on the origin of language. Its English counterpart felt the same way. In 1873 the president of the Philological Society of London declared that linguists "shall do more by tracing the historical growth of one single work-a-day tongue, than by filling wastepaper baskets with reams of paper covered with speculations on the origin of all tongues."

A century passed before linguists had a serious change of heart. The change came as they began to look at the deep structure of language itself. MIT linguist Noam Chomsky asserted that the way children acquire language is so effortless that it must have a biological foundation. Building on this idea, some of his colleagues argued that language is an adaptation shaped by natural selection, just like eyes and wings. If so, it should be possible to find clues about how human language evolved from grunts or gestures by observing the communication of our close primate relatives.

This line of thinking raised an exciting possibility: Perhaps language left a fossil record after all—not in buried bones, but in our DNA. Yet for years biologists could not find a single gene involved in language.

TEN YEARS AGO, THAT FINALLY changed. In 2001 a team of British scientists announced the discovery of a gene, called *FOXP2,* that seems to be essential for language. *FOXP2* came to light through the study of a family that had unusual difficulties with words. The KE family—so called in scientific papers for privacy reasons—lived in West London and included nine siblings, some of whom attended the same special speech and language school. Psychologists at the school discovered that four of the children struggled with language in a similar way. The meaning of sentences sometimes confused them: They might misinterpret "The girl is chased by the horse" to mean "The girl is chasing the horse." They also had trouble speaking—dropping some sounds off the beginning of words, for example, so that they would say "able" when they meant "table."

In 1987 the school headmistress referred the case to the Institute of Child Health at University College London. There, neurologists found that some of the children's cousins had the same language troubles, as did some of the parents. Geneticists traced the condition to a grandmother and deduced that she probably carried a rare mutation that she had passed along. The mutation did not alter intelligence or psychological well-being; the KE family was normal in those regards. Its effects were limited to language—but within

HORACIO SALINAS/TRUNK ARCHIVE

Limited Time Offer–Act Now!

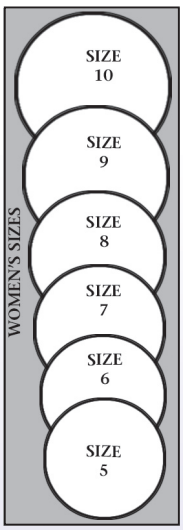
"…classic! The [Stauer] tanzanite are a beautiful shade of violet blue… full of color!"
— Praise for Stauer Tanzanite from C. of Missouri

Endangered Gem Disappearing

Tanzanite is found in only one remote spot on Earth, and it's 1,000 times rarer than diamonds. Experts say the mines will soon run dry forever, but today you can own more than 1 carat for ***less than $50!***

Time is running out. Geological experts predict the world's supply of tantalizing tanzanite will disappear in a matter of just a few years. Maybe sooner. High-end retailers are raising prices on this rare stone. And gem dealers are in a mad scramble to secure their claim before it's too late. Let them scramble.

Our buyer recently secured a huge cache of beautiful rare tanzanite, the precious stone loved for its vivid violet-blue color. Today you can own over 1 carat of this rare stone (1,000 times rarer than diamonds) in our spectacular ***1 1/5 ctw Tanzanite Cluster Ring*** with a suggested retail of $795 for only **$49.50**.



USING THE RING SIZE CHART
Place one of her rings on top of one of the circle diagrams. Her ring size is the circle that matches the inside diameter of the ring diagram. If her ring falls between sizes, order the next larger size.

It started with a lightning bolt. One strike set the African plains on fire and uncovered a secret that was buried for more than 585 million years. Tanzanite naturally occurs in only one place on Earth: Tanzania's remote Merelani Hills, in the shadow of Mount Kilimanjaro.

World's most endangered gem. Top-quality tanzanites can often fetch higher prices than diamonds. But, once the last purple gem is pulled from that remote spot beneath Kilimanjaro, that's it. No more tanzanite.

Reserve your piece of gem history. If you go online right now, you'll find one of the largest retailers selling tanzanite rings for well over $2,000 each. Ridiculous. Instead, you can secure your own piece of limited-edition tanzanite history at the right price.

Our promise of absolute satisfaction is 100% guaranteed. Our offers are so consumer friendly that we have earned an **A+ Rating** with the Better Business Bureau. But, why less than $50 for a genuine 1 1/5 tanzanite ring? It's simple. We want you to come back to Stauer for all of your jewelry and watch purchases. If you are not 100% delighted with your ring, send it back within 30 days for a full refund of the purchase price. Just remember that the odds of finding this stone at this price ever again is like waiting for lightning to strike the same place twice.

JEWELRY SPECS:
- 1 1/5 ctw tanzanite – Ring sizes 5–10
- Rhodium-layered .925 sterling silver setting

Extremely Limited Offer

Tanzanite Cluster Ring (1 1/5 ctw)—~~$795~~
***Now Only* $49.50** + S&P

Call now to take advantage of this limited offer.

1-888-870-7339

Promotional Code CTR305-05
Please mention this code when you call.

ACCREDITED BUSINESS BBB — Stauer has a **Better Business Bureau Rating** of **A+**

Stauer®
14101 Southcross Drive W., Dept. CTR305-05
Burnsville, Minnesota 55337
www.stauer.com

Smart Luxuries—Surprising Prices

that narrow sphere, its effects were profound.

The family then came to the attention of geneticists at Oxford, who began a dogged search for the gene that caused these problems. They compared the DNA of family members, looking for distinctive markers shared only among the ones who had trouble with language. Among those with the language deficit, they found shared markers in a single region of chromosome 7. Years later, the scientists received a vital new clue when the same kind of language disorder was identified in an unrelated 5-year-old boy. He had experienced a particularly dramatic mutation, in which a piece of chromosome 5 had been swapped with a piece of chromosome 7. One end of the boy's swapped DNA lodged itself in the same region that the Oxford team had identified in the West London family, right in the middle of the *FOXP2* gene.

The Oxford researchers turned back from the boy to the KE family and, using the additional information, discovered that those members with language troubles shared a mutation in *FOXP2* as well. Their mutation was far more subtle, however. Their trouble with language had been caused by the change of a single nucleotide of DNA—just one letter in the genetic sequence.

All land vertebrates carry a version of the *FOXP2* gene, so some of the Oxford researchers then teamed up with colleagues from the Max Planck Institute for Evolutionary Anthropology in Germany to analyze what is unique about the variant in humans and to track how the gene had evolved in our ancestors. They determined that after the gene arose, more than 300 million years ago, it barely changed in most branches of vertebrate evolution to the present day. In the human branch, however, two amino acids in the protein produced by the *FOXP2* gene changed notably over the course of just a few million years. The scientists concluded that *FOXP2* experienced a fast pulse of natural selection in our lineage, a development possibly related to the emergence of language.

> The *FOXP2* gene also is associated with vocal learning in young songbirds, which produce higher levels of protein when they learn new songs. If *FOXP2* is impaired, they make singing mistakes.

Several groups are now hard at work gleaning more details about the relationship between *FOXP2* and language. Cognitive neuroscientist Frederique Liegeois of University College London is using fMRI scans to compare the brain activity of members of the KE family who have a mutated copy of *FOXP2* with those who have a normal version. The most striking difference, Liegeois recently reported, arises when family members are asked to repeat a set of nonsense words, something most adults can do without trouble. Those with the mutation do badly at the task. They also have low levels of activity in several regions of the brain, especially the basal ganglia, a key hub for learning muscle movements. That makes sense, since one of the hardest aspects of speech is learning how to make the necessary rapid movements of the lips, tongue, and vocal cords.

Other scientists are probing the *FOXP2* gene further by studying the protein it produces, known as Foxp2. The protein seems to be especially active while human embryos are developing. Simon Fisher—one of the original Oxford geneticists, now at the Max Planck Institute for Psycholinguistics in the Netherlands—has found that the gene switches on in neurons within certain regions of the brain, including the basal ganglia. The Foxp2 protein then latches onto other genes in developing neurons and switches them on or off as well. By orchestrating dozens of genes, *FOXP2* appears to oversee the growth of new branches on the neurons, bringing about a level of complexity likely to facilitate language.

HUMANS ARE NOT THE ONLY species to benefit from *FOXP2*. Researchers have shown that the gene is associated with vocal learning in young songbirds, which produce higher levels of Foxp2 protein when they need to learn new songs. If their version of *FOXP2* is impaired, they make singing mistakes. Other vocal-learning species, such as whales, bats, elephants, and seals, may also rely on the gene. To probe this connection, geneticist Wolfgang Enard of the Max Planck Institute for Evolutionary Anthropology engineered mice by replacing their *FOXP2* gene with the human one. The mice did not start reciting poetry, but they did display some subtle changes. Instead of producing a high squeak, for example, the engineered mice produced lower sounds. Bigger changes took place within the animals' brains. Enard found that in the basal ganglia and connected regions involved in learning, the human version of *FOXP2* caused some neurons to develop longer branches than those found in normal mice. Around the same time, Fisher and his team engineered mice so that one copy of their *FOXP2* gene carried the same mutation as that found in the KE family. In subsequent tests, the mice with the mutation did a worse job than normal mice at learning new motor skills.

These findings hint at what happened to *FOXP2* in our ancestors. It may have started out hundreds of millions of years ago as a gene that helped regulate the learning of body movements, such as those involved in running, calling, and biting. Later mutations in the gene spurred more neural growth in certain areas of the brain, including the basal ganglia, creating the connections essential for learning and mastering complicated sounds and, eventually, full-blown language.

FOXP2 didn't give us language all on its own. In our brains, it acts more like a foreman, handing out instructions to at least 84 target genes in the developing basal ganglia. Even this full crew of genes explains language only in part, because the ability to form words is just the beginning. Then comes the higher level of complexity: combining words according to rules of grammar to give them meaning.

Language is nearly endless in its forms. So the search for its behavioral fossils—genes associated with grammar and syntax—should keep scientists busy for decades to come.

Carl Zimmer is an award-winning biology writer and author of *The Tangled Bank: An Introduction to Evolution*. His blog, The Loom, runs at blogs.discovermagazine.com/loom

Your life is on your computer.

With so much to lose, there's only one smart way to protect it.

Carbonite online backup is the easy, automatic and secure way to safeguard your irreplaceable computer files.

These days we all have things on our computers we just can't afford to lose. Photos that capture special moments in our lives. That one-of-a-kind music collection…years of financial records…contacts… emails and more. Carbonite works automatically and continually to make sure your computer files – and memories – are backed up safely offsite. Start your free trial today or call 1-877-334-7619 to learn more.

- Unlimited online backup
- Automatic & continuous
- Encrypts files for privacy
- Installs in minutes – PC or Mac
- Trusted by over 1 million customers
- Access files from any computer or smartphone

Just $59.00 a year

CARBONITE™
Back it up. Get it back.™

TWO BONUS MONTHS*

Visit carbonite.com

*Use Code CB438 and get 2 BONUS months upon purchase.

TRY IT FREE!
No credit card required

IMPATIENT FUTURIST

BY DAVID H. FREEDMAN

For the safety-conscious clotheshorse: a suit that will protect you from radiation, chemicals, bullets, and pretty much any other insult of modern life.

One chilly fall day in 2001 my brother and I were chainsawing fallen trees for firewood when the saw kicked on a knot and shot out of my brother's hands and into his groin. It took me 10 minutes to pry his hands off the area of injury so I could assess the damage, which turned out to be just an ugly gash in his jeans. Another time I watched a friend bounce off a mogul and impale himself in the upper thigh with the wrong end of his ski pole. And I'm not just an observer of mayhem; I'm a victim, too. I've survived a motorcycle accident, dog and snake bites, and the nuclear accident at Three Mile Island; I've also had a gun pulled on me in anger, escaped two flash fires, and been knocked unconscious by fire-extinguishing gas while sitting in a fake space capsule. (I'm not making any of this up; my editors wouldn't let me.)

All of which leads me to conclude there is a market for clothes that are crash-bullet-blast-toxin-radiation-proof and that also monitor both the wearer and his environment for threats. A market not for police and rescue workers and other hero types, but for ordinary disaster magnets like me. And no need for them to be particularly stylish—you can't take coolness with you, or take much advantage of it if you have been de-crotched.

To assemble such a nurturing ensemble, I'll start with Kevlar, the tough synthetic fiber used in clothing already available to protect against motorcycle falls, chain saw accidents, bullets, blasts, and even snakebites. A bunch of problems solved at once? Not necessarily. Ronald Egres, the scientist who develops high-tech fibers for protective clothing at DuPont, Kevlar's maker, notes that different types of threats call for different types of Kevlar. Slowing a bullet, for instance, requires a loosely woven version of the material with soccer-net-like elasticity, while holding together against the sharp tip of a knife requires a tightly woven fabric.

Fortunately I may not have to settle for this potentially deadly trade-off. Egres's team is finding ways to overlap different weaves of Kevlar, some of them reinforced with plastic resins, for protection against multiple hazards. "It's a division of labor among the layers," he says, noting that DuPont has already used such smart layering to reduce the thickness of a bulletproof vest from 36 layers to 11, and its weight from 5 pounds to 4.

It is conceivable, then, that in the near future I will be well shielded from my favorite life-threatening weapons, but what if during my adventures I am engulfed by flames or toxic waste? I could bolster my Kevlar duds with a few layers of plastic sheeting to seal out liquids and vapors and add an outer coating of reflective aluminum to fend off the intense but short-lived radiant heat of a flash fire. Then again, I could also suffocate to death.

Philip Mann, the technology chief at Kappler, a Guntersville, Alabama, company that manufactures such multilayer suits for emergency responders, notes that while such a suit would do a great job of sealing out nasty liquid, gas, and heat, it would also do a great job of sealing *in* all the nasty liquid, gas, and heat that my body produces. "If your sweat can't evaporate, you can't cool yourself," he says. "You might not last long." Fortunately Kappler has an answer in development: a breathable material with micropores small enough to keep out dangerous molecules, but just large enough to let out water molecules, so that I can stay comfortable for hours while I'm wading through pools of glowing green goo. Even if I don't ever don that suit, it could make life a lot more pleasant for emergency workers and cleanup crews.

That still leaves the problem of how to guard against toxic fumes. I'm too practical to want to walk around in a full breathing apparatus all day long, appealing as that sounds. RAE Systems in San Jose, California, presents a possible solution in the form of a portable gas detector small enough to mount on a belt buckle no larger than the one I wore through most of the 1970s. The company claims the device can identify more than 300 volatile organic compounds (VOCs), those foul chemical vapors that waft off solvents, new carpet and furniture, and just about anything else that comes out of a factory, plus 25 different toxic gases.

The device's sweeping sensitivity comes from a tiny sensor that uses UV light to knock electrons out of most gas molecules, creating a measurable electric current. Meanwhile a heated platinum bead in the detector ignites whatever flammable gases it encounters and then mea-

David H. Freedman is a freelance journalist, author, and longtime contributor to DISCOVER. You can follow him on Twitter at dhfreedman.

sures the resulting heat. "We can detect VOCs down to the parts per billion," claims RAE marketing manager Michael Weinstein.

WHETHER MY BUCKLE IS BEEPING or not, my über-suit thus far offers no protection against the tiniest assassins of all: High-energy radioactivity such as beta particles and gamma rays can zip through most clothing to wreak havoc on cellular DNA. But not through Demron, a material invented by physician Ronald DeMeo (DEMeo, RONald—get it?).

Convinced that there had to be a better way of protecting people in hospitals from X-rays and other radiation-based treatments and tests than draping them in 10-pound lead aprons, DeMeo spent the 1990s experimenting with ways to impregnate plastic fabrics with different metals until he found a combination that blocked radiation about as well as lead and yet could still be fashioned into more or less normal-looking clothing.

DeMeo's results were so successful that his nine-pound suits—which look a bit like Halloween-costume versions of space suits but are roomy enough to fit over my bulletproof vest and gas protector—have become the outfit of choice for workers helping clean up the post-tsunami Fukushima reactor-meltdown site in Japan.

Women at high risk of breast cancer can buy a Demron bra within the next month or so to block out the background radiation we're all exposed to, and the bra also allows patients being treated for breast cancer with a radioactive implant to leave the hospital without exposing others. (I was ready to order Demron underwear to protect the most vital of my vitals, but DeMeo explained to me that testicular cells stop actively dividing much earlier in life than breast cells, leaving the former much less likely to become cancerous due to radiation exposure. One less thing to worry about. Well, two.)

What could possibly harm me now? Oh, please. For one thing, a boulder could pin me down in the backcountry, leaving me unable to get through my Kevlar shirt to free myself by gnawing off my arm. Heart attacks, catastrophic shaving accidents, and other mishaps could happen when I'm somewhere no one can hear me whimpering semiconsciously.

My clothes could still come to the rescue, though, by recognizing my distress and relaying my whimpering over a wireless network. That's why my future undergarments will include the BioHarness, a special chest strap from an Annapolis, Maryland, company called Zephyr that measures vital signs like heart rate and skin temperature, as well as body motions, and relays any worrisome readings via a Bluetooth transmitter to whoever might be standing by with a cellphone or computer to help. The device came in handy last fall when 33 Chilean miners lay trapped half a mile beneath the ground for 69 days, allowing doctors to keep tabs on the miners' health and to gauge their ability to endure the stress of the rescue effort.

SHOULD I FIND MYSELF TRAPPED in a mine 10 years from now, I might not need to strap anything to my body, thanks to Nicholas Kotov, a University of Michigan chemical engineer specializing in nanotechnology. Kotov is creating fabrics partially made from conductive carbon nanotubes (picture microscopic ziti made of rolled carbon atoms), which he expects could lead to garments that are essentially themselves electronic devices.

In principle such clothing could not only detect blood but also run tests on it. And in theory it could look outward, too, monitoring for gases and other external threats. The biggest obstacle, Kotov says, is that he hasn't figured out how to make such fibers laundry-proof: They decompose in the washing machine. "The best solution for now is to make them as disposable fabric patches," he says. "We should be able to make them for less than 50 cents."

I wish the rest of my getup could be so affordable. A Kevlar bulletproof vest goes for about $700; a Kappler chemical-and-fire-protective suit can push $3,000; a top-of-line RAE gas detector costs more than $6,500; and that Demron suit will set me back at least $1,700. Add them up and a not-fully-protective, really sweaty, socially repellent multisuit will run me about $10,000, and that's without tailoring. Of course we know that technology is continually bringing us better stuff for less money, so I'm budgeting $80 for the fully invulnerable version that's just around the corner. Hey, my life and limb are worth it.

Now please excuse me—my gas-detector belt buckle just went off. I'm pretty sure I need to let the dog out.

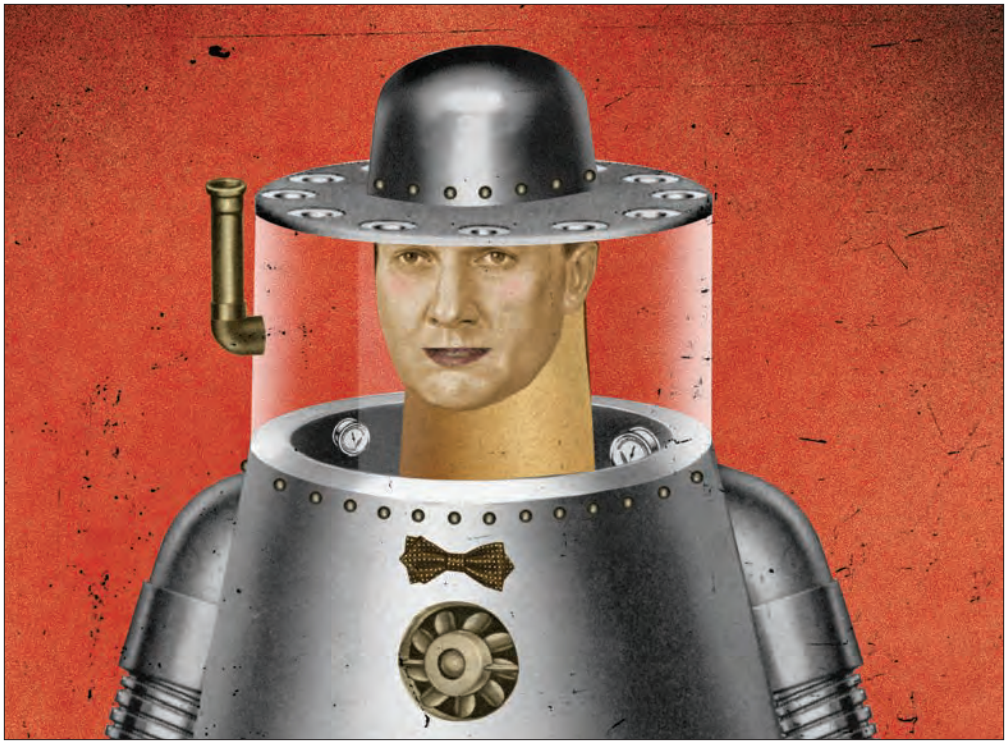


ILLUSTRATION BY DAVID PLUNKERT

VITAL SIGNS

BY W. ROY SMYTHE

A body scan reveals a lemon-size mass in the chest of a 16-month-old boy. Fearing cancer, surgeons perform a risky operation to save his life.

I WAS REVIEWING MY EMAILS LATE IN THE DAY when I found a message flagged "Important" in the subject line. It was from Kelsey, one of our hospital's new pediatric surgeons. "Consulted regarding a 16-month-old with a middle mediastinal mass," her message read. "Compression of trachea. Would love your thoughts."

The mass Kelsey referred to in her email was in an area where a lot of things can go wrong, what we call the *mediastinum*—the middle of the chest between the lungs, where several important organs, such as the heart, trachea, and esophagus, reside.

As a thoracic surgeon, I specialize in operating on organs in this area and often review cases with colleagues.

I responded that I'd be happy to speak with her, and in less than 15 minutes she was tapping on my door. Kelsey was obviously very concerned about this one, so I quickly pulled the CT scan of the mass up on the computer as she relayed the details of the case. The patient was a 16-month-old boy who was developing normally but had recently been diagnosed with asthma.

He had been admitted to the hospital because of increasing stridor, a high-pitched sound made during inhalation. Stridor indicates a narrowing somewhere in the main, or proximal, airways—the area of the respiratory tract between the vocal cords high in the neck and where the trachea, or windpipe, branches to meet the two lungs. Stridor is often thought to indicate asthma, but it usually doesn't. Asthmatics make a different sound: a wheeze. Wheezes occur during exhalation and imply obstruction of the smaller airways that are in the lungs themselves.

The boy's name was Ian, and it was clear that his breathing problems were not caused by asthma. The CT images showed a five-centimeter mass—about the size of a lemon—narrowing his trachea by more than half and encasing the adjacent esophagus, which carries food from the mouth to the stomach. It looked as if malevolent bees had built a rounded, ill-formed hive in Ian's chest.

I took in a deep breath: "That looks bad, Kelsey."

"Yeah," she replied. "It may be malignant. I'm worried about a sarcoma."

We knew that about half of mediastinal tumors in children are malignant—aggressive cancers that grow into surrounding organs. Such tumors can take various forms. Sarcomas are malignant tumors of connective tissues such as muscle and bone. Tumors can also form in the lymph glands, the small organs of the immune system that filter bacteria from the bloodstream. Mediastinal tumors are rare, however. A total of 10,000 children are diagnosed with cancer every year in the United States, and mediastinal tumors account for about 100 of those cases.

"If not a tumor, I guess this could be a fistula," Kelsey said, "with a chicken bone or something lodged there and causing an infection."

A fistula is an abnormal connection of tissue between two organs. There are a group of congenital fistulas that can connect the trachea and esophagus, which grow from the same embryonic tissue. If a child swallows an object that lodges in the fistula, it can trigger an infection that may result in an inflamed mass. But Kelsey said that Ian's white blood cell count and other tests that would indicate an infection were normal.

I considered whether we should get other tests, such as a biopsy or an MRI. "We could," Kelsey replied. "But if the mass enlarges, it will block the trachea completely. I think we just have to go for it."

We discussed the challenges of removing Ian's mass surgically. If it was attached to the esophagus extensively, we would have to remove much of the organ and replace it with a section of the stomach. The tracheal part of the procedure could get even more complex. The trachea does not heal as reliably as the esophagus, and only a small amount of tissue can be removed from it for reconstruction, giving us a narrower margin of error in the event of damage and subsequent repair. The complexities and risks were so great that Kelsey and I sought the input of other doctors as well. Kelsey called her mentor at the pediatric surgical program where she had trained, and I called a pediatric surgeon who had trained with me years earlier. These colleagues felt surgery was unavoidable.

We scheduled Ian's operation and went to see him and his family in the pediatric ward. While we talked, Ian stood in his crib, sucking his pacifier.

We did our best to assuage the parents' fears, but this was a lot of surgery for a little person, and it

W. Roy Smythe is chairman of surgery for the Texas A & M Health Science Center College of Medicine. The cases described in Vital Signs are real, but names and certain details have been changed.

involved a great deal of risk. Whether or not we found a malignancy, the outcome might be bad.

AFTER A NIGHT OF LITTLE SLEEP for me, and most likely less for Ian's parents, the morning of the surgery arrived. In the operating room, nurses carefully inserted a breathing tube into Ian's narrowed airway. He was then anesthetized, positioned with his right side up, and cleaned with an antiseptic solution. Drapes covered his tiny body, exposing only the operative field.

We made an incision in his chest and placed retractors to make room between his ribs. The mass was immediately evident. It was oval-shaped, with an irregular contour, like the surface of a reddish-tan rock. We both felt it. "It's fixed and firm," said Kelsey, not needing to mention that this was consistent with a cancerous tumor. We began by working our way around the mass with surgical scissors to the back wall of the esophagus. It was a struggle.

"It's definitely involving the esophagus," I said. "Let's try the trachea." Kelsey was a skilled young surgeon, but using a variety of tools, including an electric scalpel, we could not free the mass from either structure. It was too firmly attached. While working around the mass, we spotted an enlarged lymph node nearby. "That's not a good sign," I murmured. "Might have spread there."

We worked without speaking—four adult hands in a small space. A sense of foreboding was accumulating in the room around us like fog.

Finally, I made a desperate suggestion. "Let's divide the mass," I said. "Maybe we can see from another perspective how it's attached to the trachea and esophagus separately—we aren't making progress."

This was something we preferred not to do. When removing a tumor, an "en masse" approach is best, meaning the entire tumor is extracted intact with any surrounding tissues attached, which gives surgeons the best chance to leave no cancerous tissue behind.

"Agreed," Kelsey replied. "Maybe we can save some of the trachea that way, make the repair easier."

I took a scalpel and carefully incised the mass. After a couple of passes, it cracked open. Ian's heartbeat, a beep on the anesthesia monitor, registered five times before either of us spoke.

There was something dark and linear at the center. It looked horrifyingly like a slug. "What is that?" Kelsey asked.

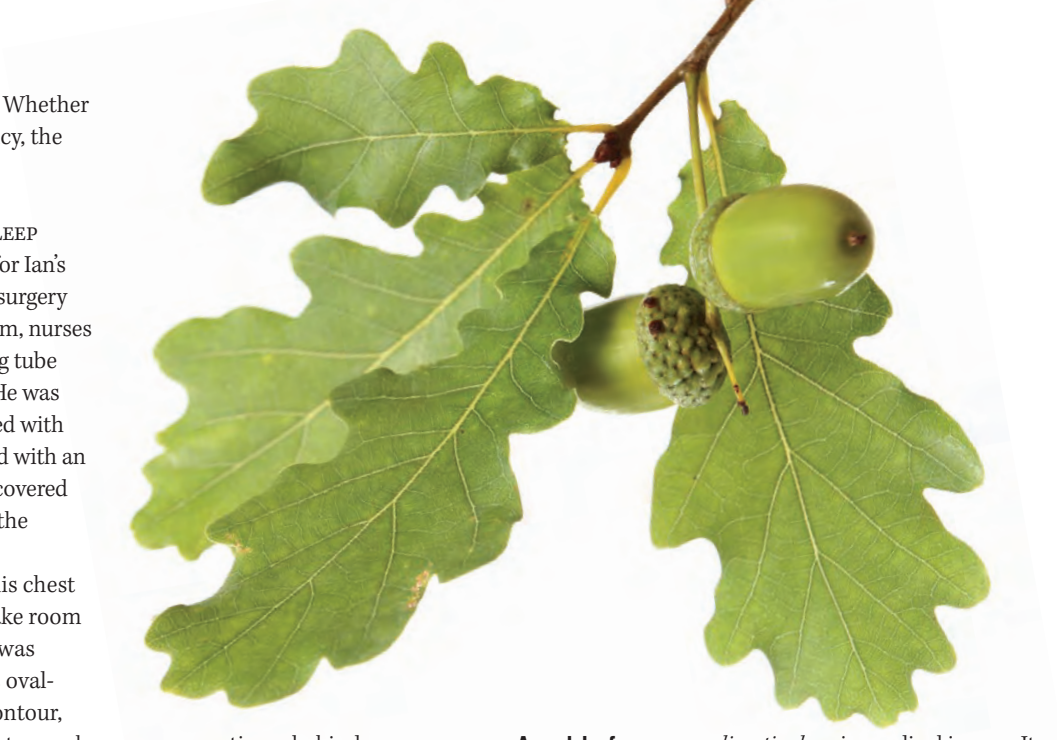
I reached down and grasped it with a pair of forceps. "It's firm," I said. Kelsey adjusted the light overhead—there was a glint of reflection. "Metal?" I asked. I carefully pulled the object free. It was dark gray, oval, and covered in a layer of mucus.

I held it up in the light between us.

It was a leaf.

"A leaf?" Kelsey asked. "A leaf?" Her eyes were squinting above her mask, and her forehead wrinkled in disbelief. Suddenly it was clear. The mass formed to protect Ian's body from the leaf and had taken on a life of its own. We both started laughing. The nurses clapped. There was no cancer; Ian was going to survive.

During the rest of the operation, we found that the leaf was nestled in a place where the normally cylindrical esophageal wall bulged out—a *diverticulum* in medical jargon. It all added up. Ian had swallowed an oak leaf months before, and it had lodged in the diverticulum, unable to pass. The leaf's tip had eroded into the trachea and eventually, after white blood cells homed in on the region to heal the lesion, a scar formed around both the inflamed tissue and the leaf.



An oak leaf can be a deadly object if it ends up in the wrong part of the body.

The young mother and father were incredibly relieved at the news, which Kelsey and I delivered immediately following the operation. They hugged each other, and after several moments, Kelsey and I left the room quietly, the two of them still embracing. Ian left the hospital after a few days. He was going to be fine.

The fact that the mass was not a malignant tumor didn't change the urgency behind the operation. If Ian's diagnosis of stridor and the surgery had been delayed, the mass could have led to the complete obstruction of the airway and sudden suffocation, or a leakage of esophageal contents, laden with bacteria from the mouth. If leaked into the trachea, these contents could have led to pneumonia, or if into the mediastinum, to sepsis and vascular collapse. We were relieved to find that the mass was not cancer, but left untreated, a simple leaf could very well have ended Ian's life.

ISTOCK

OUT THERE

BY SEAN CARROLL

Could our universe be just one of a multitude, each with its own reality? It may sound like fiction, but there is hard science behind this outlandish idea.

THEORETICAL COSMOLOGIST isn't one of the more hazardous occupations of the modern world. The big risks include jet lag, caffeine overdose, and possibly carpal tunnel syndrome. It wasn't always so. On February 17, 1600, Giordano Bruno, a mathematician and Dominican friar, was stripped naked and driven through the streets of Rome. Then he was tied to a stake in the Campo de' Fiori and burned to death. The records of Bruno's long prosecution by the Inquisition have been lost, but one of his major heresies was cosmological. He advocated that other stars were like our sun, and that they could each support planets teeming with life. Orthodox thought of the time preferred to think that Earth and humanity were unique.

These days, cosmologists like me may be safer, but our ideas have grown only more radical. One of the most controversial but widely discussed concepts in the field resembles a hugely amplified version of Bruno's cosmology: the idea that the thing we call "the universe" is just one of an infinite number of regions in a much larger universe of universes, or multiverse. A big focus of my own research asks whether a multiverse can help explain the arrow of time.

Also like Bruno, cosmologists are reaching far beyond what observational evidence can tell them. At the time of Bruno's death, Galileo had not yet turned the very first telescope upward to the stars. Today, nobody has looked beyond the boundaries of the known universe. In fact, such a far-reaching vision seems impossible by definition.

The extent of what astronomers can see is frustratingly limited by the speed of light: one light-year (about six trillion miles) per year. When we look far away, we are looking into the past, and that past doesn't stretch forever. Everything we see emerged 13.7 billion years ago from the hot, dense state known as the Big Bang, so we cannot observe anything more than 13.7 billion light-years away. If there is something so far away that its light couldn't have traveled from there to here in the time since the Big Bang, we cannot observe it.

Obviously, we don't know what the unobservable part of the universe looks like. It is conceivable that the universe as a whole is finite, closed in on itself like a sphere. It is also possible that it extends infinitely far in space but remains more or less the same no matter how far you go. And finally, it's possible that the universe extends infinitely far, but conditions vary wildly from place to place. That would be a multiverse.

Here we are not talking about disconnected universes, but rather what we cosmologists call pocket universes. Conditions are fairly uniform within any region but vary greatly from region to region. One pocket far away might be similar to our universe, but the mass of the electron might be a bit different. Even such a small change could scramble the rules of chemistry, not to mention biology. Another region might be utterly strange, with seven dimensions of space, say, and 29 forces of nature. All together, a bewildering variety of universes, each with its own laws of physics.

For all the parallels, modern physicists are quite unlike Bruno in one crucial way. They weren't led to this picture by pantheistic mystical philosophizing. Rather, they have been forced into it—kicking and screaming, in many cases—by other theoretical ideas, especially cosmic inflation and string theory.

Inflation was conceived in 1980 by MIT physicist Alan Guth to explain why the observable universe is so flat and smooth, with galaxies distributed evenly throughout space and with almost exactly the right amount of mass to balance out its expansion. The idea is that immediately after the Big Bang, the universe was trapped in a state called a false vacuum, in which empty space was filled with an incredible amount of energy. The false vacuum was unstable, like a radioactive atom waiting to decay. Eventually it broke down into the ordinary vacuum of space as we know it, releasing tremendous amounts of matter and radiation. In the process, an extremely small patch of space inflated to enormous size, evening out any irregularities and giving rise to the universe we see today.

But unlike a radioactive atom, which either decays or doesn't, the false vacuum can decay in some places but not in others. That means there can be regions where inflation continues forever. Suppose a tiny inflating region grows to tremendous size, and 90 percent of it converts into matter and radiation. The remaining 10 percent then grows to an even bigger size; 90 percent of that decays, and the cycle repeats indefinitely. There are regions like our own, where inflation has long since ended, but

Sean Carroll is a theoretical physicist at Caltech focusing on inflation and the arrow of time. His blog, Cosmic Variance, appears at blogs.discovermagazine.com/cosmicvariance

Two views of the Wizard nebula, a star-forming region 7,000 light-years away. If our universe is part of a multiverse, it might have near-twins out there, along with other drastically different universes.

J-P METSAVAINIO/ASTRO ANARCHY

also places where inflation is still going on, creating yet more regions, each forming a pocket universe.

That's where the multiverse comes from. It is not that cosmologists are so fond of all those universes; it's that we are fond of inflation, because inflation explains the observed properties of the cosmos with great precision. But many versions of inflation theory also predict an infinite number of universes, like it or not.

Things get still more interesting when we add string theory to the mix. String theory is currently the most promising way to explain the fundamental properties of all the particles and forces in our universe. But ours are not the only possible properties. String theory allows a boggling 10^{500} solutions—that's a 1 followed by 500 zeros—each corresponding to a different type of universe with its own kinds of particles and forces.

In short, string theory predicts that the laws of physics can take on an enormous variety of forms, and inflation can create an infinite number of pocket universes. So the different laws of physics predicted by string theory might not be just hypothetical. They might really be out there somewhere among the countless parts of the multiverse. This is not a situation that cosmologists dreamed up in a flight of fancy; it is something we were led to by trying to solve problems right here in the universe we observe. The question is, now that the multiverse is here, what are we going to do about it?

A LOT OF PEOPLE, BOTH INSIDE AND outside the scientific community, are viscerally opposed to the idea of other universes, for the simple reason that we can't observe them—at least as far as we know. It's possible that another universe bumped into ours early on and left a detectable signature in the cosmic background radiation; cosmologists are actively looking. But the multiverse might be impossible to test directly. Even if such a theory were true, the worry goes, how would we ever know? Is it scientific to even talk about it?

These concerns stem from an overly simple demarcation between science and nonscience. Science depends on being able to observe something, but not necessarily everything, predicted by a theory. It's a mistake to think of the multiverse as a theory, invented by desperate physicists at the end of their imaginative ropes. The multiverse is a prediction of certain theories—most notably, of inflation plus string theory. The question is not whether we will ever be able to see other universes; it's whether we will ever be able to test the theories that predict they exist.

Imagine a tribe of primitive cosmologists living on a planet perpetually covered with clouds. They cannot see the sky, so all they can do is speculate. Most of them might be content to imagine that their gray atmosphere stretches on forever, but others start imagining huge numbers of other planets, many very different from their own. These folks go so far as to suggest that their picture helps explain why their own planet is so hospitable: On the planets that aren't so pleasant, there aren't any cosmologists asking that question.

This scenario is much like our current situation. We find ourselves surrounded by an opaque barrier past which we can't see—the Big Bang. The distant universe might be uniform, or it might be full of different universes scattered throughout space. The conditions of our local environment might be the unique consequence of fundamental laws of physics, or they might just be one possibility out of a staggering number.

Right now we don't know, and that's fine. That's how science works; the fun questions are the ones we can't yet answer. The proper scientific approach is to take every reasonable possibility seriously, no matter how heretical it may seem, and to work as hard as we can to match our theoretical speculations to the cold data of our experiments.

Researchers have spent three decades trying to solve the riddle of HIV, an endeavor that infectious disease expert David Margolis calls "as difficult as inventing a warp drive to travel to other stars." A total AIDS cure is still not quite here, but researchers are getting remarkably close—and the quest has upended our understanding of the immune system and laid the groundwork for solutions to hundreds of other diseases. This process repeats again and again: Cures rarely happen with a flash of brilliance and cries of *eureka,* but their methodical unfolding fuels the dreams and enterprise of science. In this way, the world's endless supply of problems becomes a valuable resource. The list of ailments ripe for better treatments stretches far beyond AIDS, even far beyond medicine: traffic jams, radioactive fallout, and unsolved murders, to name a few. We all have someone or something we would like to cure, and big universities aren't the only ones leading the charge. These days a growing do-it-yourself movement seeks solutions in garages and community labs. The only thing really needed to solve problems is tenacity. "When a scientist gets an idea in his head, he won't stop until it's tested," says Robert Sabin, one of the leading DIYers. "Scientists are possessed by their ideas."

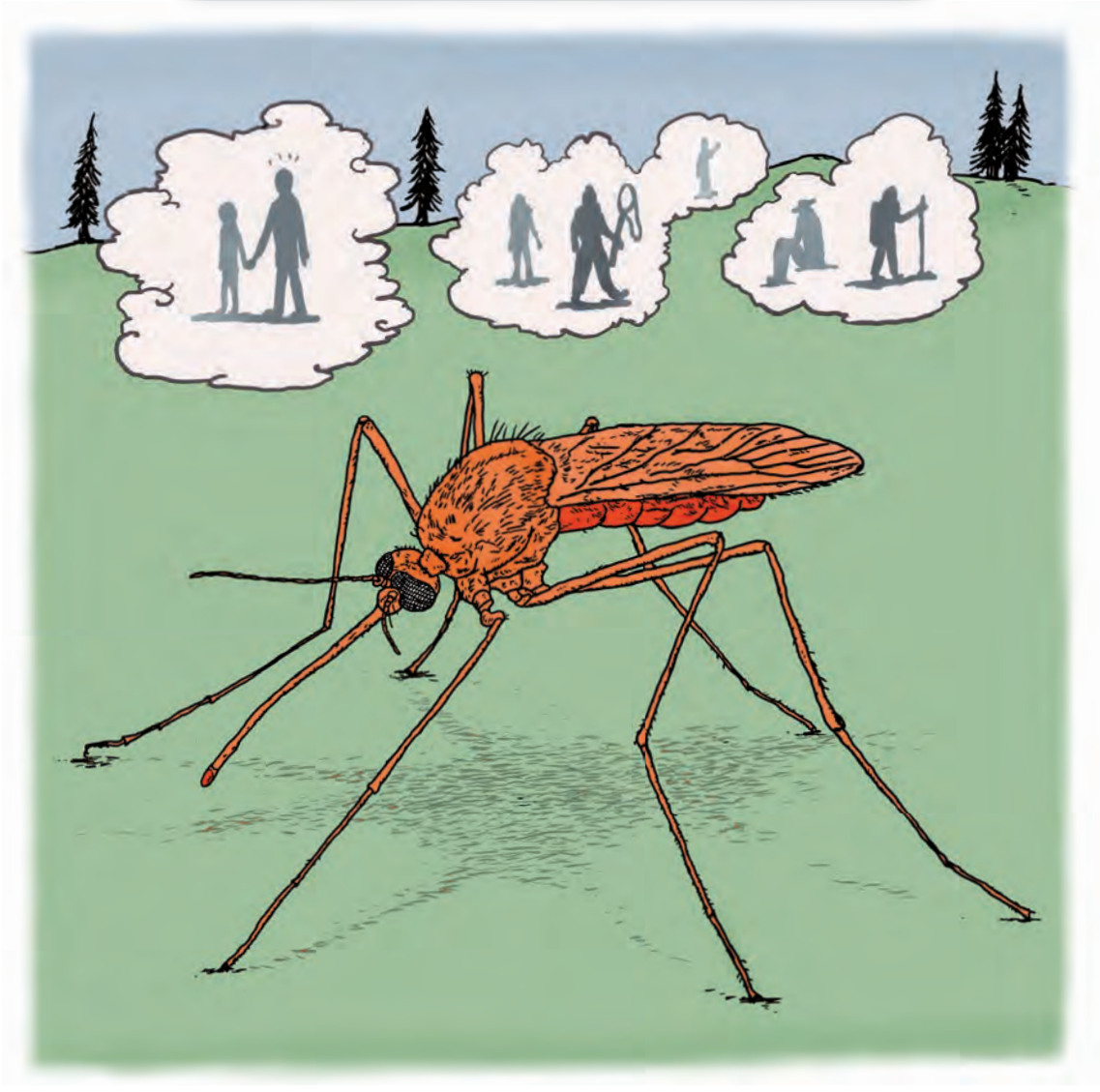
PHOTO ILLUSTRATION BY C. J. BURTON

AILMENT

MOSQUITOES

CURE

Chemical Invisibility Cloak



Since the 1940s the leading defense against mosquitoes has been the chemical repellent DEET, but unless you remember to spritz yourself with it every few hours, you will eventually get chomped. Entomologist Anandasankar Ray and colleagues at the University of California, Riverside, aim to do better with bug sprays intended for bugs, not people. They are developing a set of chemicals that disrupt the mosquito's sense of smell, effectively blinding the insects to humans.

ILLUSTRATION BY JONATHON ROSEN

Mosquitoes are basically flying hypodermic needles, infecting 700 million people annually; malaria alone kills about 800,000 a year.

Ray started with 50 compounds thought to disrupt the ability of mosquito olfactory sensors to detect carbon dioxide, the telltale sign of a living, breathing blood meal. He then turned the tables and jabbed the mosquitoes, inserting tiny electrodes into their sensors. One chemical, 2-butanone, acted as a carbon dioxide imitator, which could be exploited to lure the bloodsuckers. Another, butanal, prevented the CO_2 sensors from working, while 2,3-butanedione functioned as a blinder, flooding mosquitoes' sensors with signals, thereby rendering them useless.

Ray has since teamed up with a group of investors to found OlFactor Labs, based in Southern California, to develop commercial mosquito deterrents. He envisions odor traps that could be set up around golf courses or hotels to mimic carbon dioxide and draw mosquitoes away from populated areas. He is also exploring the possibility of an area-masking agent. Instead of DEET sprayed on the skin, an odor cloud of the binding chemicals could keep mosquitoes at bay with an "invisibility cloak" that makes CO_2 undetectable. Such cloaks could be especially valuable around homes in the world's malaria zones. So when can we ditch the DEET? Ray says cloaking sprays and odor traps could be here in five years. JASON DALEY

THE CURE

AILMENT

RADIOACTIVE FALLOUT

CURE

Blue Goop

Carting away large chunks of radioactive waste from a disaster area like Japan's Fukushima Daiichi nuclear plant is bad enough. But disposing of radioactive fallout that clings to walls, seeps into crevices, and coats rescue vehicles is an altogether more vexing problem.

You can wash off the contamination with soap and water–the traditional method–but that creates sizable reservoirs of radioactive runoff, which in turn has to be trapped, treated, and stored away for centuries.

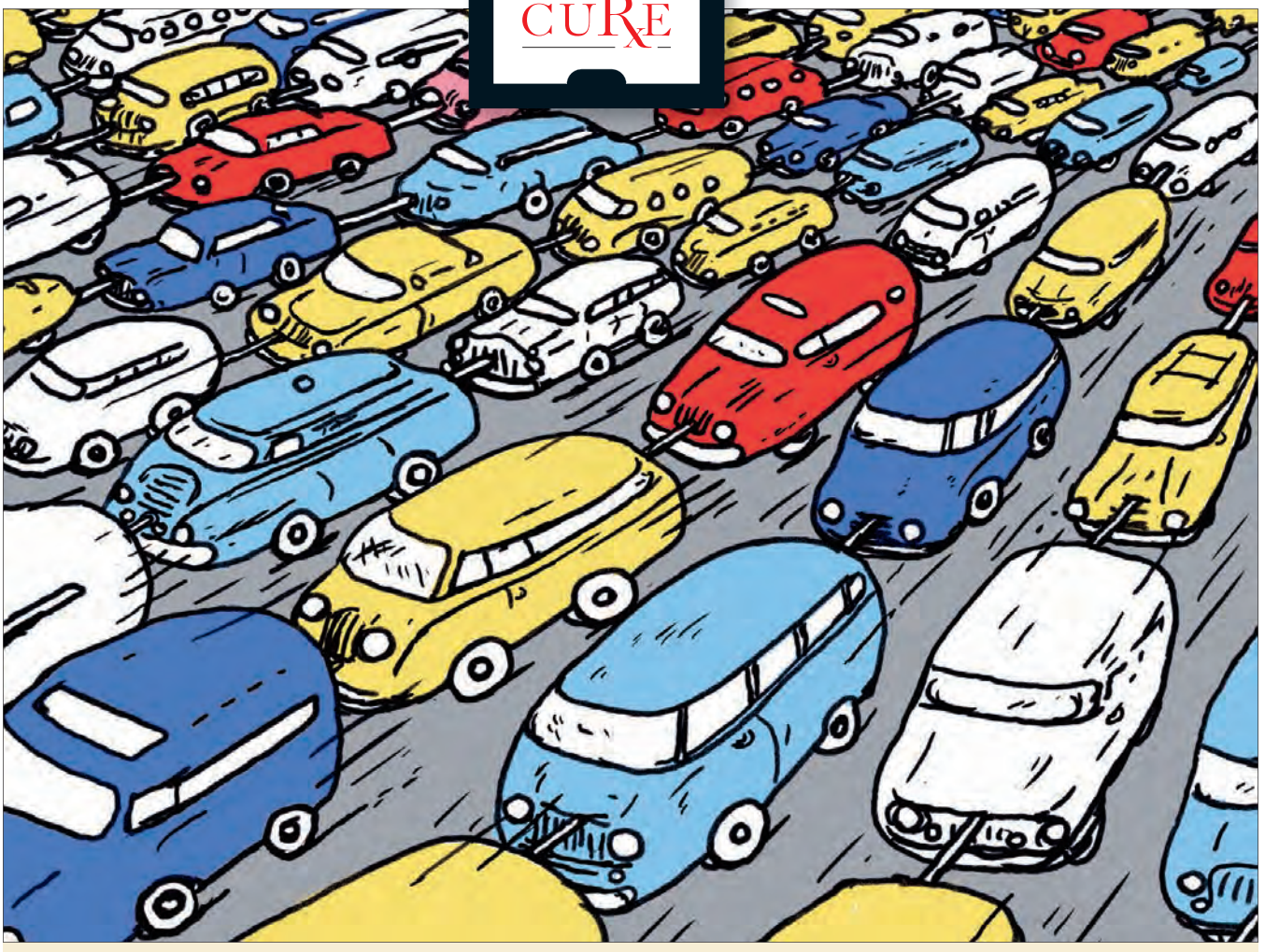
CBI Polymers, a Hawaii-based manufacturer of decontamination products, has developed another option called DeconGel, which can be sprayed, troweled, or painted onto any surface. The blue liquid (which is 95 percent water and 5 percent proprietary chemicals) oozes into microscopic pores and bonds with loose material. When it hardens, it shrinks by about 20 percent, sucking up fine radioactive particles and encapsulating them in its folds.

"Our gel helps regain control of the radioactive material and produces 90 percent less waste than water," claims Shaun McCabe, president of Asia-Pacific systems for CBI Polymers, which recently donated 100 five-gallon pails of its cleaner to the Fukushima cleanup effort and hopes to sell hundreds more there. "You can either compact that waste and dispose of it in a landfill, incinerate it and reduce its volume to ash residue, or dissolve the gel in water and then treat the water."

Scientists working for CBI's parent company, Skai Ventures, originally had their eye on an entirely different product when they discovered the sticky gel. While researching corneal implants, a careless lab tech accidentally dribbled an experimental compound on the floor. After it dried, workers peeled it off and discovered the floor was cleaner than they had ever seen it before. Amazed at the compound's cleaning abilities, they pursued the science.

CBI has since enhanced the compound with chelants, additives that bind to lead dust, radioisotopes, and other hazardous materials. The company now markets the product for everything from crime-scene cleanup to decontamination of meth labs and Department of Defense sites. ADAM PIORE

ILLUSTRATION BY JONATHON ROSEN



AILMENT **TRAFFIC** CURE **Highway Caravans**

Gridlock costs motorists in the country's 439 largest cities $115 billion a year in extra fuel and wasted time, which translates to $808 per driver, according to the Texas Transportation Institute's annual Urban Mobility Report.

Traffic is a universal source of exasperation, and the problem is getting worse. In 1982 urban motorists lost on average 14 hours a year to gridlock. By 2009 that number had jumped to 34 hours.

The best cure short of building more roadways and reducing the number of cars that drive on them, traffic experts say, is semiautonomous driving. Think of it as a sort of automotive conga line for public highways. In Sweden, Volvo is conducting road tests of one such "road train" concept, called Sartre, or Safe Road Trains for the Environment. The only human driver is the professional operating the first car. The lead vehicle wirelessly transmits data from its steering wheel, brake pedal, and throttle to the rest of the cars in the train, which rely on sensors (the same ones used in existing adaptive cruise control and lane-departure warning systems) to ensure adequate separation between vehicles. Passengers, meanwhile, are free to surf the Web, eat breakfast, or sleep until the commuter line ends. So far, Volvo's tests have been limited to three cars driving about 16 feet apart at 35 miles per hour, but five-car tests are scheduled for this fall.

In the United States, independent engineer Bruce McHenry is pushing a similar idea, only the vehicles would be physically linked like railroad cars. In his scheme, the lead car serves as the locomotive, doing most of the work so simple electric motors that deliver just enough power for tooling around town and driving to the commuter track can power the rest of the cars. In his scheme, the highways themselves would eventually be electrified, like model-car racetracks. To shuttle cars in and out of the road trains, McHenry proposes, drivers would communicate over shortwave frequencies, with cars queuing up according to size and destination and uncoupling at designated spots. McHenry estimates that road trains would more than triple highway traffic flow. And he says they would work better than conventional trains since they would not require new bridges, tunnels, and rails.

Sound enticing? The U.S. Department of Transportation is running test clinics for connected vehicles that would communicate wirelessly with each other and with traffic lights and construction zones. The DOT will decide in 2013 whether to mandate the technology in new vehicles. PRESTON LERNER

AILMENT

ROTTING GAS PIPELINES

CURE

PIGbots

U.S. utility companies spend over $300 million a year to repair leaky gas lines.

More than half of all natural gas pipelines in the United States—amounting to more than 100,000 miles of pipe—are more than four decades old, and some are approaching the century mark. Corroded steel or cast-iron pipes are ticking time bombs, a fact that made national headlines last year when a pipeline in San Bruno, California, exploded, killing eight people and prompting Senator Dianne Feinstein of California to propose a law that would bolster pipeline oversight and raise fines for any safety violations. Pipeline leaks also release methane, a potent greenhouse gas, into the atmosphere.

The most obvious solution is to replace the problem pipes with more durable plastic lines, but such an upgrade would cost hundreds of billions of dollars—not an option in this economy. The second most obvious solution is simply to repair the pipes, but that, too, presents challenges. The majority of gas lines are inaccessible to inspectors because the pipes are buried at least two to four feet underground.

That is why utility companies are increasingly turning to PIGs, short for pipeline inspection gauges, robots that slither through pipes looking for corrosion, weak welds, cracks, and other signs of disrepair. Some of the earliest "smart" PIGs, developed in the 1960s, pioneered the use of magnetic flux leakage technology to detect pipeline imperfections. Simply put, the robots use extremely strong magnets to magnetize surrounding pipe walls; wherever the robot encounters surface inconsistencies, the magnetic field warps slightly, and a detector measures the variation to estimate how much metal has eroded away.

Today PIGs are more akin to subterranean Swiss Army Knives, employing a wide range of novel inspection technologies. Ultrasonic PIGs measure how long it takes sound waves to bounce back from pipe walls in order to gauge the walls' thickness. Backscatter X-ray PIGs, which assemble images of the inside of a pipe based on reflected radiation, can detect tiny microcracks before they develop into bigger lesions. Other remote-controlled PIGs can perform internal welding or apply protective epoxy to corroded spots. Roboticist Karl Edminster, whose company, Electromechanica, specializes in PIG design, has created types that can navigate the toughest of pipes; those bent at 90 degrees, for instance, or buried beneath the frost line, where temperatures can plunge to –20 degrees Fahrenheit.

But the best in show may be the 66-pound Explorer-II, arguably the ultimate pipeline-vetting gadget. Developed by Carnegie Mellon roboticist Hagen Schempf, the Explorer-II features a remote-controlled fisheye camera that allows aboveground operators to see what the machine does; drivetrain motors that give operators unprecedented control over the PIG's direction (most PIGs still move passively according to natural gas flow); and a lightweight electromagnetic coil that detects changes in magnetized pipe walls without weighing the robot down, enabling it to inspect about two miles of pipe a day.

The Explorer-II, which completed a successful 2009 trial in Pennsylvania, should allow more cost-effective pipeline maintenance. By giving utilities crucial information they need to select the most economical fixes, Schempf estimates that his system could reduce the cost of inspections by 25 to 50 percent, saving the gas industry tens of millions of dollars each year. "Should utility budgets stay the same, this will allow them to investigate more of their pipes," Schempf says.

As the United States relies on natural gas for a growing portion of its energy mix, the newest fleet of smart inspection robots will need to be on the front lines.

ELIZABETH SVOBODA

THE CURE

AILMENT

MURDER

CURE

Corpse Detector

Searching for murder victims can be a long, arduous effort, often involving tons of manpower, cadaver-sniffing dogs, and ground-penetrating radar. When a potential grave site is found, searchers usually start digging. The process is never foolproof, however; bodies are routinely found buried in areas already scavenged by authorities.

Researchers at the National Institute of Standards and Technology (NIST), in Boulder, Colorado, have created a better grave detector using something called PLOT, short for porous layer open tube. A motorized pipette sucks in chemical vapors above what may be a grave and channels them to a hair-thin probe coated with an oxide of aluminum. When the probe is heated, it releases the chemicals it has absorbed. If any of them react with a compound that detects decomposition, then bingo: Chances are, you have a body below. The technique allows investigators to rule out in minutes sites that would before have taken a lot of shoveling or a FedEx to the lab to confirm. Even better, the tiny probe can poke through holes in concrete or into crevices to detect bodies that may be more artfully concealed.

To test the technology, Tom Bruno at NIST created a rat graveyard in his lab, burying some of the little corpses in a few inches of soil and letting others rest in peace aboveground. The machine effectively detected ninhydrin-reactive nitrogen, one of the telling compounds of decomposition, in both sites as the animals disintegrated over the next 20 weeks.

Hidden bodies are not the only use for PLOT. It can also be adapted to detect explosives in cargo, flame accelerants used in arson, and even spoiled chicken (weirder things have happened on *CSI*). NIST scientists estimate that a mobile PLOT unit could make it into the field in about a year, though we hope they do a little more field-testing. Apparently the leap between finding dead rats and Mob snitches is bigger than you might think. J. D.

AILMENT

TOO MUCH INFORMATION

CURE

Mind-Reading Machines

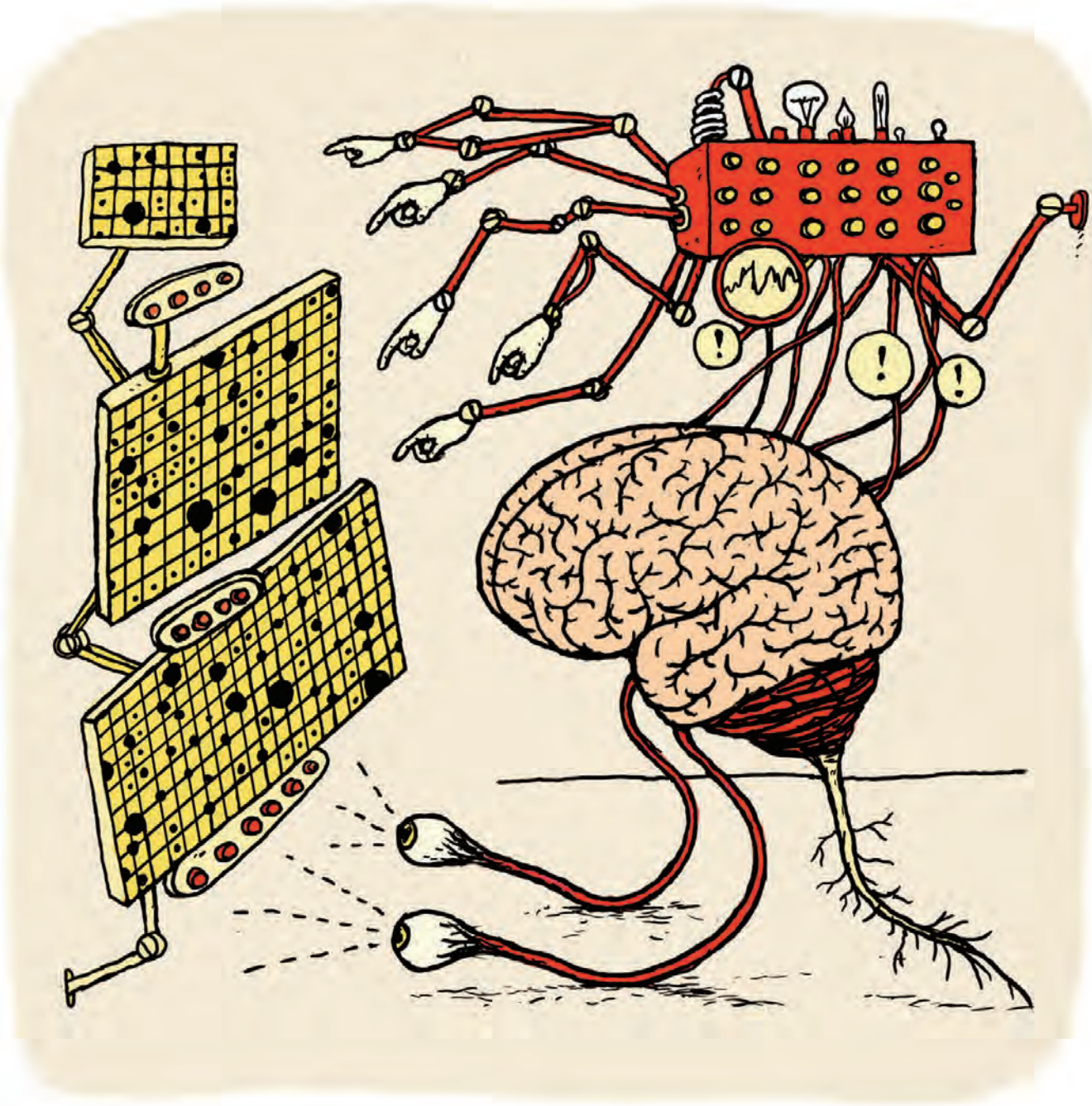
If you have ever felt overwhelmed by a multitude of choices—say, 10,000 items in an online catalog—this brain-boosting invention is for you. The Cortically Coupled Computer Vision (C3Vision) system, designed by engineers Paul Sajda and Shih-Fu Chang of Columbia University and Lucas Parra from the City College of New York, endows people with superhuman search powers, allowing them to find meaningful objects in mountains of images up to 10 times faster than they normally could.

The technology, part of an 18-month, $2.4 million Defense Advanced Research Projects Agency (Darpa) undertaking, relies on electroencephalography (EEG) to detect the cascade of neural firing patterns in your brain when you spot something novel or interesting, even if you're unaware of it. Sajda offers the example of an intelligence analyst who must rapidly scan satellite photographs or drone footage for suspicious happenings. With C3Vision, he dons an EEG skullcap and starts searching. Whenever he sees something that stands out, his brain exhibits a distinct firing pattern associated with "aha" moments. C3Vision picks that up and applies it to pattern-recognition software, which in turn flips through thousands of other satellite images to cull suspect objects or movements on its own. "The system latches on to individual perceptions and trains the computer to know what the user means by *interesting*," Sajda says. "The computer and the brain operate synergistically."

The Army is interested in using such a mind-machine interface to help soldiers navigate dangerous terrain. A driver might see something peculiar on the roadside. Maybe it is an improvised explosive device. His C3Vision headgear would register the brain waves associated with the suspicious object and inject them into the vehicle's driving system. When the system sees other things out there that look similar, it would automatically evade them. Likewise, security guards might use such gear to spot suspicious activity on surveillance video.

Sajda envisions the technology eventually improving civilian lives as well, starting with shopping. A miniaturized, wireless version of the device might be used to tag consumer items or even specialty shops that catch your fancy as you walk down

ILLUSTRATION BY JONATHON ROSEN



a city street. Just a quick glance at a dress in a window, for instance, might elicit a neural firing pattern sufficient to register with the system. A program could then offer up nearby stores selling similar items or shops you might want to investigate. "There's nothing out there that can really use your subjective preference as a signature to guide you," Sajda says. "It's the same type of problem in the analyst world. There's so much information to explore and digest, how do you make it useful to a person at a given time? We can make it unobtrusive and tag things as you move through your environment." A. P.

AILMENT

SONIC BOOMS

CURE

Extreme Makeover of the Airplane

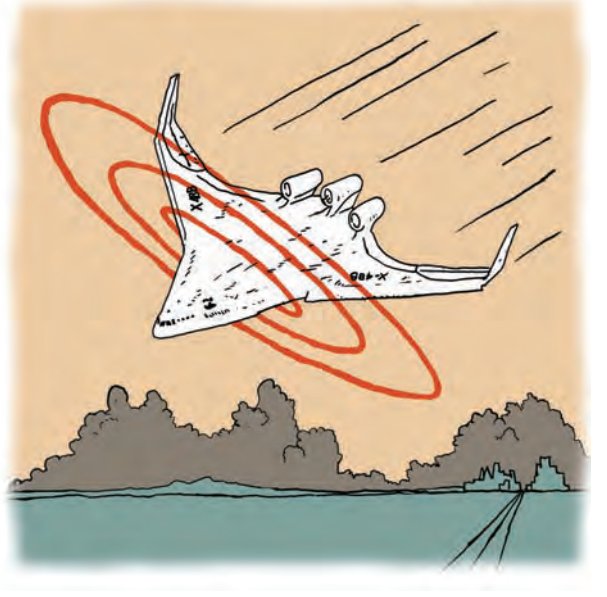
Sonic booms are the thundering percussions one hears and feels on the ground when airplanes pass overhead faster than the speed of sound (Mach 1). The signature crack of a sonic boom can shake walls, rattle windows, and frazzle nerves. A six-month-long series of sonic-boom tests in Oklahoma City in 1964 prompted thousands of complaints and damage claims, a class-action lawsuit, and the beginning of the end for supersonic airliners. Ultimately, the Federal Aviation Administration banned supersonic civilian flights over the continental United States, partly explaining why the Concorde went out of production and why airliners have been cruising at roughly the same speed for the past 50 years.

The ban on supersonic civilian flights across the U.S. partly explains why airliners have been cruising at roughly the same speed for the past 50 years.

The problem begins when a plane knifes through the air faster than the speed of sound, about 750 miles per hour at sea level. As it picks up speed, the pressure waves in its wake become so compressed they ultimately release their energy in that bone-rattling boom. Researchers have long understood that sonic booms could be mitigated by massaging the shape of the shock waves, but only recently have advanced supercomputers allowed them to model airflow accurately enough to "fully tackle the problem," says Chet Nelson, one of Boeing's leading supersonics wizards.

For testing purposes, Boeing has modeled a 100-passenger airliner capable of cruising at Mach 1.8. The virtual jet relies on several tricks to reshape the shock waves and reduce the intensity of the boom: a needle nose, narrow fuselage, swept-back wings, aerodynamic engine coverings placed above the wings to shield engine noise, and a widely spaced V-shaped tail. In computer simulations, the plane generated 80 PLdB (a measure of perceived sound intensity). By comparison, the Concorde produced 105 PLdB.

When can we hope to fly from New York to L.A. in three hours? That depends on when regulators can agree on noise standards. There are also economic and environmental issues, since flying faster burns more fuel. But if sonic booms can be reduced to 65 or 70 PLdB and companies like Boeing see a market for ultrafast flight, Peter Coen, project manager for NASA's Fundamental Aeronautics Supersonic Project, expects to see supersonic business jets flying by 2020. P. L.



THE CURE

AILMENT

POTHOLES

CURE

Ray Guns for Roads

During the summer, road crews can permanently repair potholes with "hot mix," an asphalt-based mixture that bonds well to the holes. But in the winter, when the ground turns cold and many hot-asphalt plants close, crews must resort to temporary "cold patches," which are usually pulverized by spring, leaving roads pockmarked and dangerous. "It's incredible how much damage a pothole can do to a car," says Kirk Kjellberg, an equipment salesman with Microwave Utilities in Monticello, Minnesota.

The company's wintertime solution is to thoroughly thaw a hole with a 100,000-watt industrial microwave unit, boil out any moisture, and add asphalt. Conventional asphalt works fine, but Kjellberg is working with the Natural Resources Research Institute in Duluth to make a microwave-specific mix from recycled shingles and taconite tailings, especially since improved oil-refining technology is reducing asphalt supplies. The next step is to nuke the pothole again, heating the mix to about 300 degrees Fahrenheit to vulcanize the asphalt and create a tight bond. In all, the process takes less than 10 minutes.

Successful field trials in Minnesota have proved the concept. Kjellberg is uncertain what the commercial version will be like, but he envisions an all-in-one vehicle that would deploy the microwave, squirt out asphalt, and roll it flat. By his estimates, it will be several years before the mix hits the road. J. D.

Potholes pound about $400 worth of wear and tear annually out of the average American car.

AILMENT

UNTHINKABLE STINK

CURE

Copper

Most efforts to wipe out bad funks simply mask odors instead of eliminating the agents that cause them. Copper has long been known as a great odor neutralizer—certain species of the metal react with and break down many common smelly molecules. The problem has been finding the right delivery system. Scientists at the University of Florida Particle Engineering Research Center and personal products manufacturer Kimberly-Clark recently found an answer by coating silica nanoparticles with copper ions, a potent odor-fighting combination that could be used in powders and spritzes, mixed with cat litter, or embedded in products like garbage bags.

Unlike activated carbon, which sequesters odor molecules by physically trapping them, the copper chemically reacts with the stench, breaking it down into its nonsmelly component parts. When researchers mixed copper nanoparticles with ethyl mercaptan, which gives natural gas its intense smell, the compound quickly broke down into less smelly disulfide, losing its odor in minutes flat. Nanoparticles with silver ions and other reactive metals could be effective in neutralizing other classes of odorants.

Kimberly-Clark is not keen to give away the secrets of a potentially billion-dollar product line, but a patent application published in 2009 shows that the company may be gearing up to put ion-clad nanoparticles in diapers, bandages, and drapes, as well as in packaging that can absorb the gases that cause fruit to ripen too fast. J. D.

Americans spend millions of dollars per year trying to fight odors by plugging in air fresheners, spritzing everything with Febreze, or lighting scented candles, often in vain.

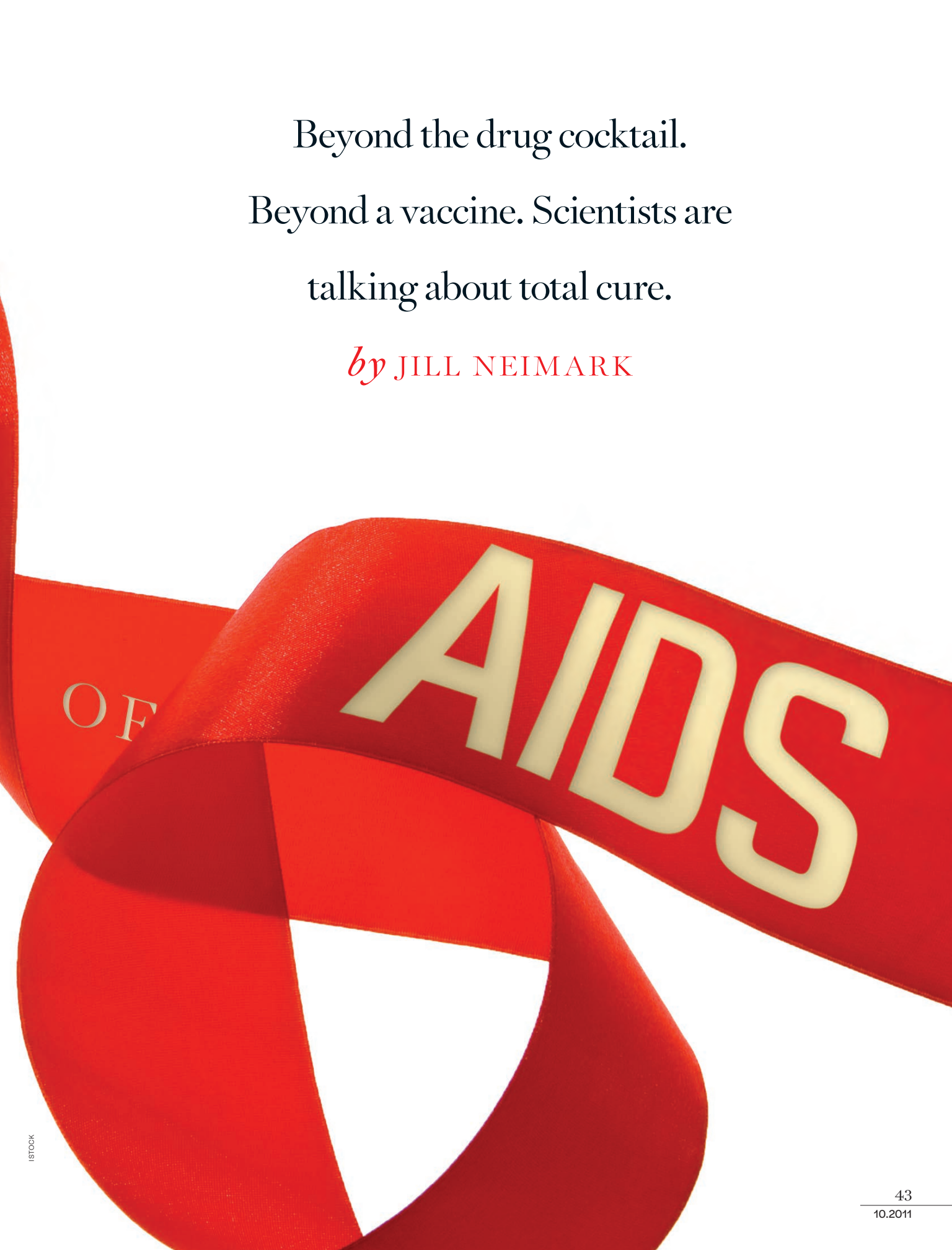
ILLUSTRATIONS BY JONATHON ROSEN

One June afternoon in 1992, a dancer named Matthew Sharp died eight times. A siren shrilled as he repeatedly dropped to the street and let strangers draw a chalk outline around his body. Then he stood up, took the chalk, and each time wrote the name of his partner, Johnny Franklin, inside the empty space—just like a cop at a crime scene. ¶ Franklin had succumbed to AIDS in Oklahoma City two years earlier, and now Sharp was marching with the AIDS awareness group Act Up along Market Street in San Francisco's annual gay pride parade. "Die-ins were a common form of AIDS activism in the 1980s and 1990s," Sharp recalls. "They were conducted in complete silence every seven minutes while we were marching, because that was how often someone died of AIDS back then."

After Franklin's death, Sharp nearly became another victim when he came down with extrapulmonary tuberculosis. "I felt I was knocking on death's door," he says. "So I quit my

Beyond the drug cocktail. Beyond a vaccine. Scientists are talking about total cure.

by JILL NEIMARK



ISTOCK

THE CURE

THE END OF AIDS

ballet company, took the life insurance money Johnny left me, and moved to San Francisco, which was ground zero for HIV," the AIDS virus. "For the next 20 years I stayed alive by participating in clinical trials of new drugs before they were released. I was aggressive about preventing opportunistic infections. When I began to die of wasting syndrome, I joined a trial for human growth hormone. I got an experimental thymus transplant. Combination therapy in 2008 finally brought my viral load down to undetectable."

Still, there was the problem of Sharp's T cells—the white blood cells, or lymphocytes, that unleash a powerful immune response against pathogens like HIV. For AIDS, the most critical of the T cells is CD4, which would normally coordinate the body's attack against the disease. But by a quirk of biology, CD4 cells end up sequestering the virus, which ultimately decimates them. With Sharp's CD4 cells hovering at around 250 per cubic millimeter of blood—a normal count is 500 to 1,500—he was prone to a host of opportunistic infections and qualified for a diagnosis of full-blown AIDS. "I was always in the danger zone, and every year I would come down with pneumonia," Sharp says.

Then came an invitation to participate in a novel form of gene therapy, one that could mark a first step toward a true cure for AIDS. The trial was run by Jay Lalezari, director of Quest Clinical Research in San Francisco. Sharp agreed to join. His blood was drawn and his CD4 cells were filtered out, frozen, and transported to a laboratory where they were genetically altered to resist invasion by HIV. This was done by deleting a receptor on the surface of the CD4 cell that HIV uses to get inside. The reengineered CD4 cells were allowed to multiply in the lab and then returned to Lalezari.

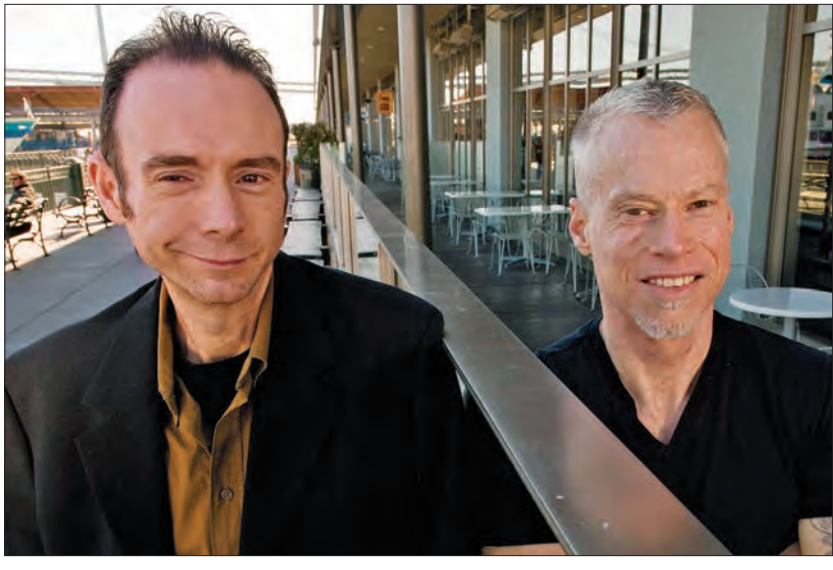
In September 2010 Sharp received a single infusion of 20 billion of his genetically engineered immune cells. Within weeks his CD4 count doubled. "They test me every month and my CD4 count hasn't fallen below 400. I haven't had the usual bout of pneumonia since this treatment. I'd love to get a second infusion," Sharp says. "I'm 55 years old and feeling better than ever, and now there's a possibility I'll actually see a full cure of HIV in my lifetime."

CURING AIDS? WIPING OUT A PANDEMIC THAT CURRENTLY affects 33 million adults and 2.5 million children worldwide and infects 7,000 new people every day? In the 30 years since scientists identified HIV as the cause of AIDS, the virus has proved unbeatable—hiding in the very immune cells that would kill it; reflexively and rapidly mutating; mysteriously persisting in the gut, kidneys, liver, and brain; subverting every vaccine (the best one so far has given only 30 percent protection); and roaring back to life almost the moment drugs are stopped. It has been years since anyone dared whisper the word *cure* at all.

But they are daring again with growing confidence, buoyed by new insights and technologies to fight a foe that Jay Levy, codiscoverer of HIV, compares to a "biological Trojan horse" and Jay Lalezari calls "a cellular bioterrorist that kills your first responders first." Tapping into medical advances from gene therapy to stem cells, researchers are launching powerful counterstrikes against the virus. The National Institutes of Health (NIH) will invest $70 million over the next five years to support three multi-institution research efforts aimed at finding a cure. And the independent International AIDS Society, known for its conferences, has assembled a working group of world experts to spearhead a global strategy for the cure.

The latest turn seems as remarkable as the one patients celebrated in 1996, when David Ho of Rockefeller University in New York presented his research on a combination drug therapy, a treatment cocktail that rendered the virus undetectable in blood. That work turned AIDS from a certain killer into a chronic disease almost overnight. "I remember witnessing a miracle," recalls Steven Deeks, an expert in the pathogenesis of HIV at the University of California, San Francisco (UCSF). "Literally within weeks, people went from a death sentence to a promise of years of health. People in hospices were sent home. And now there is a possibility we'll have another dramatic shift." He cautions, however, that it took "15 years to get from that first antiviral to truly effective, well-tolerated combination therapy. I think in terms of a total cure, we're just now starting another 15-year journey."

Renewed hope that we can defeat HIV is especially remarkable because of all we know about this outrageously complex and wily retrovirus—so called because it replicates by



Timothy Brown, left, and Matt Sharp at the Ferry Building in San Francisco, 2011. Both are in robust good health after gene therapy for HIV.

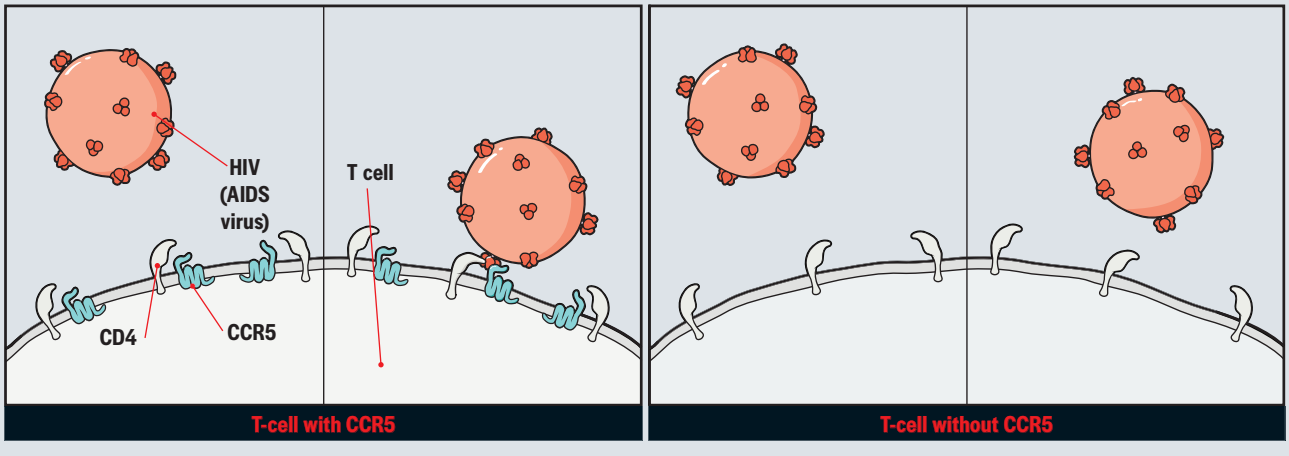
It has been years since anyone dared whisper the word *cure,* but they are daring again, buoyed by remarkable new insights to fight a foe that scientists have labeled "a cellular bioterrorist that kills your first responders first."

reversing the molecular process that most other viruses use. In most cases, viruses start with DNA as their primary genetic material and make RNA templates of themselves. Retroviruses, on the other hand, start with RNA and make DNA templates, using an enzyme called reverse transcriptase; the resulting DNA then exploits human cellular machinery to create more copies of the virus. HIV's favorite target is the CD4 T cell, which orchestrates our entire immune response against the disease. The virus worms its way into the CD4 cell via several receptors—or molecular doorways—on the cell's surface, including a crucial one called CCR5. Then it plunders that cell's supply of reverse transcriptase. If the CD4 cell is quiescent, the HIV rests too. But if the CD4 cell is activated by anything, from stress to the common cold, the HIV inside becomes active as well, generating DNA templates that integrate into the human genome within the CD4 cell. Instead of killing HIV, as it would do with other viruses, the CD4 cell makes *more* copies of HIV, which then leave to invade other CD4 cells, ad infinitum, until an irreversible, lethal cascade has been unleashed.

The CD4 cycle alone would be enough to kill a person, but HIV also enters other cells, integrating into their genomes as well. The latent virus lurks, seemingly dormant but actually awaiting its cue: Anything that stirs the immune system—stress at work, food poisoning, grief—can jolt HIV combatants to action too. Some scientists suspect that this latent reservoir causes the long-term inflammation often experienced by people living with HIV, even when they are on the drug cocktail that otherwise controls the disease. Over the years, latent HIV might wreak silent havoc, making the need for a true cure all the more pressing as time goes on.

Recent studies clarify the limitations of Ho's combination drug approach. A multicountry study published in *The Lancet* in 2008 found that someone starting HIV treatment at age 20 could expect to live to 49, a reduction of 27 years compared with those without the disease. Then there is what doctors call neuroAIDS. Even with antiretroviral treatment, between 40 and 60 percent of HIV-infected individuals develop mild neurological dysfunction; 1 to 5 percent develop dementia. A recent study suggests this syndrome results from the way HIV injures astrocytes, the most common type of cell in the brain. In people with AIDS, about 5 percent of astrocytes are infected; some scientists speculate that these cells, in turn, spew

WHY SOME PEOPLE ARE IMPERVIOUS TO AIDS



Approximately 1 percent of Caucasians lack a protein called CCR5 on their CD4 T cells–the white blood cells that normally kill invaders but that harbor HIV. CCR5 is a molecular doorway that lets the virus in. Since HIV depends on CCR5 to slip inside the CD4 cells, people with the receptor are prone to develop AIDS. Those without the CCR5 portal generally do not take HIV into their CD4 cells and have natural resistance to AIDS. Gene therapy could impart this kind of resistance to others.

out toxins that ultimately kill uninfected astrocytes nearby.

Furthermore, today's drug therapies are aimed specifically at the current strains of HIV, but the virus will probably mutate, as every virus eventually does. "We can't be complacent," says Jay Levy, now director of the Laboratory for Tumor and AIDS Virus Research at UCSF. "It's an active, untreated epidemic in other parts of the world. It could change and come back to haunt us in a new form."

In the accelerating search for a cure for AIDS, medical researchers are actively pursuing three broad approaches. The first approach is gene therapy, in which a patient's cells are genetically engineered to be invulnerable to HIV; this naturally occurring resistance already exists in 1 percent of Caucasians worldwide. The second approach involves latency activators, molecules that lure the virus out of its hiding places and into the open, where the body's immune cells and targeted drugs are able to find and destroy it once and for all. Finally, scientists are intensely studying the immune systems of a unique group of people known as elite suppressors, who remain healthy after HIV infection, controlling the virus for decades on end.

Impressive advances in the lab and in patient trials make all three strategies look promising, but in the end there might not be a single cure. As with today's drug cocktail, the best solution might be a combination of two or perhaps all three. And even the concept of "cure" may need adjusting. Since it would be staggeringly difficult to test every single cell in the body for the presence of HIV, a patient will be considered cured if there is no evidence of the disease for a certain length of time after the completion of treatment. For millions of patients, that would be a life-transforming and life-affirming event.

ANYONE LUCKY ENOUGH TO RESIST INFECTION WITH HIV altogether likely lacks the CCR5 receptor on the surface of his CD4 cells. The existence of this natural protective mutation was first reported in *Nature* in 1996. When Gero Hütter, today a specialist in blood cancers at the Institute of Transfusion Medicine and Immunology in Mannheim, Germany, read about it, he was transfixed. "I thought, wow, this could be a way to treat HIV."

But conferring resistance on someone not born that way is a tall order. It requires redrawing the immune system by knocking out the existing cells and administering HIV-resistant stem cells that can establish a new immune system. Given the effectiveness of the drug cocktail, Hütter would not have considered such a risky procedure for AIDS alone. But if he were performing a stem cell transplant for a cancer patient who also happened to have AIDS, he reasoned, then why not use stem cells with the CCR5 deletion? "And then I forgot about it," he says, "because I never saw a patient I could try it on—until Timothy Ray Brown showed up."

BROWN IS THE ONLY PERSON alive today who has been cured of HIV. He is, in the words of Gerhard Bauer, a stem cell researcher at the University of California, Davis, "the world's first natural gene therapy experiment for HIV." He came to Hütter—who was then at the Charité, a university hospital in Berlin—in 2006 with leukemia and an HIV infection that was well controlled with combination antiretroviral therapy. After cancer chemotherapy failed, Brown needed a stem cell transplant for his leukemia. The doctors' plan was to kill off Brown's cancer-producing bone marrow cells with intensive chemotherapy and replace them with stem cells from the bone marrow of a healthy donor. Hütter looked through multiple donor registries and tested the blood of more than 200 candidates for someone born with the CCR5 mutation. Luck was on Brown's side: A matching donor had the deletion. Brown underwent his stem cell transplant and stopped taking his antiretroviral drugs. For 60 days afterward, there were still signs of viral DNA in his genome, but then it seemed to vanish. "The clearance of the HIV reservoir was quite rapid," Hütter says, sounding as astonished in 2011 as he was back in 2007.

One year later Brown's cancer returned, and he was given another stem cell transplant from the same donor. Today he is free of both cancer and HIV. Hütter speculates that Brown was helped to a total cure by what is known as the host-versus-graft reaction: New stem cells and all their progeny see the old immune cells as "other" and kill them off. When that happens, all the latent reservoirs of HIV that are permanently integrated into the genomes of those cells can be eliminated as well. Brown is now being studied in San Francisco by Jay Levy and his colleagues. "The fact that you can find a person who had AIDS and who now seems to have eradicated the virus is remarkable," Levy says.

The treatment that cured Brown of his HIV and cancer has some devastating potential downsides, however. For one, transplanted donor cells can be rejected just like a donor heart, putting the patient at risk of disease and often requiring powerful immune suppressants, with all the attendant side effects and risks. With the current AIDS drug cocktail

so effective, such dangers would be unacceptable unless, as with Brown, the patient needs bone marrow therapy anyway.

BUILDING ON BROWN'S AMAZING RECOVERY BUT HOPING TO avoid the pitfalls, AIDS researchers are devising treatments based on the patient's own tissue, which would not be subject to rejection like donor cells. One of the most promising approaches uses a new type of genetic scissors known as zinc finger nucleases, developed by California-based Sangamo Biosciences. These finger-shaped proteins form when specific amino acids (protein building blocks) bind to a charged zinc atom. They can be engineered to go into cells and snip any gene a researcher wishes to target (including the gene for the T-cell receptor CCR5). The damaged cells automatically set about repairing the cut, yet 25 percent of the time that effort fails, and the deleted gene is never restored. Such cells can be separated out, creating a pool of HIV-resistant cells lacking CCR5. These lab-engineered cells can then be amplified and grown out a hundredfold or more before being infused back in. They are safer than cells transplanted from a donor because risk of rejection is gone.

The first human trials testing genetically engineered cells missing the CCR5 receptor, begun in 2009, have been small but impressive. At Quest Clinical Research, Lalezari enrolled nine men on the cocktail with persistently low CD4 counts who were HIV positive for 20 years or more. The genetically engineered cells survived after infusion, and CD4 counts went up in five of six patients he has reported on, including Matt Sharp. "The ratio of two types of immune cells, CD4 and CD8, which are often abnormally reversed in HIV, normalized, and the HIV-resistant cells even migrated to the gut mucosa, an important site for the virus," Lalezari says. "The results were as good as I could possibly have hoped for." Though his approach is distinctly different from a donor stem cell transplant like Timothy Brown's—in which the entire immune system is replaced—it is a promising start, with potentially significant clinical benefit and far less risk.

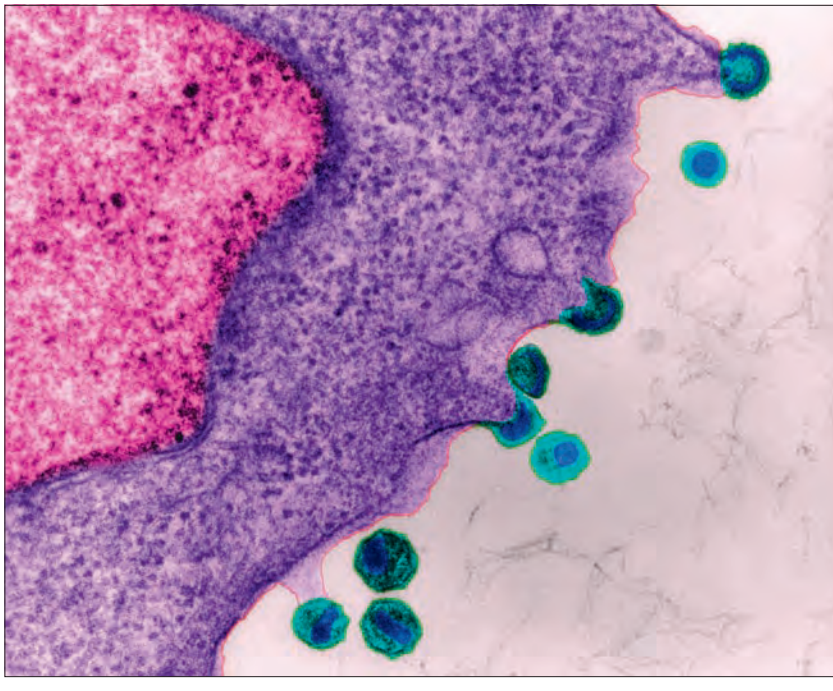
A similar trial launched in 2009 by pathologist Carl June and internist Pablo Tebas at the University of Pennsylvania has shown equal promise. Here, six patients suspended combination antiretroviral therapy for 12 weeks after infusion with altered CD4 cells, so scientists could monitor viral load and the power of the altered immune cells to survive and thrive in the presence of active HIV. At present, two of the patients have been fully studied. In one patient, the virus took 10 weeks to rebound instead of the usual two to four weeks. In the other patient, the virus was still undetectable 12 weeks out. The next step is to increase the percentage of genetically engineered cells, either by increasing the amount of cells in the infusion, by giving more than one infusion, or by administering chemotherapy to lower the number of untreated CD4 cells in the body before infusion begins. Other researchers plan to try this approach on patients who recently received a diagnosis of HIV and are not yet on antiretroviral therapy. "It sounds like science fiction, I know, as if I just told you people landed here from Mars," Tebas says. "That's how far the technology has evolved."

The most viable form of this treatment might be to target progenitor cells giving rise to CD4 cells and the rest of the immune system—stem cells themselves. If some of those cells could be removed from a person with AIDS, genetically engineered to be resistant, and then returned to the patient, they might spawn an immune system that is completely resistant to the disease. The virus could actually help, since it would continue infecting and killing unchanged, vulnerable cells—decimating its own resources in the process.

A stem cell transplant like this has already been accomplished in mice by virologist Paula Cannon of the University of Southern California. Cannon used a special strain of mouse that lacks a functioning immune system and so can be given human immune cells without rejecting them. Mice were infused with human stem cells, half of them genetically engineered so that the CCR5 receptor was gone. After 8 to 12 weeks, the modified cells had increased in number, effectively resisting infection with—and controlling replication of—HIV.

"These mice are a real breakthrough for HIV research," Cannon says. "But now we need to find the sweet spot, the Goldilocks spot, where we can alter enough stem cells to allow someone to live with HIV.

Ultimately an anti-AIDS stem cell transplant might look like this: You would have your stem cells withdrawn and genetically altered to resist HIV. Simultaneously, you would get a mild form of chemotherapy to wipe out some of your remaining vulnerable stem cells. Then you would get an injection of the new stem cells. They would proliferate rap-



HIV (blue) emerges from human lymphatic tissue. As AIDS advances, lymphatic tissue serves as a reservoir for HIV, perpetuating the disease.

DENNIS KUNKEL MICROSCOPY/CORBIS

idly and create a resistant immune system. This immune system, especially the CD4 T cells, would have an advantage because HIV could never invade or kill them, and over time, they would become dominant.

Some researchers are optimistic that stem cell therapies might be able to deliver what researchers call a functional cure: Patients would achieve a state of remission in which the viral load was less than 50 copies of HIV per milliliter of blood, undetectable on standard tests, and they would no longer require medication. "This therapy isn't about eliminating every last HIV from the body. It's about giving the body the tools to stay well when the reservoir wakes up," Cannon states. "If people can have this treatment, not have to take HIV drugs, not have detectable levels of the virus, and have a fully functioning, happy immune system, isn't that good enough?"

NOT FOR DAVID MARGOLIS, AN AIDS RESEARCHER AT THE University of North Carolina at Chapel Hill. When the virus lurks in latent reservoirs in the body, he says, there are consequences for patients' health. "You're not going to cure HIV this way. It's a giant technological problem as difficult as inventing a warp drive to travel to other stars. Unless you go in and kill all the stem cells that make CCR5, there will always be cells that the virus can grow in. You may lower the load, you may even prevent disease progression and eliminate need for antiretrovirals, but you will still have chronic immune activation and the problems caused by that."

For the ultimate cure, doctors might have to purge HIV from its silent reservoirs, routing it out so it can never recrudesce and cause damage again. Margolis and collaborators hope to do just that through a "sterilizing cure" that spurs HIV to start replicating within its hiding spots; when the virus is actively dividing, antiretrovirals can get in and do their job.

Initial attempts to lure HIV out of hiding did not fare well. An early trial conducted in the mid-1990s in the Netherlands used inflammatory antibodies to fire up patients' immune systems in hopes of activating the dormant CD4 cells where HIV was stowed away. The antibodies did in fact activate the CD4 cells but eventually killed them as well, depleting the body's best weapon against HIV. "The early studies failed miserably and had toxic side effects," says virologist Warner Greene of UCSF. "Ultimately we need to find molecules that activate the virus without activating the T cells or other viruses, and it's not a trivial task."

Some molecules are already showing promise. For example, an enzyme called histone deactylase (HDAC) keeps HIV turned off, a crucial part of the virus's strategy of hiding in the T cells to avoid the body's defenses. But in 2000, Margolis and his group discovered that they could use HDAC inhibitors—drugs already approved for stabilizing mood and preventing seizures—to reverse the effect and draw out the virus. First, the team tried a common and relatively weak HDAC inhibitor called valproic acid to bring latent HIV to life. "It was not the best drug, not the most specific or potent, but it was already in clinical use, and people were taking it every day," says Margolis, who published his initial results in *The Lancet* in 2005. It worked to a degree, reducing latent HIV load without activating T cells in about half the patients, though even in that group the effect plateaued or weakened over time. He is now focusing on a far more potent HDAC inhibitor, a relatively untested drug called vorinostat that is currently used to treat a few rare types of cancer. Finally, an immune molecule called interleukin-7 seems to flush out viruses from CD4 cells. Studies have shown it is well tolerated in HIV-positive patients on antiretroviral therapy, and several clinical trials are under way.

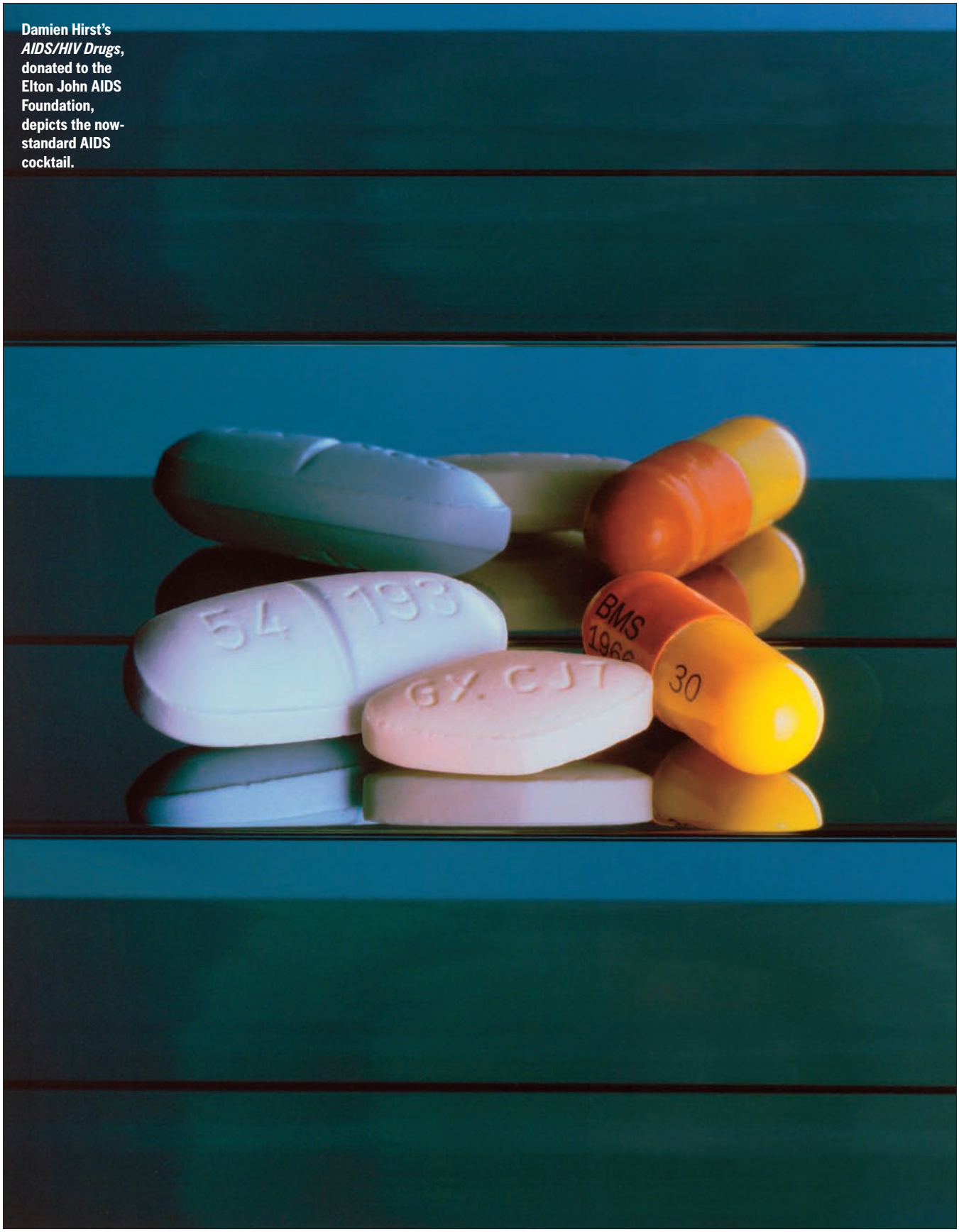
The hitch: Perfecting this kind of treatment could require a complicated and possibly dangerous new drug cocktail. HDAC inhibitors may activate viruses other than HIV, unleashing a plague from within. Alternatively, they could increase the risk of cancer by changing the way in which cells transmit genetic instructions from DNA to cellular proteins. "Whether these

DRUGS FOR THE HIV-FREE

University of North Carolina immunologist Myron Cohen was amazed to hear thunderous cheers from the audience of scientists and clinicians at the sixth International AIDS Society Conference on HIV in Rome last July. He had just presented results of a landmark trial of 1,763 heterosexual couples from nine countries in which one partner was infected with HIV and the other was virus-free. Early use of antiretroviral therapy for HIV, Cohen found, slashed the risk of transmitting the virus by 96 percent. In other words, drugs now used to treat AIDS could also prevent its transmission, winding down the epidemic if enough people begin therapy early.

The study randomly assigned couples to one of two groups. In one, the infected partner began drug therapy immediately. In the other, infected partners deferred treatment until their CD4 T cells (the immune cells the virus targets) fell to a perilous count below 250, or until they suffered an AIDS-related illness. Couples in both groups received HIV primary care, counseling, and condoms. After announcing their preliminary findings, Cohen and his colleagues offered treatment to all of the study participants and will continue to monitor them to see how the effect holds up over time. They are also planning a second study on men who have sex with men.

In a related study conducted in Kenya and Uganda, University of Washington scientists reported a profound reduction of transmission when a noninfected partner was treated instead of the infected partner. Uninfected partners who took a drug called tenofovir had a 62 percent drop in HIV infection; those who took a combination of tenofovir and another drug, Truvada, saw a 73 percent decline. With the Centers for Disease Control developing guidelines that would allow an uninfected person to take Truvada, the era of AIDS prophylaxis is about to begin.



Damien Hirst's *AIDS/HIV Drugs*, donated to the Elton John AIDS Foundation, depicts the now-standard AIDS cocktail.

approaches will work alone or require additional combination therapies is a question that we hope to be able to answer in the next few years," Margolis says. "This is not going to be a single-shot, zero-sum game."

THE PUZZLE PIECES SHOULD COME TOGETHER ONCE WE understand a special group of patients called elite suppressors, the one-in-300 HIV-positive adults with turbocharged immune systems capable of hunting and killing HIV. Timothy Ray Brown and others missing the CCR5 receptor beat HIV because their cells do not allow the virus to get in. Elite suppressors stay healthy because they pummel the virus and hold it at bay.

In June 1992 Loreen Willenberg, then a 38-year-old landscape designer, dreamed that she had been infected with HIV. "I suspected my former fiancé of risky behavior, so I went to get tested," she explains. That test was equivocal; with the dream still haunting her, she got tested again two weeks later. "This time I was positive," she says.

That September Willenberg saw an HIV specialist and her CD4 count came back astoundingly high—over 1,800. "My doctor said, 'Look, this is very extraordinary, let's just keep tabs on you.' After three years of undetectable viral load and a high CD4 count, he said, 'Loreen, I think you're a member of a special group that's being studied at the NIH now. They get infected and stay infected, but they don't get sick.'" Twenty years after getting diagnosed, Willenberg is still healthy and has participated in several long-term studies aimed at decoding why her body has been able to prevail over AIDS.

At first scientists speculated that patients like Willenberg were infected with a weaker version of HIV. Joel Blankson of the Johns Hopkins School of Medicine found otherwise. "They have a fully pathogenic virus," he says, citing his study of a monogamous married couple infected with the same strain of HIV. The husband, a former drug user, contracted the virus 20 years ago. Seven years later, the wife was diagnosed. "He's on triple antiretroviral therapy, and she is an elite suppressor who never got sick."

Only now are scientists beginning to understand the biochemistry that makes this possible. One factor: differences in surveillance proteins called human leukocyte antigens (HLAs) embedded in our cells. These molecules function by shuttling broken-down proteins called peptides from inside the cell to the surface, where other immune cells inspect them to see whether they are invaders. HLAs come in hundreds of forms, but elite suppressors tend to have two specific types, HLA-B*27 and HLA-B*57. A study published last year by the Ragon Institute (formed to facilitate collaboration among vaccine researchers at Massachusetts General Hospital, Harvard, and MIT) suggests that those antigens may help educate CD8 immune cells to make them more potent against HIV, as well as hepatitis C. All CD8 immune cells—like the CD4 cells that harbor HIV—mature in the thymus (an organ devoted to the production of T cells) before taking up active duty in the body; while there, HLAs expose the CD8 cells to a variety of peptides, both human and foreign. Some HLAs—particularly HLA-B*57—tend to bind to a much higher proportion of foreign particles; more HLA-B*57 means that the CD8 cells will be exposed to a broader range of foreign peptides, improving their ability to identify and terminate invaders, including, presumably, HIV.

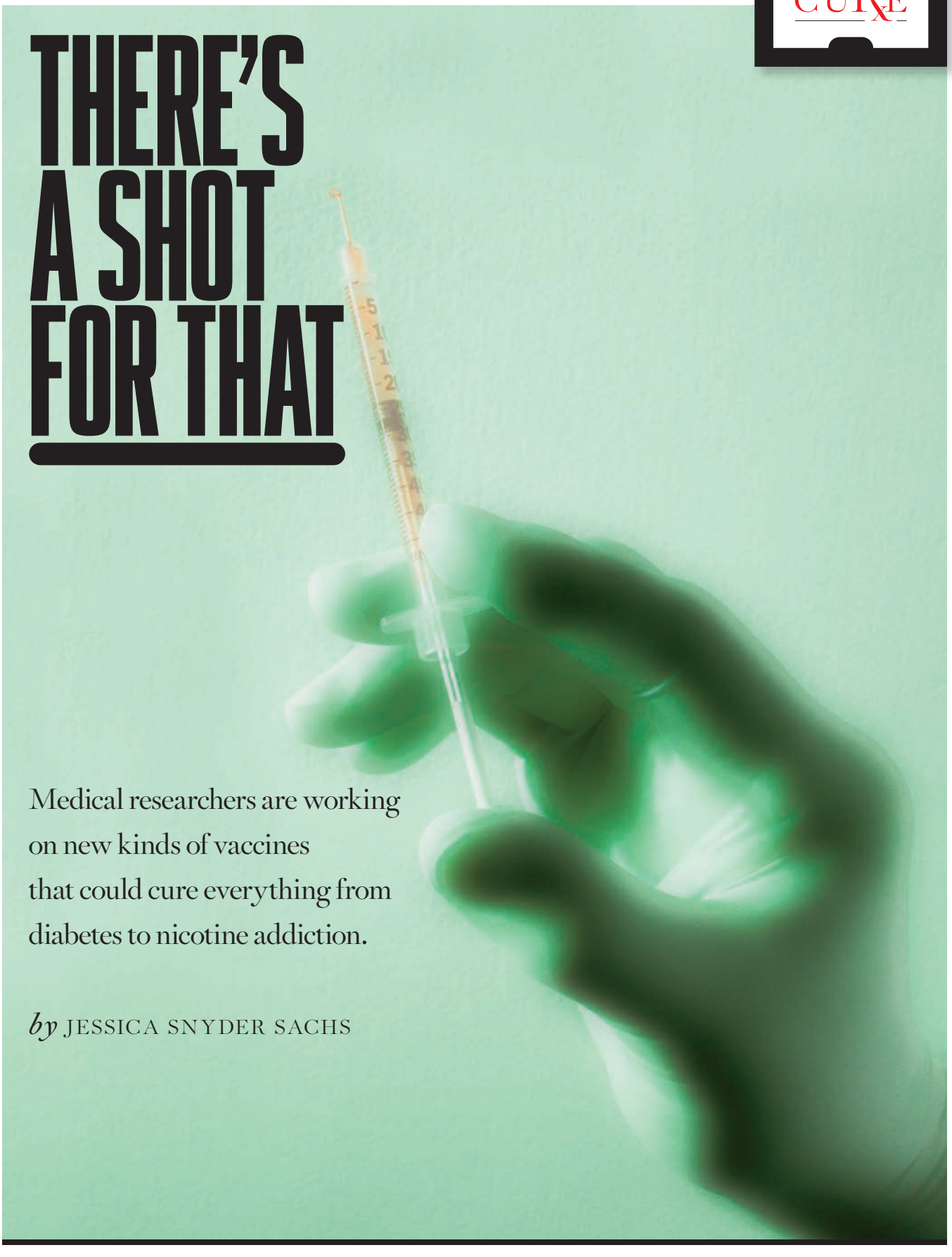
> For the ultimate cure, we might have to purge HIV infection from its silent reservoirs, routing it out so it can never recrudesce and cause damage again.

Yet the unique HLA pattern doesn't explain it all, according to Bruce Walker, one of the study's authors. Walker's colleagues tested the genes of 1,110 elite suppressors and 620 HIV-infected controls. They found that while elite suppressors often have the rare set of genes that code for HLA-B, those genes are "neither necessary nor sufficient" for controlling the virus. In other words, some elite suppressors lack the HLA-B genes and some non-suppressors have them. So the search goes on. Recently, for instance, the team found a group of elite suppressors with elevated levels of p21, a cancer-fighting protein that disrupts key aspects of the HIV life cycle in the lab.

While it's too early to grasp all the factors involved, elite suppressors should help us finesse the cure and eradicate AIDS for good. Two decades ago, researchers imagined that a vaccine would end AIDS. Their approach proved unfeasible, but the goal is now in reach. "This has been an amazing year," says Jeff Sheehy, communications director at the UCSF AIDS Research Institute and a board member of the AIDS Policy Project, also positive for HIV. "I came out about a year before the first AIDS cases were recorded. I had one brief, glorious moment before the world came crashing down, and this has defined my whole life. Now we're talking about a cure."

JILL NEIMARK is a science journalist and author. Her 'tween fantasy adventure novel, *The Secret Spiral,* was published in July. She is a contributing editor at DISCOVER.

THERE'S A SHOT FOR THAT



Medical researchers are working on new kinds of vaccines that could cure everything from diabetes to nicotine addiction.

by JESSICA SNYDER SACHS

CORBIS

THE CURE

THERE'S A **SHOT** FOR THAT

TWO CENTURIES AGO EDWARD JENNER administered the first scientifically developed vaccine, injecting fluid from a dairymaid's skin lesion into an 8-year-old boy. The English physician knew that dairymaids who contracted cowpox, a comparatively mild skin disease, became immune to the much deadlier smallpox, which at the time killed 400,000 Europeans a year. Jenner hoped the fluid from the cowpox lesion would somehow inoculate the boy against the smallpox scourge. His hunch proved correct. Today vaccines (*vaccinia* is Latin for "cowpox") of all forms save 3 million lives per year worldwide, and at a bargain price. A measles shot, for instance, costs less than a dollar per dose.

By training the human immune system to recognize and ward off dangerous pathogens, vaccines can protect against disease for decades, or even for a lifetime. Preventive vaccines work by introducing harmless microbial chemical markers, known as antigens, which resemble the markers on living microbes. The antigens train the immune system to recognize and destroy those microbes should they ever appear in the body. By injecting cowpox antigens into his patients' bloodstream, for instance, Jenner primed their immune systems to attack the similar smallpox virus.

Today medical scientists are taking Jenner's ideas in new directions. They are exploiting a growing understanding of the immune system to develop therapeutic vaccines: ones aimed not at preventing infection but at rooting out established disease or even changing how the body functions. In the spring of last year, the FDA approved Provenge, a vaccine that beats back prostate cancer and is the first of the new generation of therapeutic vaccines to go into widespread use. That may be the trickle before the flood. A 2010 survey by the market analysis firm BCC Research identified 113 therapeutic vaccines in development, many already in human trials.

THE CANCER SHOT

WITH A NEAR-ENDLESS SUPPLY OF PATIENTS willing to undergo novel treatments, cancer researchers have been among the most aggressive in experimenting with therapeutic vaccination. "Cancer vaccines are the stalking horses for therapeutic vaccines," says cancer immunologist Lloyd Old. Based at the Cancer Research Institute in New York, Old is the director of the Cancer Vaccine Collaborative, an international program dedicated to fighting cancer from the inside out.

Much of the Collaborative's work is based on Old's pioneering studies of the immune system over the last half-century. His research built on the insights of 19th-century surgeon and cancer researcher William Coley, who noticed that for then unknown reasons, postoperative cancer patients with severe bacterial infections often experienced complete remission. In 1891 Coley took the first steps toward cancer immunology when he began intentionally injecting late-stage bone cancer patients with streptococcus bacteria, which cause strep throat. The injections shrank tumors, but the resulting infections killed two of his patients. He then tried injecting a combination of heat-killed bacteria, a mixture that became known as Coley's toxin. Although it remained controversial, Coley's cancer vaccine was widely used until radiation and chemotherapy became standard treatment in the 1940s.

By the time Old began his cancer research, in the 1950s, Coley's toxin had been relegated to the American Cancer Society's "black book" of suspected quackeries. "Coley's vaccine was in such disrepute in large part because no one could explain how it worked," Old says. Nevertheless, he became fascinated with Coley's promising results, especially after hearing reports of mouse tumors shrinking after injections of zymosan, a yeast extract. Tumors in those animals continued to grow for close to two weeks after the injections but then started to disappear.

"Clearly the zymosan was not killing the tumors directly," Old says. "Instead it affected the host in a way that triggered a tumor-clearing response." He spent much of his

A VACCINE LEXICON

ANTIBODY
A Y-shaped protein that binds to a specific biochemical target in the body and marks it for destruction or elimination by the immune system. Different types of antibodies elicit different immune responses, from the tissue swelling and mucus production of an allergic reaction to a highly aggressive, tissue-killing inflammation.

ANTIGEN
Any substance, usually a foreign element in the body, that binds to a specific antibody and elicits an immune response. Viral and bacterial proteins are common antigens.

AUTOIMMUNE DISORDER
A disease such as type 1 diabetes in which the immune system attacks the body's healthy tissue.

CYTOKINE
An immune-system signaling molecule that regulates the intensity, duration, and direction of an immune response.

T CELL
An immune cell that can kill both injured cells and microbes; some can also direct the actions of other immune cells.

T-REGULATORY CELL
A regulatory immune cell whose job it is to turn off destructive immune responses.

career investigating ways the immune system can clear the body of cancer. In the process he identified one of the first recognized cytokines, or immune signaling molecules. Cytokines direct the biochemical conversation that immune cells use to coordinate their activities. Old's insights suggested that Coley's toxin worked because it tricked the body into releasing a flood of cytokines by exposing the immune system to what seemed like an enormous bacterial attack. The cytokines then directed an immune response to the bacteria, an onslaught that also killed cancer cells.

Many of the cancer vaccines in development today tap into our current understanding of how dozens of these cytokines help coordinate an effective cancer-clearing response. (The much-publicized HPV cancer vaccine works in a more traditional style: It primes the immune system to fight off human papillomavirus, which can cause cervical cancer.) To make the Provenge prostate cancer vaccine, biochemists at Seattle's Dendreon Corporation extract a sample of a patient's own immune cells and bathe them in a chemical soup of prostate cancer antigens that are chemically linked to a cytokine that screams, "Attack this!" The activated immune cells are then injected back into the patient's body to spread the call to arms.

In the study of 512 prostate cancer patients that led to Provenge's approval, one-third of the vaccinated patients remained alive after three years, compared with one-quarter of those who received a placebo shot, for an average life extension of four months. Old is hopeful the next wave of cancer vaccines can improve those numbers. The Cancer Vaccine Collaborative is working on treatments that target multiple cancer antigens, which should trigger a more aggressive immune response and increase the odds of defeating tumors.

POTENTIAL PATIENTS: 1.5 million Americans are diagnosed with cancer each year.

THE DIABETES SHOT

IN CANCER, THE IMMUNE SYSTEM IS TOO indulgent of diseased cells within the body. In autoimmune disease, the opposite problem occurs: For reasons still unclear, cells of the immune system mistakenly turn against healthy tissues such as insulin-making pancreatic beta cells (causing juvenile diabetes) or the fatty sheaths that protect nerves (multiple sclerosis). The job of an autoimmune vaccine is to shut down these self-attacks. One promising approach boosts T-regulatory cells, or T regs, a recently discovered subgroup of the white blood cells known as T cells. At the University of Calgary's Diabetes Research Centre in Alberta, immunologist Pere Santamaria is focusing on what he calls "weak" T regs, cells that seem to have only a very feeble antigen response.

"Most immunologists would tell you that these cells are garbage in the system," Santamaria says. "But I don't think anything in our bodies is junk." He believes that weak T regs are designed to thwart budding autoimmune reactions before they become threatening. In essence, he says, weak T regs can mature into killer T cells that weed out other immune cells mounting attacks on healthy tissues.

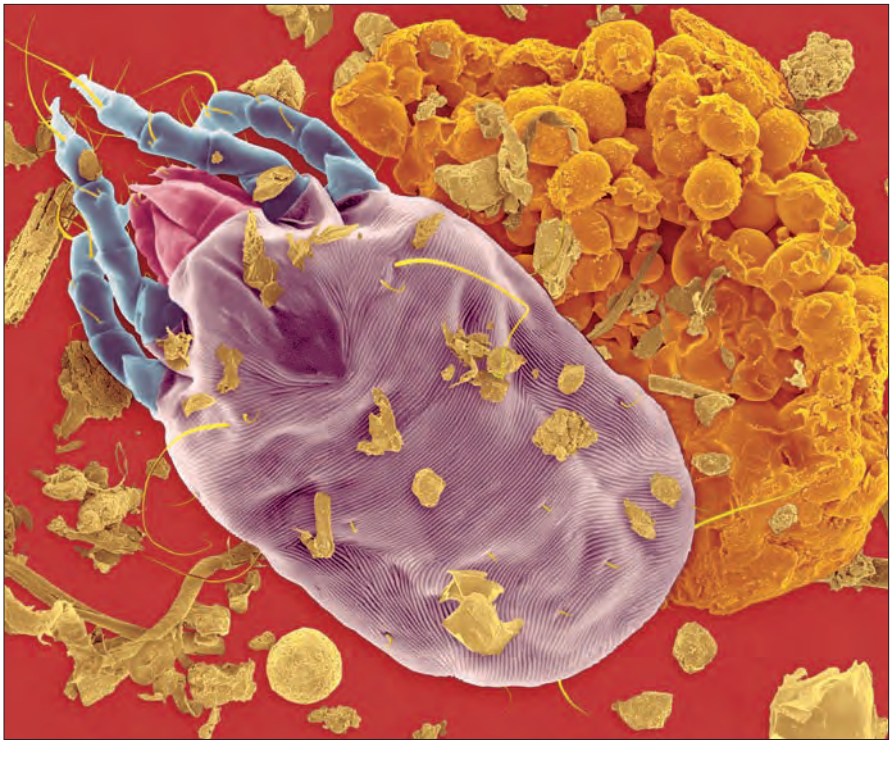
To create a diabetes vaccine, Santamaria has attached a cocktail of antigens from pancreatic beta cells to synthetic iron oxide nanoparticles. This biosynthetic hybrid stimulates the development of weak T regs into killer T cells that destroy the immune cells directing the autoimmune attack. Santamaria's team recently tested his vaccine in diabetes-prone mice. It restored normal blood sugar and insulin levels in animals that already had diabetes and prevented or slowed its onset in young mice that had not yet developed the disease. The team is now readying the vaccine for human trials and is designing related vaccines to treat other autoimmune diseases, including multiple sclerosis, rheumatoid arthritis, and inflammatory bowel disease.

POTENTIAL PATIENTS: Three million Americans have type 1 diabetes; 400,000 have been diagnosed with multiple sclerosis.

THE ALLERGY SHOT

ALLERGIES ARE THE RESULT OF A MILDER type of internal combat in which the body turns against itself. Allergy treatments that involve repeated injections of minute amounts of allergens such as pollen, mites, and mold have been around for nearly a century. Until recently, scientists did not know how such shots worked, simply that they did—at least in a significant percentage of patients. But these allergy shots must be given at least once a week for months and then at least monthly for three to five years. They work best against mild respiratory allergies, such as hay fever, but generally can't be used to counteract severe

Dust mites produce up to 20 fecal pellets a day. Their waste often triggers allergies in humans.



DENNIS KUNKEL MICROSCOPY/VISUALS UNLIMITED

allergies to certain foods or drugs because of the danger of triggering anaphylaxis, a life-threatening immune reaction.

Many immunologists now believe this type of "desensitization" allergy therapy boosts levels of T-reg cells specific to the allergens in the shots. Thereafter, when the T regs encounter their associated allergens, they respond by secreting inflammation-calming cytokines. Equipped with this deeper understanding, researchers are trying to make allergy vaccines safer and more effective by designing them to micromanage the allergic immune response. One way to do that, Swiss immunologist Martin Bachmann has found, is to mimic a microbial infection. He has taken DNA from *Mycobacterium tuberculosis* and slipped it into synthetic protein capsules virtually identical to those produced by viruses. "The immune system immediately recognizes this pattern as a foreign invader," Bachmann says. This spurs the immune system to create more cytokine-producing T regs and suppresses the body's allergic response.

When injected into animals, Bachmann's virus-bacteria hybrid induces a strong antibody response that his company, Cytos Biotechnology, is exploiting to design vaccines against two common inflammatory disorders. In 2009 Cytos reported the results of a placebo-controlled study with 299 patients allergic to dust mites. Each subject received six weekly injections with either a placebo or one of two doses of active vaccine. At the end of the trial, those who received the high-dose vaccine scored an average of 39 percent lower on symptoms and medication use than did those who got the dummy shots.

Bachmann has had similar success with an asthma vaccine that uses the same virus-bacteria combination. In clinical trials with moderately asthmatic patients who were on chronic steroid treatment, the vaccine has proved just as effective as steroids at keeping asthma at bay. Cytos plans on testing the vaccine in more expansive trials soon.

POTENTIAL PATIENTS: Up to 50 million people in the United States suffer from allergies.

THE HEART DISEASE SHOT

SOME OF THE NEW THERAPEUTIC VACCINES are actually designed to attack the body, albeit in a selective way. A new experimental heart-disease vaccine takes aim at unwanted biochemicals within the body, specifically low-density lipoprotein (LDL), better known as bad cholesterol. When large quantities of LDL cholesterol circulate through the bloodstream, it can be deposited on artery walls, leading to a buildup of plaque and triggering inflammation. Anti-cholesterol vaccines that encourage the immune system to attack LDL have been in the research pipeline for decades, but early attempts produced mixed results in animals.

Part of the problem may be that an overly aggressive immune attack on artery-clogging plaque can worsen the situation, says Prediman Shah, director of cardiology at Cedars-Sinai Medical Center in Los Angeles. In the early stages of cholesterol buildup, the immune system removes LDL from artery walls with a relatively gentle antibody-clearing response. But if the plaque buildup continues, the immune response may escalate into overaggressive inflammation that further damages the arteries and clogs them with bits of plaque and dead immune cells.

"The last thing we need from a vaccine is more inflammatory damage," says Shah, who has been working with Swedish cell biologist

Jan Nilsson on a vaccine that boosts the antibodies responsible for gentle plaque removal while damping vessel-damaging inflammation. They have found they can manipulate the desired immune response by varying which piece of the LDL molecule they include in their vaccine. They have also discovered the vaccine lowers blood pressure in mice and protects against the rupture of aneurysms.

Shah and his colleagues expect to complete their animal studies by the end of the year and then plan to ask the FDA for permission to launch human trials. "The challenge shouldn't be underestimated," he cautions. He points to the disastrous results of a small patient trial using an experimental Alzheimer's vaccine, a related type of therapeutic vaccine. Like cardiovascular disease, Alzheimer's involves the buildup of plaque, in this case tangled beta-amyloid proteins in the brain. In 1999 scientists published spectacular results from a study in which a vaccine cured the mouse equivalent of Alzheimer's. The vaccine contained bits of beta-amyloid protein and directed an immune attack against them. When the vaccine was rushed into clinical trials, however, 18 of the 298 participating Alzheimer's patients developed life-threatening brain inflammation. Twelve recovered fully, but six suffered permanent, disabling brain damage. Years later, autopsies showed that the vaccine had indeed cleared amyloid plaque from the volunteers' brains, but the associated inflammation had killed tissue elsewhere in the brain.

POTENTIAL PATIENTS: Cardiovascular diseases kill more than 800,000 Americans a year.

D. HURST/ALAMY

A pizza can pack 3,000 calories. But a vaccine could block one of the hormones that make it so appealing.

THE OBESITY SHOT

VACCINATING AGAINST ONE OF THE BODY'S own hormones seems counterintuitive, or even dangerous. But to ease the obesity epidemic, a vaccine that targets ghrelin—a gastrointestinal hormone that appears to stimulate appetite—could be well worth the risk. Here, too, the strategy is to micromanage how certain molecules behave in the body.

"When you diet, the body responds as if it were starving and produces ghrelin to slow down fat metabolism and stimulate eating," explains Eric Zorrilla, a neuroscientist specializing in eating disorders at the Scripps Research Institute in La Jolla, California. Zorrilla's experimental antiobesity vaccine consists of ghrelin molecules chemically linked to hemocyanin, a protein extracted from the keyhole limpet marine snail. Hemocyanin is known to provoke a powerful immune response in humans. In theory, the response to a vaccine combining ghrelin and hemocyanin should clear ghrelin from the bloodstream.

After trying several biochemical configurations, Zorrilla and colleague Kim Janda hit on one in 2006 that caused immunized mice to lose weight. There are potential dangers to immunizing against the body's own chemicals, though. In particular, the researchers must ensure that their vaccine does not result in an autoimmune response to cells that produce ghrelin, which could trigger severe swelling and inflammation. "We didn't see evidence of that in the animal studies, but it's a concern," Janda says. He and Zorrilla continue to refine the vaccine in preparation for human trials.

POTENTIAL PATIENTS: Nearly 75 million adults are classified as obese in the United States.

THE ADDICTION SHOT

EFFORTS TO PRODUCE ANTI-ADDICTION VACcines began in the 1970s, but those currently in clinical trials trace back to newer research from the mid-1990s, when Barbara Fox, then an immunologist at ImmuLogic Pharmaceutical Corporation, helped develop a cocaine vaccine. The hurdle, she explains, was to get the immune system to register and attack the small, relatively uncomplicated cocaine molecule rather than the complex biological proteins typically found on microbes.

"We had to couple the cocaine to a carrier protein," Fox explains. "We needed a longer molecule that the immune system could recognize as foreign and dangerous." Eventually Fox and her colleagues attached a cocaine molecule to one piece of the deadly toxin produced by cholera bacteria. "This molecule itself isn't toxic," Fox says. "But it's the part that generates the strongest response from the immune system."

In lab animals the vaccine prompted the immune system to produce antibodies custom-tailored to attach to cocaine molecules. Once bonded, the antibodies make the cocaine molecules too large to slip through the tight blood-brain barrier. As a result, the chemical cannot deliver its addictively pleasurable effects to the brain.

Fox's vaccine has been sustained and improved by psychiatrist Thomas Kosten at Baylor College of Medicine in Houston. In 2009 Kosten reported the results of a clinical trial with 115 cocaine addicts, half of whom received the vaccine. The others received dummy shots. The vaccine produced a strong antibody response in 38 percent of those who received it. These patients were cocaine-free at 45 percent of their follow-up exams two to four months after receiving the vaccine.

What's more, the urine tests used to verify abstinence revealed that several users had

tried to thwart the vaccine by overdosing. "Some urine samples showed cocaine levels over a million," measured in nanograms per milliliter, Kosten says. "I've never seen any living person with over 100,000." Yet no one was dying of heart attack or stroke, as would be expected if a high level of cocaine reached the heart or brain. In fact, the participants reported that they were not feeling much of anything. The vaccine is currently in a national clinical trial expected to end within the year.

Cigarette smoking causes roughly 90 percent of lung cancer deaths in the United States.

JAMES REID/MILLENNIUM IMAGES

Kosten is also researching vaccines for methamphetamines and opiates, which are among several anti-addiction shots that have the keen interest of the National Institute on Drug Abuse, says NIDA director Nora Volkow, a research psychiatrist who has used brain imaging to investigate the addictive properties of drugs. NICVAX, an antismoking vaccine that recently received $10 million in funding from NIDA, is in large clinical trials under the auspices of its maker, Nabi Biopharmaceuticals. The vaccine generates antibodies to nicotine by linking the addictive molecule to an inactivated bacterial toxin. As with the cocaine vaccine, the resulting antibodies do not clear nicotine from the blood so much as stick to it, creating a chemical complex too large to migrate into the brain.

Volkow was initially skeptical about the possibility of a nicotine vaccine. "I thought people would simply overcompensate by smoking more cigarettes," she says. But in a pilot study conducted on heavy smokers, 24 percent of those who received the NICVAX vaccine were smoke free for the last two months of the six-month study—double the quit rate of those who received placebo shots. Among those who developed antibodies to nicotine but were not able to abstain from smoking, the number of cigarettes they smoked dropped significantly.

It is too soon to know how long these vaccines will last and whether they will prevent addicts from switching to other drugs. But NIDA is embracing the approach and is now researching a vaccine against heroin, the use of which is a vector for HIV transmission in many countries. Volkow has moved past her doubts about addiction vaccines. "That was before I saw the results of early trials," she says. "Now I see how vaccine technology can be used against a host of public health issues."

POTENTIAL PATIENTS: 46 million Americans smoke cigarettes; an estimated 1.6 million used cocaine in 2009.

Jessica Snyder Sachs is the author of *Good Germs, Bad Germs: Health and Survival in a Bacterial World.*

DANIEL STEIGER

DOUBLE DISCOUNT

85%OFF

LIST PRICE

~~$1,195~~

WAS

$249

NOW JUST

$179

YOU SAVE

$1,016

6 GENUINE DIAMONDS

30 DAY MONEY BACK GUARANTEE

5 YEAR UNLIMITED MOVEMENT WARRANTY

CERAMIC PERFECTION....*style meets science*

NOW WITH DIAMONDS AS STANDARD

The Daniel Steiger Bravado Diamond Ceramic. A luxury timepiece with a high precision chronograph movement and diamond dial, is now available direct from the manufacturer at the astonishingly low price of just $179, a saving of $1,016 on the retail price of $1,195. All the features and styling you would expect from a designer watch including a magnificent presentation case, but at a fraction of the price you would expect to pay.

We just make beautiful watches, beautifully simple to buy.

• 6 Genuine diamonds on the dial • Butterfly buckle • Rose gold colored accents • Date calendar • Scratch resistant solid ceramic case and bracelet • Precision movement with chronograph and date dials • Water resistant to 3atms (98ft) • Supplied to you in a magnificent presentation case

VISA AMERICAN EXPRESS Card MasterCard DISCOVER NETWORK

CALL OUR CREDIT CARD HOTLINE ON 1-877 550 9876

Please quote **DIS119BRV** or go to **www.timepiecesusa.com/dis119**

Timepieces International Inc, 3580 NW 56th Street, Fort Lauderdale, Florida, 33309

BIO HACKE

Do-it-yourself biologists are hunting down genetic disorders and creating synthetic life-forms in garages, closets, and backyards around the world.

by DELTHIA RICKS

HUGH RIENHOFF CLIMBS THE STAIRS INTO HIS ATTIC AND ASCENDS INTO A UNIVERSE OF genes, a space dominated by printouts and digital displays of his daughter's DNA. It is a ritual he has followed regularly for the past five years, retreating here or to a makeshift basement lab in his San Francisco–area home, on the hunt for an error hidden somewhere within Beatrice Rienhoff's genetic code. A mutation for which there are no data anywhere in medicine has depleted her muscle mass and weakened her joints. As an infant, Beatrice could not hold up her head at a time when most other babies her age were long past that milestone. Today, at age 7, she is heartbreakingly thin and wears braces in her shoes to support her fragile ankles. Finding the cause could point the way to a meaningful treatment.

Even though Rienhoff is the founder of two biotechnology companies and holds a medical degree from Johns Hopkins University, he has conducted his hunt not as an expert in human genomics but as a do-it-yourself biologist, teaching himself the tricks of the trade as he moves along and doing his research at home. As a gene tracker, he has collected data on more than a billion DNA sequences in a lonely search that has taken him down dozens of blind alleys. Yet despite occasional doubts, he knows he is moving in the right direction. In fact, Rienhoff suspected his daughter's condition was caused by a genetic glitch the moment he laid eyes on her. The problem was that neither he nor any of his colleagues knew which gene, or genes, was to blame.

PHOTOGRAPHY BY GRANT DELIN

To find out, Rienhoff and his wife, Lisa Hane, first sought out an army of geneticists from coast to coast. "When my daughter was born, we went through the usual diagnostic circles, and arriving at nothing concrete, we went through a more extensive process, going outside the San Francisco Bay Area, going to Hopkins where I trained. And I said to them, 'Why don't you take a crack at this?'" Doctors offered many possibilities, but their theories inevitably led to dead ends. And since a medical condition with an apparent patient population of one could hardly garner federal funding, Rienhoff recast himself as a citizen scientist, a do-it-yourselfer who now finally has a candidate gene in hand.

Rienhoff retreated to his solitary attic to help his daughter, but he is not alone in his approach. A growing cadre of do-it-yourself (DIY) biologists have taken to closets, kitch-

RS

ens, basements, and other offbeat lab spaces to tinker with genomes, create synthetic lifeforms, or—like Rienhoff—seek out elusive cures. Robert Sabin has been an independent researcher for more than 30 years, focusing on nutrition and disease; he works in the library, in his bedroom, or out by the pool of his Long Island house. In Cambridge, Massachusetts, MIT grad Kay Aull reprogrammed the genome of *E. coli* bacteria, a type of life-based engineering known as synthetic biology. That work gained Aull a lot of attention from fellow DIY-ers, including movement leader Mackenzie Cowell, who called her feat "a cool hack."

DIYbio, as its practitioners call it, has some of the trappings of computer hacker culture,

A student at the Genspace Lab in Brooklyn works with her own epithelial cells, which she will use to process her DNA.

including a rapidly growing global community. Facilities erected specifically for biology hobbyists have sprung up around the United States. And an online network, DIYbio.org—started by two Cambridge, Massachusetts, enthusiasts, including Cowell—facilitates communication among citizen scientists worldwide. Cathal Garvey, a garage biotech enthusiast in Cork, Ireland, and an expert on the DIYbio movement, predicts that the new breed of homegrown experimenters will relaunch the kind of creative, idiosyncratic innovation that is often missing from today's big science. DIYbio is not a counterculture, he claims. "The separation of science from society is a fad that is coming to an end."

Beatrice Rienhoff and her father, Hugh, surrounded by data in his attic research center.

THROUGH MOST OF SCIENTIFIC HISTORY, biological research has been done by individuals exploring the world around them. Early farmers were DIY bioscientists who bred crops and domesticated animals to improve agriculture. Early doctors were tribal leaders trying to heal injuries, fight infection, and mitigate the assaults of the natural world. Even modern genetics started with a hobbyist: Gregor Mendel, the 19th-century Austrian monk who performed groundbreaking studies of crossbreeding in his spare time while tending the grounds of his monastery. Mendel, who theorized that unseen units were transmitting traits from one generation to the next, based his conclusion on a mind-numbing series of experiments involving more than 30,000 pea plants. Yet his enormous contributions went unrecognized for more than a decade after his death in 1884.

More recently, huge corporations and vast university centers supported by government grants have been the engines of bioscience, but that has not stopped hobbyists from trucking on. One DIYbio pioneer was the Russian-American novelist Vladimir Nabokov, the renowned author of *Lolita*. He spent his leisure time studying butterflies and

CODY PICKENS PHOTOGRAPHY

writing poignant scientific papers on his results. Nabokov served briefly as a curator of butterflies at Harvard's Museum of Comparative Zoology, but he worked largely at home, where as a self-taught lepidopterist he mounted specimens, planned expeditions, and wrote about butterfly evolution and migration. In 1945 he advanced a hypothesis that *Polyommatus* blues—strikingly beautiful azure butterflies—arrived in the New World across the Bering Strait. Mid-century entomologists dismissed his ideas, but Nabokov, who died in 1977, was vindicated by researchers from Harvard just this year.

Then there was the case of Lorenzo's Oil, the medicine concocted by Augusto Odone, an economist, and his wife, Michaela, in their Virginia kitchen in 1987 in hopes of saving their son, Lorenzo, who suffered from a degenerative genetic disease. They taught themselves advanced biochemistry and contracted with a lab to synthesize their medication. Working under the deadline of a fatal illness, the Odones created a novel treatment for adrenoleukodystrophy, which disrupts fat metabolism, primarily in boys. Lorenzo, who was not expected to live past the age of 8, died a day after his 30th birthday, in 2008.

RIENHOFF BOUGHT A USED THERMOCYCLER FOR UNDER $800, ALLOWING HIM TO AMPLIFY HIS DAUGHTER'S DNA TO SEEK THE CAUSE OF HER CONDITION.

Yet it is only now, at a time when bioscience and the university-industrial complex have all but merged, that the DIY movement has really taken off. With increased access to information and off-the-shelf supplies, the practice of bioscience is becoming available to a burgeoning community that includes gene hunters, curious tinkerers, and independent bioengineers eager to try their hand at creating synthetic life.

ROBERT SABIN IS ONE OF THE MOVEMENT'S pioneers. He forged a path as a citizen scientist in 1980, when he was 33 years old, after making a fortune melting and refining metals. Family members considered his unexpected passion for homegrown biology frivolous and quixotic, but after watching a once-robust refinery employee slowly waste away and die of stomach cancer, Sabin felt compelled to

use his money to cure disease. His obsession emerged at a time rife with discovery, including such advances as drugs derived from recombinant DNA and monoclonal antibodies, molecules synthesized in the lab to recognize invasive pathogens or even cancer cells, aiding targeted drug delivery and diagnostic tests. A dropout from three colleges, Sabin hoped to make his *own* contributions to biology despite having no formal training and no connections—trivial matters, he says, compared with his commitment and desire to learn.

Sabin describes his journey while sitting in his home, nestled amid 200-year-old oaks and elms on Long Island's North Shore. Not just another high-priced piece of real estate, this is a genuine institute of learning, tailored to a student body of one. "You don't need a Ph.D. to be a scientist," he says emphatically. "You need passion. When a scientist gets an idea in his head, he won't stop until it's tested. Scientists are possessed by their ideas and what they want to do. I am like that."

His biological obsession zeroed in on phytic acid, the principal form in which phosphorus is stored in whole grains. Usually it is removed in processing. But "when nature creates something, it's there for a reason; there's nothing wasted," Sabin says. Most scientists back then argued that phytic acid was useless, but he wondered whether its lack might be at the root of some disease.

Although scientists were divided over phytic acid's nutritive value, proponents like Sabin pointed to its role as an antioxidant. With this strength in mind, he sat down at his typewriter and began tapping out an argument for full-fledged animal studies to examine phytic acid's potential for protecting against heart disease and cancer. He sent his proposal to the Linus Pauling Institute of Science and Medicine in Palo Alto, California, and hoped for good news.

A positive answer arrived quickly. "They said I could do the work if I could fund it," Sabin recalls. He arrived at the institute in the summer of 1984 for a crash course in laboratory protocols and then got down to work. Each project required armies of Fischer rats, the pink-eyed albinos widely used in biomedical research. Sabin wrote checks totaling more than $100,000 to get his projects off the ground. In one study, the object was to determine whether phytic acid could retard cancer in rodents. The results, published in *Nutrition Research* in 1988, showed reduced tumor growth rates in animals receiving phytic acid, but not in a control group. In a similar heart study, rodents dosed with phytic acid registered a drop in serum cholesterol of 32 percent and a decrease in triglycerides of 64 percent. That work, which proved the hypothesis that phytic acid could lower key markers for heart disease, was published in the *Journal of Applied Nutrition* in 1990.

Last January Sabin coauthored another study, his most gratifying to date, in the *Journal of Alzheimer's Disease*. The paper grew out of research at the Oregon Health and Science University, yet another project involving phytic acid. Sabin donated $20,000 to the investigation, which also received substantially larger grants from the United States Department of Veterans Affairs and the National Institutes of Health. The study tested phytic acid in an Alzheimer's mouse model and in a human cell line. The double-barreled study showed that phytic acid reduced the production of beta-amyloid protein, which is associated with the degenerative brain disease, and pointed to a possible new treatment. (A study currently under way in mice shows that phytic acid might be therapeutic for patients with Parkinson's disease as well.)

"I see myself as a medical pioneer," Sabin says. "But I recommend that anyone who wants to do this think long and hard about it. You'll mostly be working alone."

HUGH RIENHOFF'S ATTIC OFFICE HAS PROvided a peaceful elevation from which to ponder in solitude the mutation that affects his daughter Beatrice—and what it might do to her as she grows older. Although he has achieved a measure of fame as a DIY gene-searching dad (he was one of the stars of a UCLA conference last year on "outlaw" biology), Rienhoff is by no stretch an amateur. Now graying and in his fifties, he studied genetics in the 1980s under the late Victor McKusick, one of the most accomplished medical geneticists of the last half-century. McKusick had once been part of a panel considering whether Abraham Lincoln might have been affected by Marfan syndrome, an uncommon genetic disorder involving the body's connective tissues.

McKusick hadn't been convinced, but after Beatrice was born, Rienhoff started wondering whether the rare syndrome could explain the constellation of symptoms affecting his little girl. In particular, his baby's feet were especially long, a feature often associated with Marfan.

Concerned too that Beatrice never extended her fingers, Rienhoff and his wife took her to the first of many Bay Area specialists when she was 10 days old. It was a seemingly small deficit, yet Rienhoff and Hane worried that it was a sign of something deeper, possibly related to her apparent lack of muscle mass.

The doctor they consulted suggested Beals syndrome, a condition like Marfan but with less serious consequences. In the end, however, Rienhoff became convinced that neither diagnosis fit. Beatrice lacked the heart problems associated with Marfan as well as the constricted knees and elbows seen in Beals.

When Beatrice reached 18 months, her muscle mass still deficient, Rienhoff contacted colleagues at Johns Hopkins, then caught a flight to Baltimore, cradling his daughter in his arms. Certainly, he figured, doctors there would have a clue.

In the medical genetics department at Rienhoff's alma mater, a colleague introduced him to Bart Loeys, an expert physician and geneticist who found Beatrice had a split uvula, the projection of the soft palate at the back of the throat. Rienhoff was not prepared for the diagnosis Loeys offered. "He said she had Loeys-Dietz syndrome," Rienhoff says, referring to a genetic condition of the connective tissue named after Loeys and his Hopkins collaborator, pediatrician and geneticist Harry Dietz. A split uvula is a key feature of the condition, which, like Marfan, affects the heart, threatening to kill its carriers through a rupture of the aorta at an average age of 27 years. Marfan and Beals syndromes affect genes that code for fibrillin, a protein that helps form elastic fibers in connective tissue. In contrast, Loeys-Dietz is traced to a

Kay Aull working in her home lab–a closet in her bedroom in Cambridge, Massachusetts.

WHEN AULL ACTIVATED HER ENGINEERED BACTERIA, SHE SAW PULSES OF BLUE MIMICKING A COMPUTER'S LOGIC SYSTEM.

genetic defect in the TGF–beta (transforming growth factor–beta) signaling pathway. That pathway affects a vast number of cellular activities, including muscle development and myostatin, the growth factor responsible for muscle size.

Once again, though, Beatrice suffered none of the major deficits that normally come with a Loeys-Dietz diagnosis. The Hopkins specialists had some important insights, but Rienhoff felt they hadn't nailed it. Back in California, he concluded that if he wanted an answer, he would have to dig for it himself.

Rienhoff started in 2006 by taking a blood sample from Beatrice and driving south to a nearby university, where a friend with a lab allowed him to centrifuge it, separating the blood's components. The next step was purchasing a used thermocycler, a machine for amplifying DNA, for a little less than $800. The machine enabled Rienhoff to perform polymerase chain reaction, or PCR, a process that copies a minuscule tidbit of DNA up to a billion times. Ensconced in his basement, he heated Beatrice's white blood cells in his thermocycler until the double-stranded helix of her DNA unwound, leaving single strands in its place. Primed by enzymes that Rienhoff added, the single-stranded molecules served as templates for building others, which were used to synthesize more single strands, en masse.

By repeating this process for hours, Rienhoff collected more than four dozen microliter ampules of genetic material, enough to send to a lab that sequenced Beatrice's myostatin receptor genes, where he suspected the problem might lie. When the printout of that section of Beatrice's DNA came back, Rienhoff found nothing that could explain her condition. So he broadened his search, asking another friend to sample Beatrice's blood and sequence her entire genome, but even that information seemed to lead nowhere.

Night after night Rienhoff tediously compared his daughter's DNA sequence with reference sequences stored in several major genomic databases—Ensembl, Heidelberg, and the UCSC Genome Bioinformatics gene bank, among others. Because of the Loeys-Dietz diagnosis, he focused particularly on genes in the TGF–beta signaling pathway, but nothing significant seemed to turn up. Last summer Rienhoff thought he had caught the culprit in a gene called *CPNE1,* but he quickly discarded the possibility because the mutation turned out to be too

Brooklyn to Big Bioscience: Fuhgeddaboudit

In the outer boroughs, biology gets small.

As the president of Genspace, a community laboratory in downtown Brooklyn, New York, Ellen Jorgensen is helping to democratize biology–making it less the purview of academics and Big Pharma and more an enterprise accessible to anyone who wants a hands-on scientific experience. Here on the top floor of an old bank building, lab benches are fashioned from former restaurant countertops, and the doors are open to the public. Want in? Just apply for membership or attend a workshop.

The lab has physically existed only since last December, but Jorgensen and her Genspace cofounders first encountered one another two years ago. All had been searching for like-minded citizen scientists in New York City but had come up empty–at least until they logged on to the DIYbio Google group for amateur biologists. "I wrote, basically saying 'Let's meet,' " says Jorgensen, an adjunct professor of pathology at New York Medical College. "I set a time and place, and three people showed up. The four of us formed the core group of Genspace."

In addition to Jorgensen, who holds a doctorate in molecular biology, founding members include science writer Daniel Grushkin; Sung Won Lim, a physics undergraduate; and Russell Durrett, who studies biotechnology and entrepreneurship at the Polytechnic Institute of New York University. They were quickly joined by Oliver Medvedik, an instructor at Harvard, and artist Nurit Bar-Shai. Throughout 2009 and most of last year, the group gathered periodically to pursue rudimentary experiments under Jorgensen's guidance, first in Grushkin's living room and then in a hacker collective in the Brooklyn neighborhood of Boerum Hill. All along, though, they longed for their own full-fledged lab.

Their search for dedicated quarters led them to the top floor of the aged Metropolitan Exchange Building on Brooklyn's bustling Flatbush Avenue. The 500-square-foot space rents for $750 per month, a cost divided among Genspace's members. The landlord, whom Jorgensen affectionately calls a "pack rat," used recycled sliding glass doors to cordon off the portion of the floor where the actual laboratory work is done; a biotech firm donated equipment. Now Genspace has a "wet lab," a work space for experiments involving biological materials and water.

One of Jorgensen's first acts after starting Genspace was to inform local law enforcement and the FBI that she and her colleagues had created a lab. "We reached out to our local weapons of mass destruction coordinator," she says of the FBI division tasked with preventing bioterrorism. "We are very friendly with our local FBI representative. He has come to our workshops and he came to our opening. The FBI wishes us well because they know the more educated the public is about what could constitute a biological threat, the easier its job is going to be."

Genspace qualifies as a Biosafety Level 1 lab, suitable for handling life-forms that present no risk to humans. Federal designations go up to BSL-4, for facilities that handle highly contagious airborne pathogens like smallpox, ebola, or avian flu.

Since its founding, Genspace has grown to 12 members. A few hail from the sciences. The chief technology officer for Bodega

Ellen Jorgensen, at work in the Genspace laboratory where she tests a stained culture to see if it glows under ultraviolet light.

Algae in Boston tries out new ideas here as she attempts to create an algae-based biofuel. But most of the Genspace DIY-ers come from the arts, banking, architecture, and other areas far removed from the world of genes and cells. The learning curve can be steep. Jorgensen estimates that it takes an hour to teach new hobbyists how to use a standard laboratory pipette.

Funding for Genspace has been tight, in part because so many of its outreach efforts are done for free. In one project, local schoolchildren were taught to extract DNA from strawberries. Classes typically cost just $300, lab materials included. "I teach a biotech crash course, and Dr. Medvedik teaches synthetic biology," Jorgensen says.

One common teaching tool at Genspace is BioBricks, preassembled DNA sequences that allow do-it-yourselfers to program organisms the way a software engineer assembles lines of code. Many projects here quickly reach beyond the lab and out into the world. "We are sending a weather balloon into the stratosphere to do microbial sampling," Jorgensen says. "Hopefully this will result in microbial mapping of the stratosphere and become a blueprint for other groups interested in putting together a community laboratory of their own." D. R.

common to explain such a rare disorder.

Rienhoff dug deeper and studied harder, obtaining higher-resolution genetic data on Beatrice and comparing it with the genes of his entire family. He worked up from the roots and out to the branches of his small family tree, hoping to find a change in his daughter alone. Then, on an otherwise ordinary day last October, something extraordinary happened. Rienhoff found it: a mutation, a rare genetic miscue, the likely DNA signature of Beatrice's lack of muscle mass. It was deep in the TGF–beta signaling pathway in a gene involved with uvula development. Why it hinders muscle growth is unclear, but it could interfere with production of myostatin in the womb.

Rienhoff is now rushing to confirm his finding and continuing to collect data in preparation for a paper he hopes to publish in a major scientific journal. He is also trying to puzzle out the mechanism by which the mutation affects his daughter's muscles and joints. "The mutation Bea has could be unique in her genome," he says, "but we will be looking for other cases, and I think we'll find them."

IF DO-IT-YOURSELF BIOTECH HAS A GLOBAL hub, Cambridge, Massachusetts, could be it. Not only is it the birthplace of the movement's major mouthpiece, DIYbio.org, but it is also the originating site of iGEM, an annual competition for well-trained students trying to build synthetic organisms and biological machines. Some retrofit microorganisms with BioBricks, Lego-like snippets of DNA that perform well-defined genetic functions, producing everything from antibiotics to biofuels. Others genetically alter microbes to communicate with computers or even function as crude computers themselves. Thousands of competitors from around the world have taken part in iGEM since its inception by four MIT scientists in 2004, converging on Cambridge each fall for the iGEM Jamboree.

The city is also home to some of the most elite do-it-yourselfers and their celebrated biohacker spaces—independent labs tucked away in closets and lofts. These citizen scientists explicitly identify with the computer hackers of a generation ago. Like those young electronics wizards working out of garages who ushered in the personal computing boom, today's young DIYbio enthusiasts are driving an underground tech revolution, this time in the science of life.

One of them is Kay Aull, who built a sophisticated biology workstation in her bedroom closet after graduating from MIT. Smart, bespectacled, curious, Aull is a member of its first class to receive bachelor's degrees in biological engineering, in 2008. She has been tinkering with genes since childhood, when, like an elfin Mendel, she spent long hours crossbreeding plants in her parents' garden. Today she has one of the tiniest full-fledged synthetic biology laboratories in the world, making her one of DIYbio's brightest stars.

As soon as Aull decided to build her lab, she knew she would have to follow government safety protocols for a Biosafety Level 1 facility secure enough to handle well-known agents not implicated in human disease. For Aull that meant "being able to close the door of my closet and have screens on the windows. When fruit flies are used in labs," she says "screens are very important." But Aull had no plans to work with flies. Her first project involved genetically engineering *E. coli* into a new life-form.

Lacking space in her bedroom for a lab bench, she bought a vertical shelving unit and built her workstation straight up. Like Rienhoff, she needed a DNA thermocycler to do PCR. She managed to find one on eBay for $59. Her thermocycler is an antique model from the 1990s, but the machine's age was

A Genspace student in Brooklyn learns the fine art of performing detailed genetic analysis.

gravity defyer™

VERSOSHOCK REVERSE TRAMPOLINE SOLE

Steroid Syringe?
Now that we have your attention, Try Gravity Defyer FREE for 30 Days

SHOES ON STEROIDS?

Tip Top Shoes
New York City

Greater Washington D.C. and Virginia

Footwear etc.
walk your world in our shoes
Northern California and Greater San Diego

J. Stephens
Southern California and Arizona

Scientifically Engineered to Defy Pain, Defy Aging & Defy Fatigue

This is my story

I used to be more active. I used to run, play basketball, tennis, football… I was more than a weekend warrior. I woke up every day filled with life! But now, in my late 30's, I spend most of my day in the office or sacked out in front of the TV. I rarely get to the gym –not that I don't like working out, it's the nagging pain in my knees and ankles. Low energy and laziness has got me down. My energy has fizzled and I'm embarrassed to admit that I've grown a spare tire (I'm sure it's hurting my love life). Nowadays I rarely walk. For some reason it's just harder now. Gravity has done a job on me.

Wear them and you'll know

That's what my doctor recommended. He said, "Gravity Defyer shoes are pain-relieving shoes." He promised they would change my life –like they were a fountain of youth. "They ease the force of gravity, relieving stress on your heels, ankles, knees and back. They boost your energy by propelling you forward." The longer he talked, the more sense it made. He was even wearing a pair himself!

Excitement swept through my body like a drug

I received my package from GravityDefyer.com and rushed to tear it open like a kid at Christmas. Inside I found the most amazing shoes I had ever seen –different than most running shoes. Sturdy construction. Cool colors. Nice lines…
I was holding a miracle of technology. This was the real thing.

GDefy Benefits

- Relieve pain
- Ease joint & spinal pressure
- Reduce fatigue & tiredness
- Be more active
- Have more energy
- Appear taller
- Jump higher, walk and run faster
- Have instant comfort
- Cool your feet & reduce foot odor
- Elevate your performance

I put them on and all I could say was, "WOW!" In minutes I was out the door. I was invincible; tireless in my new Gravity Defyer shoes. It was as if my legs had been replaced with super-powered bionics. What the doctor promised was all correct. No more knee pain. I started to lose weight. At last, I was pain free and filled with energy! I was back in the game. Gravity had no power over me!

Customer Satisfaction Speaks for Itself!
4 out of 5 customers purchase a 2nd pair within 3 months.

Nothing to lose: Start your 30 Day Trial Today!

So, my friend, get back on your feet like I did. Try Gravity Defyer for yourself. You have nothing to lose but your pain.

Tell us your story! Login at Gravitydefyer.com and share your experience.

ABSORB SHOCK
Eliminate pain from every step.

REBOUND PROPELS YOU FORWARD
Reduce fatigue. Be more active.

Gravity Defyer Customer Survey Results

$119.95 LIMITED TIME ONLY
was ~~$129.95~~
MEN (Shown above)
TB902MBL
sizes 7 - 13
Med/Wide and ExtraWide/ XXWide Widths
WOMEN (Black on Black)
TB902FBL
sizes 5 - 11
Med/Wide and ExtraWide/XXWide Widths

EXCLUSIVE ONLINE OFFER

30 DAY TRIAL – Pay only $14.95 Shipping & Handling

Visit **ShoesOnSteroids.com/MB2ICE7** or take advantage of this exclusive offer by phone, and dial **(800) 429-0039** and mention the promotional code below.

Promotional Code: MB2ICE7

Offer not available in stores.

BBB A+

not an issue. "You can do useful things with cast-off equipment," Aull says. Encouraged, she went online for more, finding a $20 thermometer and $50 worth of terrarium parts she could assemble into an incubator to heat samples. Each of those units could have cost her thousands of dollars, had she purchased them new and at cost. Inventive in engineering, Aull built a centrifuge that was totally "home brew." She rigged it from a plastic food container and a power drill. She went online to buy *E. coli*, DNA, plasmids (self-replicating particles used to transport genes into foreign organisms), biochemical compounds, and restriction enzymes (proteins that serve as infinitesimal scissors to clip DNA in specific regions). Her total bill, including hardware store purchases, came to $500.

Her closet now humming with technological activity, Aull was ready to hack into the genome of ordinary intestinal bacteria. Her goal was to genetically modify them into a rudimentary logic system resembling the basic logic underlying computer processes. She titled her project "A Binary Counting System" and tweaked *E. coli* to respond to and then pass on molecular signals that toggle on and off, something like the computer's alternating binary system of zeros and ones. Computers do this electronically as they process data. But cells also have electrical properties, and by genetically modifying the behavior of *E. coli* it is possible, Aull says, to reprogram the bacteria to function as units in a counting system; the difference is that the microbes turn on and off via an organic toggle switch composed of plasmids.

Her system included pulse-generating proteins that could send and receive signals. Aull swapped in a gene that colored the *E. coli* blue, allowing her to see her counting system in action. When she activated the toggle mechanism, she saw tiny pulses of blue, their pattern mimicking a computer's logic when it carries a digital "one."

For Aull, this achievement was just the start. Microbes that can be altered to perform simple processes of logic, she says, should also be capable of advanced operations now common to computers. This is a regular theme among DIYbio enthusiasts. Garage and closet techies point out that DNA functions like pieces of digital code, which makes it ideal for custom-designed organic machines. Last year a team of students in Hong Kong encrypted a mind-boggling amount of data in a single gram of *E. coli*—as much data, the students reported, as can be stored in 450 state-of-the-art, two-terabyte computer hard drives.

FOR HER SECOND PROJECT, AULL DEVELOPED A DNA TEST TO SEE IF SHE HAD A HEREDITARY DISORDER.

AULL ENTERED HER BINARY COUNTING BACTERIA into a freewheeling synthetic biology contest hosted by the sci-fi site io9.com, but she did not win first prize. That honor went to Vijaykumar Meli, a graduate student in India. He managed to hack bacteria so they would perform a vital service for young rice plants, helping them utilize nitrogen and grow more efficiently with less fertilizer. Aull did not go without accolades, though. She took second place, and her project was praised by her biohacking colleagues in Cambridge.

For her second DIYbio project, Aull tackled something only slightly less complex: developing a genetic test for the hereditary disorder hemochromatosis. Her father had been recently diagnosed and her paternal grandfather probably also had the condition, which results in the absorption of too much iron, leading to a damaging buildup of the metal in the liver. Hemochromatosis can also affect the joints, heart, pancreas, thyroid, and adrenal glands. It is one of the most common genetic conditions in the United States, and if left untreated, it can cause arthritis, liver cirrhosis, congestive heart failure, and some forms of cancer.

Commercial DNA tests for hemochromatosis have long been available, but Aull's diagnostic had two specific aims. First, it was personal. She wanted to find out for herself whether she, too, carried the DNA flaw. Symptoms usually do not appear in women until the age of 50, and Aull was just 22. Second, her test would demonstrate that a noteworthy diagnostic could be developed in a makeshift biolab. "It's not where you're working, but what you're working on that's important," Aull says, while admitting that she would have preferred a larger station—but "my room is only so big."

To start, she used a cotton swab to get a sample of cells from her cheek, boiled them in a test tube in her kitchen to free the DNA, then added primers, nucleic acids that mark the part of the sequence. Next Aull put her DNA in the thermocycler for amplification. Finally she ran her genetic material through a gel-electrophoresis machine, a Lucite box containing a semi-porous gel. DNA fragments are placed in the gel and exposed to an electrical field. The DNA migrates in response to the field, with smaller fragments moving most quickly. Her end product looked like a bar code. The distribution of those lines of DNA suggested to Aull that she had the mutation linked to hemochromatosis. Follow-up screening by a professional laboratory confirmed that she is a carrier who can pass on the mutation but is not likely to develop the disease.

Beginners considering home-based biology projects probably would not want to start with complex experiments in synthetic DNA, Aull cautions. "If you start talking about the deep-future benefits, you also bring about the deep-future fears and the Michael Crichton scenarios. I wanted to set a benchmark: I am a professional. I wanted to show what you can do in your closet for $500. It took a month and a half of weekends and whatever supplies I could get my hands on as a private citizen." After completing her two major closet-based experiments, Aull started working out of a couple

Advertisement

Special Market Opportunity

First Federal

Your Expert Guide to the World's Finest Coins

Nicholas J. Bruyer, Chairman & Founder, First Federal Coin Corp.
ANA Life Member Since 1974

$5,690 for an Ounce of Silver Bullion? Impossible!

10 years ago I'd have called you crazy to make such a prediction. Yet today it's a fact. Now our deal with a $4 billion precious metals wholesaler nets you a great deal for America's hottest ounce of silver!

It wasn't more than ten years ago that we met with former U.S. Mint Director Donna Pope. She spoke with pride about what she considered to be her greatest achievement as Director under President Reagan: Creation of the American Eagle silver and gold bullion coin programs, the first of their kind in our nation's history.

The purpose of these coins was to give people the opportunity to own physical silver and gold in a form certified for weight and purity by the U.S. Mint. While the bullion coin program was a signal success, nobody took into account the profound effect it would have on the collector market.

Silver Eagles = Today's Morgan Dollars

In the 1800s and early 1900s, the U.S. Morgan Silver Dollar was struck year upon year at various mints and circulated at face value. Their core value was in their precious metal content. However, in top grades, Morgan Silver Dollars can sell today for tens and even hundreds of thousands of dollars each!

For the same reason, many collectors today see the Silver Eagle series as a literal "ground floor" opportunity to acquire the top-grade coins as they are released. They started submitting Silver Eagles to the leading independent coin grading services, Professional Coin Grading Service (PCGS) and Numismatic Guaranty Corporation (NGC), praying that the coins would come back with the highest possible grade: MS70 (all Uncirculated coins are graded on a point system from a low of 60 to a high of 70, with 70 representing flawless perfection). Of all the Silver Eagles produced by the U.S. Mint in 2010, less than one out of every 681 earned the NGC MS70 grade!

MS70 = $$$$$!

In the rarified atmosphere of MS70, Silver Eagles have soared to market prices that I can only characterize as surreal. Consider this: MS70 Silver Eagles have been selling for truly stratospheric prices. Here are just a few eye-popping examples:

1996 MS70 Silver Eagle	$5,690
1988 MS70 Silver Eagle	$3,190
1991 MS70 Silver Eagle	$2,810
1994 MS70 Silver Eagle	$1,470

It Just Keeps Getting Better

I was thrilled to lock up a guaranteed supply of Perfect Gem MS70 2011 Silver Eagles from a primary distributor who gets them directly from the U.S. Mint. (This is a coin you cannot buy directly from the U.S. Mint). Moreover, every coin is certified and encapsulated by NGC, one of the top two firms for grading coins. But better yet, because we received the very first coins released from the mint, they all have the value-enhancing "Early Release" designation.

What Does "Early Release" Mean?

NGC designates only those coins it certifies as having been released during the first 30 days of issue as Early Release. Collectors place a premium on these coins because they are struck from freshly made dies, which is thought to impart superior quality. Only a miniscule number of the mintage gets the Early Release pedigree.

Actual size is 40.6 mm

This Early Release certification can turbo charge the value of an already valuable MS70 coin. For example, a MS70 2006 20th Anniversary Silver Eagle from the West Point Mint is valued at $2,000—but add the NGC "Early Release" pedigree and the value skyrockets to $2,995—that's 50% more!

CALL IMMEDIATELY BEFORE THEY'RE GONE

Because of our industry-leading status, you can take advantage of our "bolt of lightning" deal on these Perfect Gem MS70 2011 Silver Eagles at blowout prices *even lower* than the 2010s: just $149 each! But, you can save even more. Order 5-9 for only $139 each, and order 10 or more at the best deal—only $129 each! To avoid disappointment I urge you to call immediately. **Hurry! This is a first-come-first-served offer. Call 1-888-324-9123 to find our how to qualify for free shipping. Mention offer code: FFE157**

Call First Federal Toll-FREE today 1-888-324-9123 to Reserve Your 2011 Silver Eagle MS70 Early Release!

Offer Code FFE157
Please mention this code when you call.

Past performance is not an indicator of future performance. Prices subject to change without notice. *Note: First Federal Coin Corp. is a private distributor of government and private coin and medallic issues and is not affiliated with the United States government. Facts and figures were deemed accurate as of January 2011. ©First Federal Coin Corp, 2011.*

ACCREDITED BUSINESS BBB

American Numismatic Association
Nicholas Bruyer
Life Member 4489

1-888-324-9123
www.firstfederalcoin.com/FFE157

VISA MasterCard DISCOVER

of hacker spaces, one in Cambridge and another in nearby Somerville, where she would have more room to spread out.

IN 2010 PRESIDENT OBAMA ASKED HIS COMmission for the Study of Bioethical Issues to assess the nascent field of synthetic biology. The biotech industry had already taken precautions against the DIY-ers, prohibiting companies from selling deadly pathogens to anyone without serious credentials and a certified lab. But in May 2010, when entrepreneur J. Craig Venter announced the creation of Synthia, a bioengineered life-form capable of replicating itself, the science underlying synthetic biology suddenly seemed worth scrutinizing in depth. Synthia had been created with off-the-shelf parts, mostly purchased online. The commission's panelists completed their report in December 2010, recommending that hobbyists be watched but neither regulated nor barred. The conclusion unleashed a torrent of protest, including a letter warning of possible inadvertent releases and environmental and public health threats, which was signed by 58 organizations from 22 countries around the world. Even Harvard molecular geneticist George Church got into the act, opining that DIYbio hobbyists should be licensed, much like amateur pilots, fishing enthusiasts, or shortwave radio operators.

DIYbio.org founder Mackenzie Cowell agrees that some regulation may be appropriate as experiments become more sophisticated but dismisses the notion of scary life-forms emerging from a hacker space, where most of the hobbyists are just not that skilled. "It's not easy to take a genetic sequence and turn it into something that is alive," he says.

Aull echoes that sentiment. "DIYbio is one of the least efficient ways to kill people that I have ever come across," she says. "If you have the know-how to do something even remotely dangerous in your basement, you are smart enough to get a job at a major lab and pocket something on your way out the door." DIYbio is taking the mystery out of science, she adds, "but these kinds of rules will scare people off."

ECKARD WIMMER, A STONY BROOK UNIversity microbiologist who made headlines when he constructed a polio virus from scratch in 2002, argues that it would be virtually impossible to create a pathogen of polio's magnitude in a makeshift lab. "I have never heard of anyone who set up a lab in an attic or garage and put together a virus. You would need more than a garage; you would need a great garage and a lot of money. And it's not trivial. You need the oligonucleotides to stitch genes together, and as far as I know, most companies will check the order if the sequence represents that of a dangerous virus." He estimates that re-creating the polio virus cost about $300,000 and required his expertise as well as a team of graduate students.

At FBI headquarters in Washington, D.C., meanwhile, supervisory special agent Ed You is pursuing a collaborative relationship with the DIYbio community. He and his colleagues in the Weapons of Mass Destruction Directorate's Biological Countermeasures Unit have been developing a rapport with leaders in the DIYbio community for the past few years, encouraging a kind of neighborhood watch. If any suspicious activity ever arose, community members would probably be the first to catch wind of it.

"We are looking for a partnership," says You, who holds a master's degree in molecular biology and biochemistry and worked in both cancer and gene therapy research before joining the FBI. "That's the rationale behind our outreach efforts." The directorate wants to connect with biohackers, and You says his office does not want to see the community overburdened with regulation. In his view, the freedom of homegrown bio is good for science and science literacy. "There is a lot of innovation and resourcefulness coming out of the DIYbio community," he says. At the same time, the FBI's outreach suggests the agency worries about hackers working under the radar. You acknowledges that the tools of biotechnology are getting easier to come by and that "with the emergence of synthetic biology and the availability of equipment, the barrier to do mischief is getting lower and lower."

WITH THE EMERGENCE OF SYNTHETIC BIOLOGY AND THE AVAILABILITY OF EQUIPMENT, THE BARRIER TO MISCHIEF IS GETTING LOWER AND LOWER.

Although he is formally charged with policing the DIY-ers, You cannot help but marvel at their skills. He describes the winners of an iGEM competition a few years ago, a team from Slovenia that developed a vaccine against *H. pylori,* a bacterium that causes stomach ulcers. The pathogen infects more than half the world's population and also can contribute to stomach cancer. The Slovenian students genetically modified *E. coli* to produce the vaccine, suggesting a less costly means of manufacture and immunization down the road.

The agent momentarily loses sight of his law enforcement role to voice his astonishment. "These were kids—*kids*—who didn't even have bachelor's degrees."

Delthia Ricks is a science and medical writer for New York *Newsday*. Her last story for DISCOVER, "Flu Wars," published in December 2009, covered the international battle over ownership of viral genome data needed for vaccine development.

Imagine Living Your Entire Life Looking Like This Because You Could Never Afford $250 For Surgery.

Free cleft surgery which takes as little as 45 minutes and costs as little as $250, can give desperate children not just a new smile — but a new life.

"...one of the most productive charities — dollar for deed — in the world."
—The New York Times

Your support can provide free treatment for poor children with clefts.

❒ $250 Surgery. ❒ $125 Half surgery. ❒ $50 Medications. ❒ $ _____

Mr./Mrs./Ms. _____ Zip _____

Address _____ City _____ State _____

Telephone _____ eMail _____

Credit Card # _____ Expires _____

❒ Visa ❒ MasterCard ❒ AMEX ❒ Discover Signature _____

❒ My check is enclosed. Z11101086ZFKY13

Smile Train, P.O. Box 96211, Washington, DC 20090-6211

Donate online: www.smiletrain.org or call: 1-800-932-9541

SmileTrain
Changing The World One Smile At A Time.

According to the U.S. Government, women should take sufficient levels of folic acid (400 micrograms/day) during pregnancy to help prevent neural tube defects and reduce the risk for cleft lip and palate. When folic acid is taken one month before conception and throughout the first trimester, it has been proven to reduce the risk for neural tube defects by 50 to 70 per cent. Be sure to receive proper prenatal care, quit smoking and drinking alcohol and follow your health care provider's guidelines for foods to avoid during pregnancy. Foods to avoid may include raw or undercooked seafood, beef, pork or poultry; delicatessen meats; fish that contain high levels of mercury; smoked seafood; fish exposed to industrial pollutants; raw shellfish or eggs; soft cheeses; unpasteurized milk; pâté; caffeine; and unwashed vegetables. For more information, visit www.SmileTrain.org. Smile Train is a 501 (c)(3) nonprofit recognized by the IRS, and all donations to Smile Train are tax-deductible in accordance with IRS regulations.

ADVERTISEMENT

Choose Life
Grow Young with HGH

From the landmark book Grow Young with HGH comes the most powerful, over-the-counter health supplement in the history of man. Human growth hormone was first discovered in 1920 and has long been thought by the medical community to be necessary only to stimulate the body to full adult size and therefore unnecessary past the age of 20. Recent studies, however, have overturned this notion completely, discovering instead that the natural decline of Human Growth Hormone (HGH), from ages 21 to 61 (the average age at which there is only a trace left in the body) and is the main reason why the the body ages and fails to regenerate itself to its 25 year-old biological age.

Like a picked flower cut from the source, we gradually wilt physically and mentally and become vulnerable to a host of degenerative diseases, that we simply weren't susceptible to in our early adult years.

Modern medical science now regards aging as a disease that is treatable and preventable and that "aging", the disease, is actually a compilation of various diseases and pathologies, from everything, like a rise in blood glucose and pressure to diabetes, skin wrinkling and so on. All of these aging symptoms can be stopped and rolled back by maintaining Growth Hormone levels in the blood at the same levels HGH existed in the blood when we were 25 years old.

There is a receptor site in almost every cell in the human body for HGH, so its regenerative and healing effects are very comprehensive.

Growth Hormone first synthesized in 1985 under the Reagan Orphan drug act, to treat dwarfism, was quickly recognized to stop aging in its tracks and reverse it to a remarkable degree. Since then, only the lucky and the rich have had access to it at the cost of $10,000 US per year.

The next big breakthrough was to come in 1997 when a group of doctors and scientists, developed an all-natural source product which would cause your own natural HGH to be released again and do all the remarkable things it did for you in your 20's. Now available to every adult for about the price of a coffee and donut a day.

GHR now available in America, just in time for the aging Baby Boomers and everyone else from age 30 to 90 who doesn't want to age rapidly but would rather stay young, beautiful and healthy all of the time.

The new HGH releasers are winning converts from the synthetic HGH users as well, since GHR is just as effective, is oral instead of self-injectable and is very affordable.

GHR is a natural releaser, has no known side effects, unlike the synthetic version and has no known drug interactions. Progressive doctors admit that this is the direction medicine is seeking to go, to get the body to heal itself instead of employing drugs. GHR is truly a revolutionary paradigm shift in medicine and, like any modern leap frog advance, many others will be left in the dust holding their limited, or useless drugs and remedies.

It is now thought that HGH is so comprehensive in its healing and regenerative powers that it is today, where the computer industry was twenty years ago, that it will displace so many prescription and non-prescription drugs and health remedies that it is staggering to think of.

The president of BIE Health Products stated in a recent interview, I've been waiting for these products since the 70's. We knew they would come, if only we could stay healthy and live long enough to see them! If you want to stay on top of your game, physically and mentally as you age, this product is a boon, especially for the highly skilled professionals who have made large investments in their education, and experience. Also with the failure of Congress to honor our seniors with pharmaceutical coverage policy, it's more important than ever to take pro-active steps to safeguard your health. Continued use of GHR will make a radical difference in your health, HGH is particularly helpful to the elderly who, given a choice, would rather stay independent in their own home, strong, healthy and alert enough to manage their own affairs, exercise and stay involved in their communities. Frank, age 85, walks two miles a day, plays golf, belongs to a dance club for seniors, had a girl friend again and doesn't need Viagara, passed his drivers test and is hardly ever home when we call - GHR delivers.

HGH is known to relieve symptoms of Asthma, Angina, Chronic Fatigue, Constipation, Lower back pain and Sciatica, Cataracts and Macular Degeneration, Menopause, Fibromyalgia, Regular and Diabetic Neuropathy, Hepatitis, helps Kidney Dialysis and Heart and Stroke recovery.

For more information or to order call 877-849-4777
www.biehealth.us
©copyright 2000

New! Doctor Recommended

The Reverse Aging Miracle

RELEASE YOUR OWN GROWTH HORMONE AND ENJOY:

- Improved sleep & emotional stability
- Increased energy & exercise endurance
- Loss of body fat
- Increased bone density
- Improved memory & mental alertness
- Increased muscle strength & size
- Reverse baldness & color restored
- **Regenerates Immune System**
- Strengthened heart muscle
- Controlled cholesterol
- **Normalizes blood pressure**
- Controlled mood swings
- Wrinkle disappearance
- Reverse many degenerative disease symptoms
- Heightened five senses awareness
- Increased skin thickness & texture

All Natural Formula

This program will make a radical difference in your health, appearance and outlook. In fact we are so confident of the difference GHR can make in your life we offer a 100% refund on unopened containers.

A Product of Global Health Products

1-877-849-4777

www.biehealth.us

BIE Health Products
3840 East Robinson Road
Box 139
Amherst, NY14228

GHR

DIV 2037839 ON

These statements have not been evaluated by the FDA.

CODE DSC

CanadaDrugs.com

1-800-CAN-DRUG (226-3784)
Call toll free. 24 hours a day. 7 days a week.

The biggest difference is the price.*

Experience 20-80% Drug Savings with the Canada Drugs price difference. No plans. No premiums. No deductibles. Just simple savings made easy.

U.S. RETAIL PRICE		CANADA DRUGS RETAIL PRICE
CELEBREX™ $404.97 200mg, 90 CAPSULES manufactured by Pfizer™	VS	CELEBREX™ $155.25 200mg, 90 CAPSULES manufactured by Pfizer™
CIALIS™ $251.99 20mg, 12 TABLETS manufactured by Eli Lilly and Company™	VS	CIALIS™ $132.36 20mg, 12 TABLETS manufactured by Eli Lilly and Company™
CRESTOR™ $426.96 10mg, 90 CAPSULES manufactured by Astra Zeneca™	VS	CRESTOR™ $197.10 40mg, 10 CAPSULES manufactured by Astra Zeneca™

U.S. RETAIL PRICE		CANADA DRUGS RETAIL PRICE
LIPITOR™ $460.97 20mg, 90 TABLETS manufactured by Pfizer™	VS	LIPITOR™ $169.35 20mg, 90 TABLETS manufactured by Pfizer™
PROPECIA™ $184.99 1mg, 90 TABLETS manufactured by Merck™	VS	PROPECIA™ $146.70 1mg, 90 TABLETS manufactured by Merck™
VIAGRA™ $232.79 100mg, 12 TABLETS manufactured by Pfizer™	VS	VIAGRA™ $144.42 100mg, 12 TABLETS manufactured by Pfizer™

Prescription price comparison valid August 3, 2011 for Canadian drug price and major U.S. Retail Pharmacy price. Actual savings may vary. All trade-mark rights associated with the brand name products shown in this advertisement belong to their respective owners. *Plavix™ may differ in such things as packaging, labelling, color and form.

SAVE 25%
on your first order

Call us today to SAVE 25% on your first order. Why Pay More?

Use this coupon code to save 25% on your first order with Canada Drugs. Not valid in conjunction with any other offer.
Expires June 30, 2012

1-800-CAN-DRUG (226-3784)
Call toll free. 24 hours a day. 7 days a week.

CanadaDrugs.com

Coupon Code: **DSC5742**

How Has Christianity Changed over 2,000 Years?

Follow the Story of Lost Christianities, an Intriguing, 24-lecture Series in Audio or DVD

In the first centuries after Christ, there was no New Testament. However, books of Gospels, Acts, Epistles, and Apocalypses were widely read, and were fervently followed by groups of early Christians. But they would not be among the books that formed the New Testament.

From the many different scriptures then available, Christians held beliefs that today would be considered bizarre: that there were two, 12, or as many as 30 gods; that a malicious deity, rather than one true God, created the world; that Christ's death and resurrection had nothing to do with salvation—others insisted that Christ never really died at all.

What did these "other" scriptures say? Do they exist today? How could such outlandish ideas ever be considered Christian? If such beliefs were once common, why do they no longer exist? These are just a few of the many provocative questions that arise in **Lost Christianities: Christian Scriptures and the Battles over Authentication**.

A Good Mystery Story

This 24-lecture series is a richly rewarding learning opportunity for anyone interested in religion, history, or a good mystery story. Professor Bart D. Ehrman lends his expert guidance as you follow scholars' efforts to recover knowledge of early Christian groups who lost the struggle for converts and subsequently disappeared.

A major theme of this course is the struggle for orthodoxy—or right belief—among the various early Christian groups. You will witness the process by which certain Christian beliefs gained legitimacy, while others were relegated to the status of footnotes to history.

You will see how Christianity developed through its early and lost writings. The struggle for orthodoxy can be seen in both the New Testament and in central Christian creeds. You will explore the development of the New Testament into an approved canon of scripture.

How did the process of forming the orthodox canon take place? Who decided which books should be included? On what grounds? If so many scriptures existed, how do we know that those who selected the final books got it right? If many of these writings were forgeries, how can we be sure that forgeries weren't included in the New Testament?

In these lectures you will also hear about a remarkable archaeological event: the discovery in 1945 of a treasure trove of missing Gnostic scriptures at Nag Hammadi, an Egyptian village near the city of Luxor.

Consisting of 13 leather-bound volumes unearthed in an ancient grave by Bedouin camel drivers (the full story, which you will hear, resembles the plot of a bestselling adventure novel), the Nag Hammadi Library was a watershed event in the search for lost Christianities.

About Your Professor

Dr. Bart D. Ehrman is the James A. Gray Professor and Chair of the Department of Religious Studies at The University of North Carolina at Chapel Hill. He received his Masters of Divinity and Ph.D. from Princeton Theological Seminary. He has won several teaching awards, including the Students' Undergraduate Teaching Award and the Bowman and Gordon Gray Award for Excellence in Teaching. Professor Ehrman has written or edited more than 15 books, including *The New York Times* bestseller, *Misquoting Jesus,* and *Jesus: Apocalyptic Prophet of the New Millennium*.

About The Great Courses

We review hundreds of top-rated professors from America's best colleges and universities each year. From this extraordinary group we choose only those rated highest by panels of our customers. Fewer than 10% of these world-class scholar-teachers are selected to make The Great Courses.

We've been doing this since 1990, producing more than 3,000 hours of material in modern and ancient history, philosophy, literature, fine arts, the sciences, and mathematics for intelligent, engaged, adult lifelong learners. If a course is ever less than completely satisfying, you may exchange it for another, or we will refund your money promptly.

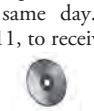
Lecture Titles

1. The Diversity of Early Christianity
2. Christians Who Would Be Jews
3. Christians Who Refuse To Be Jews
4. Early Gnostic Christianity—Our Sources
5. Early Christian Gnosticism—An Overview
6. The Gnostic Gospel of Truth
7. Gnostics Explain Themselves
8. The Coptic Gospel of Thomas
9. Thomas' Gnostic Teachings
10. Infancy Gospels
11. The Gospel of Peter
12. The Secret Gospel of Mark
13. The Acts of John
14. The Acts of Thomas
15. The Acts of Paul and Thecla
16. Forgeries in the Name of Paul
17. The Epistle of Barnabas
18. The Apocalypse of Peter
19. The Rise of Early Christian Orthodoxy
20. Beginnings of the Canon
21. Formation of the New Testament Canon
22. Interpretation of Scripture
23. Orthodox Corruption of Scripture
24. Early Christian Creeds

THE GREAT COURSES®

About Our Sale Price Policy

Why is the sale price for this course so much lower than its standard price? Every course we make goes on sale at least once a year. Producing large quantities of only the sale courses keeps costs down and allows us to pass the savings on to you. This also enables us to fill your order immediately: 99% of all orders placed by 2 pm eastern time ship that same day. Order before November 4, 2011, to receive these savings.



SAVE UP TO $185!
OFFER GOOD UNTIL NOVEMBER 4, 2011

1-800-832-2412
Fax: 703-378-3819

Special offer is available online at
www.THEGREATCOURSES.com/5dscy

THE GREAT COURSES®
4840 Westfields Blvd., Suite 500
Chantilly, VA 20151-2299

Priority Code 50883

Please send me **Lost Christianities: Christian Scriptures and the Battles over Authentication**, which consists of 24 30-minute lectures plus Course Guidebooks.

- ☐ **DVD $69.95** (std. price $254.95) **SAVE $185!** plus $10 Shipping & Handling
- ☐ **Audio CD $49.95** (std. price $179.95) **SAVE $130!** plus $10 Shipping & Handling
- ☐ **Check or Money Order Enclosed**

* Non-U.S. Orders: Additional shipping charges apply. For more details, call us or visit the FAQ page on our website.

** Virginia residents please add 5% sales tax.

** Indiana residents please add 7% sales tax.

Charge my credit card:

☐ VISA ☐ ☐ ☐

Account Number Exp. Date

Signature

Name (please print)

Mailing Address

City/State/ZIP

Phone *(If we have questions regarding your order—required for international orders)*

☐ **FREE CATALOG.** Please send me a free copy of your current catalog (no purchase necessary).

Special offer is available online at www.THEGREATCOURSES.com/5dscy
Offer Good Through: November 4, 2011

HARBOR FREIGHT TOOLS

Quality Tools at Ridiculously Low Prices

LIFETIME WARRANTY ON ALL HAND TOOLS!

FACTORY DIRECT TO YOU!

How does Harbor Freight Tools sell high quality tools at such ridiculously low prices? We buy direct from the factories who also supply the major brands and sell direct to you. It's just that simple! See for yourself at one of our 350 Stores Nationwide and use this 20% Off Coupon on one of our 7,000 products*, plus pick up a Free 9 LED Aluminum Flashlight, a $6.99 value. We stock Shop Equipment, Hand Tools, Tarps, Compressors, Air & Power Tools, Woodworking Tools, Welders, Tool Boxes, Generators, and much more.

- Over 5 Million New Customers in the Last 2 Years!
- 1 Year Competitor's Low Price Guarantee
- No Hassle Return Policy!
- 100% Satisfaction Guaranteed!

Nobody Beats Our Quality, Service and Price!

SUPER COUPON!

FREE! WITH ANY PURCHASE

3-1/2" SUPER BRIGHT NINE LED ALUMINUM FLASHLIGHT

ITEM 65020

REG. PRICE $6.99

HARBOR FREIGHT TOOLS - LIMIT 1 Free item only available with qualifying minimum purchase (excluding price of free gift item). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases. Offer good while supplies last. Shipping & Handling charges may apply if free item not picked up in-store. Coupon cannot be bought, sold or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the offer. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

61871656

SUPER COUPON!

20% OFF ANY SINGLE ITEM!

HARBOR FREIGHT TOOLS - LIMIT 1 Use this coupon to save 20% on any **one** single item purchased when you shop at a Harbor Freight Tools store. *Cannot be used with any other discount or coupon. Coupon not valid on any of the following: gift cards, Inside Track Club membership, extended service plans, Compressors, Generators, Tool Cabinets, Welders, Floor Jacks, Campbell Hausfeld products, open box items, Parking Lot Sale items, Blowout Sale items, Day After Thanksgiving Sale items, Tent Sale items, 800 number orders or online orders. Coupon not valid on prior purchases after 30 days from original purchase date with original receipt. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store in order to receive the offer. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

17658916

SUPER COUPON!

12" RATCHET BAR CLAMP/SPREADER

PITTSBURGH

LOT NO. 46807

SAVE 77%

$1.99 REG. PRICE $8.99

HARBOR FREIGHT TOOLS - LIMIT 9 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

47363910

SUPER COUPON!

LOT NO. 97626

80 PIECE ROTARY TOOL SET

drill master

SAVE 65%

$6.99 REG. PRICE $19.99

HARBOR FREIGHT TOOLS - LIMIT 7 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

94647048

SUPER COUPON!

1000 LB. CAPACITY MOVER'S DOLLY

Haul Master

SAVE 46%

LOT NO. 93888

REG. PRICE $14.99

$7.99

HARBOR FREIGHT TOOLS - LIMIT 8 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

97082715

SUPER COUPON!

CHICAGO ELECTRIC POWER TOOLS

Item 68303 shown

OSCILLATING MULTIFUNCTION POWER TOOL

SAVE 66%

LOT NO. 68303/67256

8 Functions: Sanding, Cut Flooring, Cut Metal, Scrape Concrete, Remove Grout, Cut Plastic, Scrape Flooring, Plunge Cut

$19.99 REG. PRICE $59.99

HARBOR FREIGHT TOOLS - LIMIT 5 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

78643152

SUPER COUPON!

drill master

29 PIECE TITANIUM NITRIDE COATED DRILL BIT SET

LOT NO. 5889

$9.99 REG. PRICE $27.99

SAVE 64%

HARBOR FREIGHT TOOLS - LIMIT 6 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

31960659

SUPER COUPON!

5 SPEED DRILL PRESS

CENTRAL MACHINERY

LOT NO. 38119/44506

Item 38119 shown

$49.99 SAVE 44%

REG. PRICE $89.99

HARBOR FREIGHT TOOLS - LIMIT 4 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

43893929

SUPER COUPON!

800 RATED WATTS/ 900 MAX WATTS PORTABLE GENERATOR

CHICAGO ElectricGenerators

LOT NO. 66619

SAVE $60

$89.99 REG. PRICE $149.99

HARBOR FREIGHT TOOLS - LIMIT 5 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

70103312

SUPER COUPON!

12 VOLT JUMP-START AND POWER SUPPLY

CHICAGO ELECTRIC POWER TOOLS

LOT NO. 38391

SAVE 40%

900 PEAK AMPS

$35.99 REG. PRICE $59.99

HARBOR FREIGHT TOOLS - LIMIT 3 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

37660294

SUPER COUPON!

SAVE $60

500 LB. CAPACITY ALUMINUM CARGO CARRIER

Haul Master

LOT NO. 92655

$69.99 REG. PRICE $129.99

HARBOR FREIGHT TOOLS - LIMIT 5 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

59246198

SUPER COUPON!

CENTRALPNEUMATIC

3 GALLON, 100 PSI OILLESS PANCAKE AIR COMPRESSOR

LOT NO. 95275

SAVE 40%

$44.99 REG. PRICE $74.99

HARBOR FREIGHT TOOLS - LIMIT 3 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

47112661

SUPER COUPON!

580 LB. CAPACITY FOUR DRAWER ROLLER CART

LOT NO. 95659

US★GENERAL

SAVE $130

$99.99 REG. PRICE $229.99

HARBOR FREIGHT TOOLS - LIMIT 4 This valuable coupon is good anywhere you shop Harbor Freight Tools (retail stores, online, or 800 number). Cannot be used with any other discount or coupon. Coupon not valid on prior purchases after 30 days from original purchase date with receipt. Offer good while supplies last. Coupon cannot be bought, sold, or transferred. Original coupon must be presented in-store, or with your order form, or entered online in order to receive the coupon discount. Valid through 1/6/12. Limit one coupon per customer and one coupon per day.

78283375

3 EASY WAYS TO SHOP!

1. VISIT! 350 Stores Nationwide

2. GO TO! www.HarborFreight.com

3. CALL! 1-800-423-2567

Make the most *of every* starry night!

Each monthly issue of ***Astronomy*** magazine is packed with all the tools you need to unlock the mysteries of the cosmos. Whether you're a beginner or an experienced stargazer–***Astronomy*** can help you enjoy every minute under the stars!

Your subscription will include:

- **A monthly pullout sky chart showing the constellations and more**
- **Tips for locating stars, planets, and deep-sky objects**
- **Dazzling full-color images that bring the universe to life**
- **Readable user-friendly articles**
- **Easy-to-understand science reporting**
- ***BONUS:***
  SUBSCRIBERS ALSO GET UNLIMITED PREMIUM CONTENT ON ASTRONOMY.COM!

Subscribe now for just $29.95

Visit www.Astronomy.com/save

Or call 1-800-533-6644

Mon.-Fri., 8:30am-4:30pm CST. Outside U.S. and Canada, call 262-796-8776, x661.

P12780

A11R1A

Own a piece of the Wild West

An exclusive, heirloom-quality ring featuring a genuine U.S. Indian Head Nickel

SIDES FEATURE A DRAMATIC BUFFALO PORTRAIT RECALLING THE INDIAN HEAD NICKEL'S REVERSE DESIGN

CENTERPIECE IS A GENUINE U.S. INDIAN HEAD NICKEL

◆

OUR COIN RING IS A STRICT LIMITED EDITION DUE TO THE SCARCITY OF INDIAN HEAD NICKELS

◆

A BRADFORD EXCHANGE MINT EXCLUSIVE—NOT AVAILABLE ANYWHERE ELSE ... AND ONLY FOR A LIMITED TIME!

COMES IN A HANDSOME PRESENTATION CASE

Honor the spirit of America's West

Long a collector's favorite, the classic obverse design of the Indian Head Nickel was chosen to honor the proud Native American heritage and spirit of America's West. Expertly crafted with 24K gold plating and turquoise enameling, the ***Indian Head Nickel Ring*** features a genuine—and increasingly scarce—U.S. Indian Head Nickel as its centerpiece. Because each coin has its own unique characteristics, each ring is a true one-of-a-kind! Engraved inside is the inscription: "Indian Head Nickel: Honoring the American West."

A hand-crafted jewelry exclusive ... and a superb value

Act now, and this genuine piece of American history can be yours for just $129, payable in three convenient installments of $43 each. To reserve your ring, backed by our unconditional, 120-day guarantee, send no money now. Just return the Reservation Certificate. But hurry—this is a limited time offer!

LIMITED TIME OFFER

Actual Size

Your Complete Satisfaction Guaranteed

To assure a proper fit, a ring sizer will be sent to you after your reservation has been accepted.

www.bradfordexchange.com/ihr

PRIORITY RESERVATION CERTIFICATE

THE BRADFORD EXCHANGE MINT

9307 Milwaukee Avenue · Niles, IL 60714-1393

YES. Please reserve the ***Indian Head Nickel Ring*** for me as described in this announcement.
Limit: one per order.

Please Respond Promptly

Mrs. Mr. Ms.

Name (Please Print Clearly)

Address

City

State Zip

17-00176-001-E84001

$9.00 shipping and service per item. Please allow 4-6 weeks after initial payment for shipment. Sales subject to product availability and order acceptance.

CLASSIFIEDS

EMPLOYMENT

$300 TO $1000 WEEKLY
Assembling Products. Free Information
Rush SAE: Inkling Press Box D28
105 Morin Street, Field; ON. Canada P0H 1M0

$400 WEEKLY ASSEMBLING
Electronic circuit boards/products from home.
For free information send S.A.S.E:
Home Assembly-D, P.O. Box 450
New Britain, CT 06050-0450

TRAVEL

AMAZON RAINFOREST
Award-winning lodge in Tamshiyacu-Tahuayo Reserve shown to have the world's greatest diversity of primates. Customized itineraries. Weekly departures. 1-800-262-9669. Visit: www.perujungle.com.

20 THINGS YOU DIDN'T KNOW ABOUT FIRE

By LeeAundra Keany

1. Fire is an event, not a thing. Heating wood or other fuel releases volatile vapors that can rapidly combust with oxygen in the air; the resulting incandescent bloom of gas further heats the fuel, releasing more vapors and perpetuating the cycle. **2.** Most of the fuels we use derive their energy from trapped solar rays. In photosynthesis, sunlight and heat make chemical energy (in the form of wood or fossil fuel); fire uses chemical energy to produce light and heat. **3.** So a bonfire is basically a tree running in reverse. **4.** Assuming stable fuel, heat, and oxygen levels, a typical house fire will double in size every minute. **5.** Earth is the only known planet where fire can burn. Everywhere else: Not enough oxygen. **6.** Conversely, the more oxygen, the hotter the fire. Air is 21 percent oxygen; combine pure oxygen with acetylene, a chemical relative of methane, and you get an oxy-acetylene welding torch that burns at over 5,500 degrees Fahrenheit—the hottest fire you are likely to encounter. **7.** Oxygen supply influences the color of the flame. A low-oxygen fire contains lots of uncombusted fuel particles and will give off a yellow glow. A high-oxygen fire burns blue. **8.** So candle flames are blue at the bottom because that's where they take up fresh air, and yellow at the top because the rising fumes from below partly suffocate the upper part of the flame. **9.** Fire makes water? It's true. Place a cold spoon over a candle and you will observe the water vapor condense on the metal... **10.** ...because wax—like most organic materials, including wood and gasoline—contains hydrogen, which bonds with oxygen to make H_2O when it burns. Water comes out your car's tailpipe, too. **11.** We've been at this a long time: Charred bones and wood ash indicate that early hominids were tending the first intentional fires more than 400,000 years ago. **12.** Nature's been at it awhile, too. A coal seam about 140 miles north of Sydney, Australia, has been burning by some estimates for 500,000 years. **13.** The ancient Greeks started fire with concentrated sunlight. A parabolic mirror that focuses solar rays is still used to ignite the Olympic torch. **14.** Every 52 years, when their calendar completed a cycle, the Aztecs would extinguish every flame in the empire. The high priest would start a new fire on the ripped-open chest of a sacrificial victim. Fires fed from this flame would be distributed throughout the land. **15.** Good burn: The 1666 Great Fire of London destroyed 80 percent of the city but also ended an outbreak of bubonic plague that had killed more than 65,000 people the previous year. The fire fried the rats and fleas that carried *Yersinia pestis*, the plague-causing bacterium. **16.** The Peshtigo Fire in Wisconsin was the second deadliest blaze in United States history, taking 1,200 lives—four times as many as the Great Chicago Fire. Both conflagrations broke out on the same day: October 8, 1871. **17.** America's deadliest fire took place April 27, 1865, aboard the steamship *Sultana*. Among other passengers were 1,500 recently released Union prisoners traveling home up the Mississippi when the boilers exploded. The ship was six times over capacity, which helps explain the death toll of 1,547. **18.** The Black Dragon Fire of 1987, the largest wildfire in modern times, burned some 20 million acres across China and the Soviet Union, an area about the size of South Carolina. **19.** Spontaneous combustion is real. Some fuel sources can generate their own heat—by rotting, for instance. Pistachios have so much natural oil and are so prone to heat-generating fat decomposition that the International Maritime Dangerous Goods Code regards them as dangerous. **20.** Haystacks, compost heaps, and even piles of old newspapers and magazines can also burst into flame. A good reason to recycle DISCOVER when you are done.

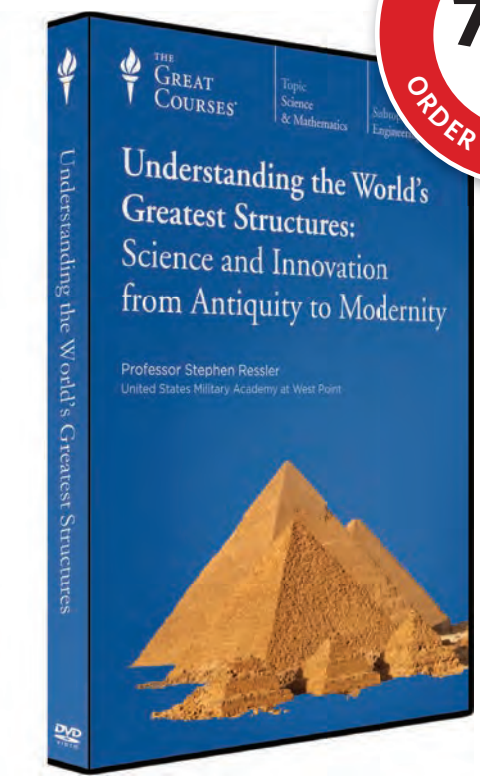
ANTHONY ARCIERO/GALLERYSTOCK.COM

LeeAundra Keany coaches public speaking to support her writing habit. **www.thecontrarypublicspeaker.com**

DISCOVER (ISSN 0274-7529, USPS# 555-190) is published monthly, except for combined issues in January/February and July/August. Vol. 32, no. 8. Published by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612. Periodical postage paid at Waukesha, WI, and at additional mailing offices. POSTMASTER: Send address changes to DISCOVER, P.O. Box 37807, Boone, IA 50037. Canada Publication Agreement # 40010760, return all undeliverable Canadian addresses to P.O. Box 875, STN A Windsor, ON, N9A 6P2. Back issues available.

THE GREAT COURSES®

LIMITED TIME OFFER
70% off
ORDER BY NOVEMBER 4



Visit the Greatest Structures on Earth

Your world is filled with structures that have stood the test of time. That give character to the cities and landscapes in which they're located. And that capture our wonder for the marvels of engineering innovation and progress.

Experience the genius that makes works such as the Giza pyramids, Brunelleschi's dome, and the Brooklyn Bridge possible with **Understanding the World's Greatest Structures: Science and Innovation from Antiquity to Modernity**. These 24 lectures, delivered by civil engineer and award-winning Professor Stephen Ressler, take you around the world and reveal the stories behind the most famous bridges, churches, skyscrapers, towers, and other structures from thousands of years of history. Featuring stunning 3-D animations and detailed physical models, this course is an unforgettable survey of the world's most remarkable man-made masterpieces.

Offer expires 11/04/11

1-800-832-2412

WWW.THEGREATCOURSES.COM/5DISC

Understanding the World's Greatest Structures: Science and Innovation from Antiquity to Modernity

Taught by Professor Stephen Ressler
UNITED STATES MILITARY ACADEMY AT WEST POINT

LECTURE TITLES

1. Learning to See and Understand Structure
2. The Science of Structure—Forces in Balance
3. Internal Forces, Stress, and Strength
4. From Wood to Steel—Properties of Materials
5. Building Up—Columns and Buckling
6. Building Across—Beams and Bending
7. Trusses—The Power of the Triangle
8. Cables and Arches—The Power of the Parabola
9. Loads and Structural Systems
10. Egypt and Greece—Pyramids to the Parthenon
11. The Glory of Rome in Arches and Vaults
12. The Rise and Fall of the Gothic Cathedral
13. Three Great Domes—Rome to the Renaissance
14. How Iron and Science Transformed Arch Bridges
15. Suspension Bridges—The Battle of the Cable
16. Suspension Bridges—The Challenge of Wind
17. Great Cantilever Bridges—Tragedy and Triumph
18. The Rise of Iron- and Steel-Framed Buildings
19. The Great Skyscraper Race
20. The Beauty and Versatility of Modern Concrete
21. Amazing Thin Shells—Strength from Curvature
22. Vast Roof Systems of Iron and Steel
23. The Incredible Lightness of Tension Structures
24. Strategies for Understanding Any Structure

Understanding the World's Greatest Structures: Science and Innovation from Antiquity to Modernity
Course no. 1153| 24 lectures (30 minutes/lecture)

SAVE $185

DVD ~~$254.95~~ NOW $69.95
+$10 Shipping, Processing, and Lifetime Satisfaction Guarantee
Priority Code: 50881

Designed to meet the demand for lifelong learning, The Great Courses is a highly popular series of audio and video lectures led by top professors and experts. Each of our more than 300 courses is an intellectually engaging experience that will change how you think about the world. Since 1990, over 9 million courses have been sold.


RELAY 4 LIFE
1776
CITGO
FUELING GOOD IS MORE THAN A CATCH PHRASE. WE'RE LIVING IT.
Every day, CITGO works to ensure you have the fuel you need to get on your way. Plus, the people of CITGO strive to fuel good things in the communities we serve. By giving back through programs that provide heating oil for needy families, compact fluorescent light bulbs for low-income homes, and by raising more than $130 million for MDA. From the smallest of good deeds to the largest economic impact, CITGO is committed to improving the quality of life across the nation.
Learn more about the impact CITGO has in your community, go to FuelingGood.com.
FUELING GOOD
CITGO
DAVID | CITGO Process Design Engineer | Lake Charles Refinery
FUELING GOOD
SCHOOL BUS