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# ScienceNews

MAGAZINE OF THE SCIENCE & THE PUBLIC ■ APRIL 7, 2012

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This story breaks my heart every time. Allegedly, just two years after the discovery of tanzanite in 1967, a Maasai tribesman knocked on the door of a gem cutter's office in Nairobi. The Maasai had brought along an enormous chunk of tanzanite and he was looking to sell. His asking price? Fifty dollars. But the gem cutter was suspicious and assumed that a stone so large could only be glass. The cutter told the tribesman, no thanks, and sent him on his way. Huge mistake. It turns out that the gem was genuine and would have easily dwarfed the world's largest cut tanzanite at the time. Based on common pricing, that "chunk" could have been worth close to \$3,000,000!

The tanzanite gem cutter missed his chance to hit the jeweler's jackpot...and make history. Would you have made the same mistake then? Will you make it today?

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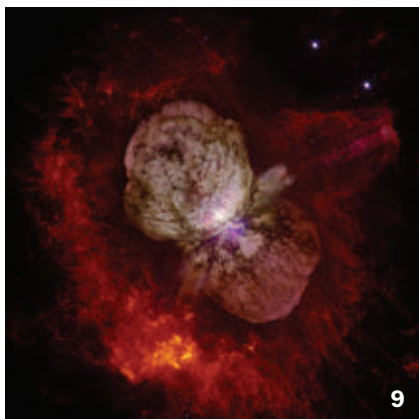
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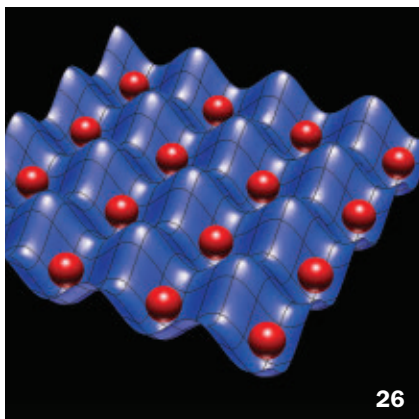
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**COVER** Chimpanzees are among many non-human primates and other animals that have shown evidence of forming mutually beneficial friendships. © Eureka/Alamy

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## FROM THE EDITOR

# Erasing any doubt that information is physical



Everybody knows how a pencil eraser works.

Oh, wait. On second thought, perhaps the electron-savvy communicators of the latest generations don't even know what a pencil is. Still, it wouldn't be hard to teach erasing. Rub the eraser over the pencil mark until it goes away. You just

need to generate a little friction.

Most people will have no trouble believing that without friction, there's no erasing a pencil mark. But it's not so obvious that a similar principle applies to erasing anything, even a number stored in the memory of an electronic computer. Any erasing of information requires some energy, emitting some waste heat, just as friction does.

Experts in the physics of computing have known this rule for half a century. It was formulated in 1961 by an IBM physicist named Rolf Landauer. His erasure principle has long been regarded as the foundation for the study of the physics underlying information processing; it is inviolate regardless of what sort of machine or physical system is doing the computing.

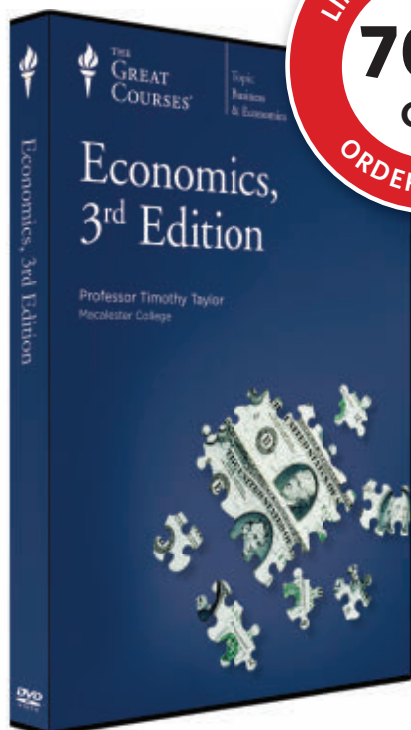
It is very good news, therefore, that an actual experiment has now verified Landauer's principle, as Alexandra Witze reports in this issue (Page 13). Testing it isn't easy, because the minimum amount of energy consumed in erasing a single bit of information is quite small. In real computers lots of other processes use up energy, so the inevitable erasure cost doesn't get noticed. But Landauer showed that computing itself doesn't have to use any energy at all. If you compute more and more slowly (analogous to reducing friction), you can compute with as little energy as you want, all the way to zero.

Erasing, though, always has some energy cost. The new experiment shows that the amount of energy needed to erase a bit never drops below the limit that Landauer calculated.

As computing devices get smaller and smaller, and waste heat becomes a bigger and bigger problem, understanding the implications of Landauer's principle will be essential in designing ways to cope with it.

Landauer, who died in 1999, always insisted that "information is physical," and that understanding the physical universe would require coming to grips with just what that meant. Investigations of quantum information (see my essay on Page 26) are an important part of that effort. Verifying Landauer's principle is another reminder of the significance of his slogan. —Tom Siegfried, *Editor in Chief*

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## Say What?

**Efflorescence** \ehf-floh-REH-sens\ n. The formation of flowering patterns as salt crystals grow on damp surfaces. Scientists have now explained why the crystals grow in discrete patches rather than coating the surface evenly. It all comes down to the way moisture wicks through and evaporates from a salt-saturated solution, researchers from the University of Toulouse in France write in the Feb. 3 *Physical Review Letters*. Liquid naturally finds channels through which it flows faster toward the surface, where it evaporates and builds up crystals (shown). Knowing why and how efflorescence occurs could help conservators better preserve old damp buildings and artwork. —Alexandra Witze

## Science Past | FROM THE ISSUE OF APRIL 7, 1962

**FRESH WATER FOR SPACE** — Spacemen on the moon or on a space platform or spaceship may continuously produce more water than they need with a new high-temperature



method of burning wastes described at the American Chemical Society meeting in Washington, D.C. Frank J. Hendel of North American Aviation, Inc., Downey, Calif., told the Society of a process of oxidizing or burning all human wastes, including perspiration and water vapor

from breath to produce more water than is originally used. The water needed for a healthy astronaut is seven pounds each day.

## Science Future

### April 20–29

Science festivals in Philadelphia and Cambridge, Mass., both include science carnivals with games, plus check out video game-making in Cambridge and Astronomy Night in Philly. See [bit.ly/fairCam](http://bit.ly/fairCam) and [bit.ly/fairPhilly](http://bit.ly/fairPhilly)

### April 28–29

Meet Bill Nye and the hosts of the TV show *MythBusters* at the USA Science & Engineering Festival in Washington, D.C. See [bit.ly/fairUSA](http://bit.ly/fairUSA)

## SN Online

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### SCIENCE & SOCIETY

Intel Science Talent Search finalists present their research. See “Science competition finalists go public.”

### ATOM & COSMOS

Reflected light yields chemical clues in “Aura of life captured in Earthshine.”



### ENVIRONMENT

A plastics ingredient bumps up insulin production. See “BPA fosters diabetes-promoting changes.”

### ON THE SCENE BLOG

Researchers stung by NASA budget cuts. Read “Proposed cuts in planetary science take center stage.”

## How Bizarre

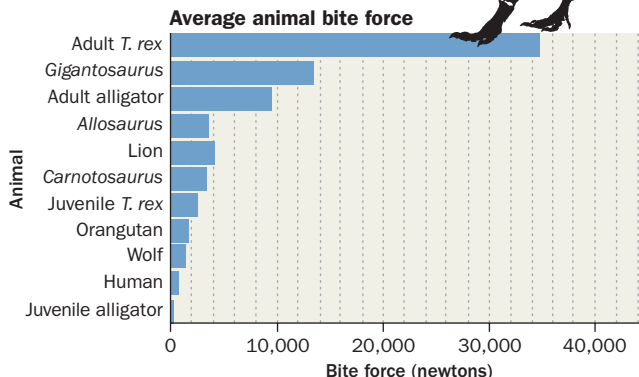
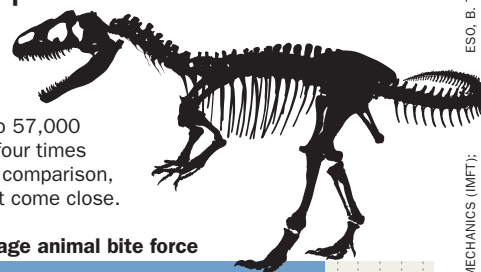
For two weeks in November 2009, ocean currents flowing around Antarctica changed noticeably enough to temporarily speed up the planet’s spin by about one ten-thousandth of a second. Scientists precisely monitor the length of Earth’s day through space geodetic techniques, such as counting how long it takes laser light to travel from Earth to a mirror on the moon and back again. Big changes in how mass is distributed across the planet — such as changes in the atmosphere, or a monster earthquake — can alter the pace of rotation. The 2009 shift in

Antarctica marks the first time such a shift has been traced to a short-term pattern in the oceans, scientists from NASA’s Jet Propulsion Laboratory in Pasadena, Calif., and Paris Diderot University in France report February 28 in *Geophysical Research Letters*. —Alexandra Witze



## Science Stats | BIG BITE

A new computer simulation suggests that *Tyrannosaurus rex* could have chomped down with a force up to 57,000 newtons — more than four times previous estimates. In comparison, modern alligators don’t come close.



SOURCE: K.T. BATES AND P. L. FALKINGHAM/BIOLOGY LETTERS 2012

ESO, B. TAFRESHI, TWAN (TWANIGHT.ORG); 4X6/ISTOCKPHOTO; NASA, NOAA

CLOCKWISE FROM TOP LEFT: TOULOUSE INST. OF FLUID MECHANICS (IMFT);

“ Our metabolic pathways aren’t designed to handle Big Gulps. ”

— KATHLEEN MELANSON, PAGE 16

**Genes & Cells** Stem cells for new eggs

**Atom & Cosmos** Neutrinos reclocked

**Science & Society** Science talent saluted

**Earth** Shrinking sea ice means more snow

**Humans** Pi master’s memory secret

**Matter & Energy** Erasure extracts a cost

**Life** Sawfishes don’t saw

# In the News

## STORY ONE



## Icy isolation may have led to new human species

Cold-climate refuges possibly influenced *Homo* evolution

By Bruce Bower

After ancient people left their African homeland, they migrated into Asia and Europe, taking refuge from ice age conditions in areas isolated from other populations, two new reports suggest. That isolation may have prompted the evolution of new *Homo* species, including a mysterious Asian population dubbed Denisovans and possibly an unusual-looking humanlike group now identified in China.

Ice age asylums “are critical to understanding the expansion of *H. sapiens* out of Africa, the extinction of Neandertals and Denisovans, and interbreeding between these populations,” comments anthropologist Robin Dennell of the

Fossils reveal some of the diversity of human and humanlike species, including (from left) a skull from an unidentified possible new species found recently in China, *Homo sapiens*, *Homo heidelbergensis* and Neandertal. These and related species may have evolved in ice age refuges throughout Asia and Europe.

University of Sheffield in England.

Fossils unearthed in two caves in southwestern China come from an unusual-looking line of *Homo sapiens*, or perhaps a previously unknown *Homo* species, say anthropologist Darren Curnoe of the University of New South Wales in Sydney and his colleagues. This group lived near modern-looking people between 14,300 and 11,500 years ago.

Ancient bones unearthed previously and in new digs at the Chinese caves combine features of people today with flaring cheekbones and other traits of poorly understood African *Homo* fossils from more than 100,000 years ago. Because this anatomically peculiar population survived alongside modern-looking people until almost 11,000 years ago, Curnoe suspects that the new fossils represent a separate *Homo* species that originated in Asia.

“We’re cautious about classifying these fossils, because scientists lack

a satisfactory biological definition of *Homo sapiens*,” Curnoe says. He and his colleagues report the findings online March 14 in *PLoS ONE*.

Ancient people left Africa as early as 120,000 years ago, so the Chinese fossils might be those of early migrants who evolved in relative isolation for tens of thousands of years without contributing genetically to people today, Curnoe suggests.

Instead, the ancient features of the new Chinese finds might reflect interbreeding with the Stone Age, humanlike species called Denisovans, remarks anthropologist Chris Stringer of the Natural History Museum in London. Denisovans, identified from DNA taken from a single finger bone found in Siberia, interbred with humans in southeastern Asia at least 44,000 years ago (*SN: 11/5/11, p. 13*). Researchers regard Denisovans as close relatives of Neandertals.

In the March 16 *Science*, Stringer and



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evolutionary ecologist John Stewart of Bournemouth University in England propose that the evolution of humans and earlier *Homo* species that reached Asia and Europe hinged on small populations that took refuge in ecological sanctuaries during recurring ice ages.

As with many plants and animals, climate-induced corralling of *Homo* groups into restricted habitats prompted the evolution of new species, most notably Neandertals and Denisovans, Stringer and Stewart hypothesize. Their new work lays out a framework of what early human migration and evolution might have looked like.

Consider *Homo heidelbergensis*, a likely ancestor of Neandertals and *H. sapiens* that left Africa between 600,000 and 400,000 years ago. *H. heidelbergensis* apparently survived in livable parts of southwestern Asia during ice ages. A

long-isolated *H. heidelbergensis* population evolved into Neandertals, Stringer suggests.

Neandertals interbred with *H. sapiens* around 45,000 years ago, as ancient people reached a climate-friendly part of southern Europe already populated by their evolutionary cousins, Stringer proposes. Neandertals then headed to Europe's southwestern corner and died out by 30,000 years ago.

A still mysterious population of Asian migrants found an ice age retreat and evolved into *Homo floresiensis*, Stringer says. This tiny, humanlike species, nicknamed hobbits, lived from around 95,000 to 17,000 years ago in southeastern Asia.

Climate fluctuations need not have regularly chased Stone Age folk into "safe" areas, remarks anthropologist Rick Potts of the Smithsonian Institution in Washington, D.C. Geological



**New species?** Fossils unearthed from two caves in China include a skull that combines modern human facial features with those of earlier *Homo* species (reconstruction shown).

evidence suggests that *H. sapiens* and its African ancestors originated during volatile periods — lasting up to 300,000 years — when the climate veered from extremely rainy to bone-dry every 8,000 to 12,000 years, Potts says.

Faced with constantly shifting habitats, ancient people and their precursors evolved to deal with a wide range of environments, he asserts. East Asian migrants would have adapted to ice ages rather than seeking ecological shelter.

Anthropologist David Frayer of the University of Kansas in Lawrence also doubts that cold-weather refuges stoked human evolution. In fact, he goes as far as to argue that Stone Age groups in Asia and Europe interbred enough, even during ice ages, to maintain *H. sapiens* as a widespread, diverse species that encompassed both Neandertals and the newly reported Chinese individuals.

Consistent with Stringer's argument, an analysis of ancient DNA, published online February 23 in *Molecular Biology and Evolution*, suggests that one portion of the Neandertal population sought ice age sanctuary in Western Europe between 70,000 and 55,000 years ago before dying out and giving way to remaining Neandertals from Eastern Europe. Geneticist Love Dalén of the Swedish Museum of Natural History in Stockholm and his colleagues found much less genetic diversity in Western European versus Eastern European Neandertals.

Such evidence may point toward refuge-driven evolution outside Africa, but much remains unknown. "Asia is huge and we know little about ancient human populations there," Stringer says. ■

## Back Story | SKULL TO SKULL

Although DNA analyses have allowed the identification of distinct hominid species like the Denisovans, human evolutionary scientists still rely largely on fossil studies to reveal differences between early human and humanlike species. A comparison of the skulls of contemporaries *Homo neanderthalensis* and *Homo sapiens*, for example, argues that these were indeed two separate species, both thought to have evolved from the more ancient *Homo heidelbergensis*. Scientists look to certain key features when evaluating such fossils.



*Homo neanderthalensis*

**Skull** The Neandertal skull is thicker, with a round protrusion at the back of the head. *H. sapiens'* skull has a more rounded dome shape.

**Face** *H. sapiens* has a relatively flat, small face. Neandertals had a sloping face.

**Braincase** The Neandertal braincase is slightly larger.



*Homo sapiens*

**Forehead** The Neandertal forehead recedes while *H. sapiens* has a high, distinctive forehead.

**Brow ridges** Protruding brow ridges distinguish the Neandertal.

**Chin** *H. sapiens* has a well-developed chin.



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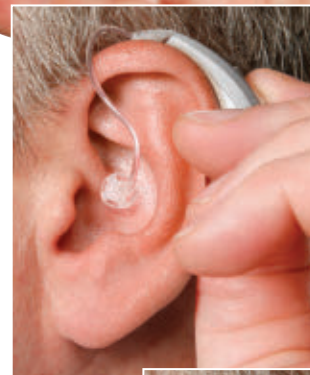
thanks to the efforts of the doctor who leads a renowned hearing institute, there is Perfect Choice HD. It's designed to accurately amplify sounds and deliver them to your ear. Because we've developed an efficient production process, we can make a great product at an affordable price. The unit has been designed to have an easily accessible battery, but it is small and lightweight enough to hide behind your ear... only you'll know you have it on. It's comfortable and won't make you feel like you have

### Perfect Choice HD vs Traditional Hearing Aids

	Perfect Choice HD	Traditional Hearing Aids
Lightweight and Inconspicuous	YES	Some
Easy Toggle Switch Adjustment	YES	Few
Intelligent Setting Memory	YES	Few
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# Adult women might replenish eggs

Stem cells found in ovaries produce precursors to gametes

By Tina Hesman Saey

A newly discovered type of stem cell in the ovary could mean big things for women's health, possibly leading to new fertility treatments and maybe even a way to delay menopause.

Since the 1950s it has been thought that women are born with all of the egg cells they will ever have. But with the discovery of egg-producing stem cells in mice and now in humans, it appears that the ovary can replenish its egg supply. Researchers led by Jonathan Tilly, a reproductive biologist at Massachusetts General Hospital in Boston, report the finding online February 26 in *Nature Medicine*.

Others hail the work as a genuine breakthrough with huge implications. "This is like discovering a new planet in our solar system that has a bacterium on it," says Kutluk Oktay, a reproductive biologist at the New York Medical College in Valhalla. At the very least, he says, the cells offer hope for extending a woman's reproductive life span.

Tilly didn't set out to overturn the dogma that women don't make new eggs. Studying the onset of menopause, he and his colleagues developed ways to track the death of egg cells over time. When counting the number of healthy egg cells in mouse ovaries, the researchers saw a steady decline with age as expected. But the team also found that dying cells greatly outnumber the starting population of eggs. "What we had was a math problem," Tilly says. "We refocused all of our efforts on this glaring mathematical dilemma."

In 2004, Tilly's group reported the answer to the math problem: There are more dying eggs than healthy ones because stem cells in mouse ovaries are constantly making more eggs, which then die off. The discovery didn't go over well. "The vast majority of our colleagues were not very receptive," Tilly says. Many of those who did accept the existence of egg-forming

stem cells in mice didn't think humans would have similar cells.

In the new study, the team isolated stem cells from ovaries that had been removed from six women during sex reassignment surgeries in Japan. About 1.7 percent of cells in the ovaries fit the stem cell profile. The researchers compiled molecular profiles of the cells and demonstrated that the stem cells are able to make precursors to eggs when transplanted into other ovaries.

Tilly's group convincingly shows that stem cells in human ovaries can make egg cell precursors, says Evelyn Telfer of the University of Edinburgh. But it remains to be seen if the cells can make mature gametes, she says.

Eggs grown from the mouse version of the stem cells can be successfully fertilized and develop into baby mice. If the researchers can make fully functional human eggs from the cells, researchers might be able to solve fertility problems for some women. It raises the possibility that "we can not only replace the number, but also bring egg quality back to where a woman was in her 20s," Oktay says.

Sperm-producing stem cells in men can go dormant with age. Tilly suspects the same thing may happen with egg-making stem cells in women. The problem may stem from organelles called mitochondria, which generate energy for cells. Mitochondria may run out of steam as people age. Reviving aged mitochondria in the egg stem cells could extend fertility and delay menopause, Tilly thinks. His team has already stopped "mouseopause" in female mice.

Stopping the depletion of eggs or keeping ovaries functioning could help stave off many of the health problems women experience after menopause, Tilly says. "If we can somehow control this biological clock, to me, the possibilities are endless." ■

**"If we can somehow control this biological clock, to me, the possibilities are endless."**

JONATHAN TILLY



Some birds, fish and other animals can make new eggs throughout life. Women may have the same capability. A new study shows that ovarian stem cells can produce immature egg cells. A mature human egg cell is shown above.

## Atom &amp; Cosmos

20  
yearsLength of the 19th  
century Eta Carinae  
eruption10  
solar massesMaterial shed  
during the  
eruptionReflected glow  
lights up pastVisible echoes make sense  
of explosion from long ago

By Nadia Drake

Scientists are closer to understanding an enormous two-decade-long eruption that transformed one of the galaxy's most massive stars into a fireball millions of times brighter than the sun.

From 1838 to 1858, astronomers watched the giant star Eta Carinae erupt, shedding more than 10 solar masses of material and producing an oddly shaped, double-lobed cloud 7,500 light-years from Earth. Scientists have thought a dense stellar wind fueled the outburst and considered it the prototype for "supernova impostors," or shorter-lived eruptions that don't quite destroy a star.

But new observations suggest that an explosion may have caused Eta Carinae's Great Eruption, says study coauthor Armin Rest, an astrophysicist at the Space Telescope Science Institute in Baltimore. While scientists already knew much about the star (now recognized as a binary star system), Rest says they lacked infor-

After analyzing light echoes left over from an outburst of the binary star system Eta Carinae seen more than 150 years ago, scientists suggest an explosion rather than an energetic stellar wind created the spectacle.


mation about the outburst, originally observed without modern technology.

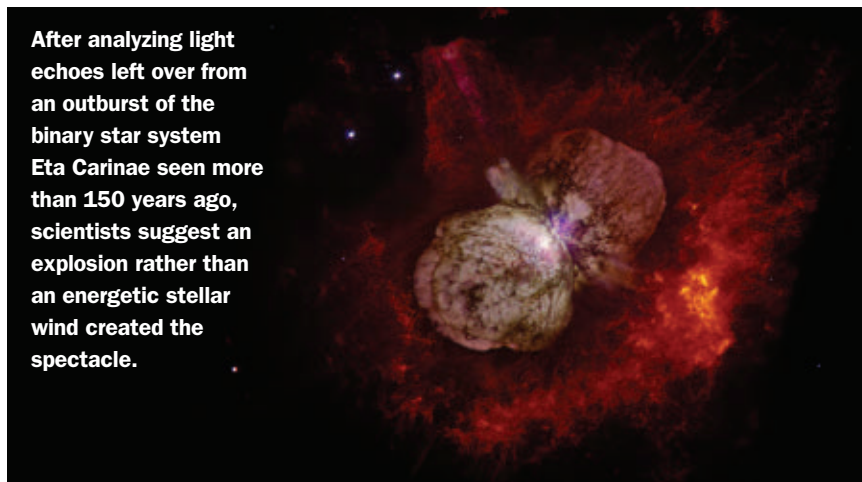
So Rest's team sifted through dust clouds forming a sort of net that bounces the eruption's original light back to Earth in what's known as light echoes.

These echoes act like time capsules that preserve the energy spectrum of the light as it appeared in the mid-1800s. "It is like a science fiction dream to be able to travel in time to ... analyze the Big Eruption with 21st century instrumentation," says Augusto Damineli, an astrophysicist at the University of São Paulo.

The spectrum didn't match predictions of accepted stellar wind theory, Rest and

colleagues report in the Feb. 16 *Nature*. The temperature indicated by the light echoes was about 2,000 degrees Celsius cooler than anticipated, suggesting that something other than windblown star stuff, such as a mini-explosion or an interaction between Eta Carinae and its companion, played a role in the eruption.

But some scientists say the temperature discrepancy isn't enough to overthrow the classical stellar wind theory. "The spectrum that they describe is, in fact, reasonably consistent with what we expected based on theory," says astrophysicist Kris Davidson of the University of Minnesota in Minneapolis. 



## Neutrino speed blamed on cable

Evidence mounts against faster-than-light finding in Italy

By Devin Powell

Faulty wiring has been proposed as the glitch that caused a European physics experiment to clock particles flying faster than light.

Scientists at Italy's OPERA experiment reported in September that nearly weightless particles called neutrinos were apparently traveling from the CERN laboratory on the Swiss-French border to an underground detector in Italy, 730 kilometers away, faster than the


speed of light in a vacuum. The apparent violation of Einstein's theory of special relativity immediately produced a chorus of theorists offering reasons why neutrinos simply could not be going that fast (*SN: 11/5/11, p. 10*).

During a second run of the experiment in November, neutrinos again appeared to arrive 60 nanoseconds earlier than light in a vacuum would have.

On February 23 the OPERA team announced what might be causing the surprising observations: A bad connection

with a cable that relays satellite GPS signals to keep the experiment's clocks in sync could have made each particle's trip seem to take less time than it actually did.

ICARUS, another Italian experiment, has also been timing neutrinos that came from CERN. That group announced March 16 that the particles clocked in at about — but not faster than — the speed of light, casting further doubt on OPERA's results.

"We should have been more cautious in the way we framed the results," says Luca Stanco, a physicist who works on OPERA at the National Institute of Nuclear Physics in Padua, Italy. "Now we are a little embarrassed." 



# Science & Society



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## Cancer research wins top prize in science contest

Gala honors 40 finalists in Intel Science Talent Search

By Devin Powell

**WASHINGTON** — Nithin Tumma captains his high school's robotics team and plays tennis. But it's his work to understand the wily ways of cancer that has made him a champion. For figuring out how a protein helps cancer evolve and hide from the body's immune system, Tumma, 17, won first place in the 2012 Intel Science Talent Search. Tumma, of Fort Gratiot, Mich., received a \$100,000 award from the Intel Foundation at a black-tie gala held March 13 in Washington, D.C.

The event honored this year's 40 finalists, who distinguished themselves from more than 1,800 entries. The budding scientists hailed from 16 states and split \$630,000 in awards. The Intel Science Talent Search has been administered by Society for Science & the Public, which publishes *Science News*, since 1942.

"There are 40 individuals here who prove we still have the capability in this country to cultivate the next generation of innovators, thinkers, scientists and entrepreneurs," Intel President and CEO Paul Otellini told the students at the gala. "I'm keenly looking forward to watching you make wonderful things happen in the coming years."

Second place went to Andrey Sushko, 17, of Richland, Wash., who got a \$75,000 award. He created a tiny motor, only 7 millimeters across, powered by the surface tension of water. A coating of water-repellent material made this unusual alternative form of energy possible.

Mimi Yen, 17, of Brooklyn, N.Y., won third place and \$50,000 for identifying a gene that causes some worms to behave strangely. Males with a mutant form of



Intel President and CEO Paul Otellini (right) congratulates the top three finalists of the 2012 Intel Science Talent Search (from left): second-place winner Andrey Sushko, first-place winner Nithin Tumma and third-place winner Mimi Yen.

this gene attach globs of mucus to each other's orifices, a behavior that's usually reserved for impregnating the hermaphrodites of the species.

Fourth place and \$40,000 went to David Ding, 18, of Albany, Calif., who studied a branch of mathematics called Cherednik algebras. Benjamin Van Doren, 18, of White Plains, N.Y., won fifth place and a \$30,000 award for showing that birds migrating in autumn get their bearings during the morning and tend to fly into the wind. The sixth place award of \$25,000 went to Neel Patel, 17, of Geneva, Fla., for a device that uses sounds instead of pictures to convey information.

Coming in seventh was Anirudh Prabhu, 17, of West Lafayette, Ind., who received \$25,000 for demonstrating that odd perfect numbers, which equal the sum of every number they can be cleanly divided by, have a lower limit.

Eighth through 10th places, which each come with a \$20,000 award, went to Clara Fannjiang, 17, of Davis, Calif., for her work on creating images of celestial bodies that give off radio waves; Alissa Zhang, 17, of Saratoga, Calif., who explored three different ways to monitor blood glucose levels using light instead of needles; and Jordan Cotler, 17, of Northbrook, Ill., who developed a new

way to send encrypted messages using quantum mechanics and Einstein's theory of special relativity.

The other 30 finalists will each receive \$7,500. All of the competitors have now joined an exclusive club of Science Talent Search alumni that includes seven Nobel laureates, four National Medal of Science winners, 11 MacArthur Fellows and physicist Brian Greene, who visited with students at a dinner on March 9.

"This is one of the most interesting groups of people I have ever met," said Marian Bechtel, 17, of Lancaster, Pa. "Only at a science fair do you get total strangers to bond within seconds about quantum mechanics and multivariable calculus." Bechtel was chosen by this year's finalists for the Glenn T. Seaborg award, named for the late Nobel Prize winner and longtime chairman of Society for Science & the Public's board of trustees.

Elizabeth Marincola, president of Society for Science & the Public and publisher of *Science News*, reminded the teens of the value of bringing a scientific mindset to all their endeavors. "My hope," she said, "is that each of you will look up, reach out and always use your science as a vehicle for good in this world." 📖

## Earth

“When we have a dramatic reduction in sea ice, we end up with more snow.” — JIPING LIU

## Fault's twists may raise risk

San Andreas geometry could dictate future temblors

By Devin Powell

California's southern San Andreas Fault isn't vertical in most places, a new study finds. Instead, it twists in opposite directions along its length, meaning a rupture might shake some places harder than current forecasts predict.

“We now have a picture of a propeller-shaped San Andreas,” says Gary Fuis, a geophysicist at the U.S. Geological Survey in Menlo Park, Calif. Fuis and his colleagues report the new findings in the February *Bulletin of the Seismological Society of America*.

This shape could make the San Andreas — parts of which have been locked and building up strain as the Pacific and North American plates try to slide past each other — even more hazardous.

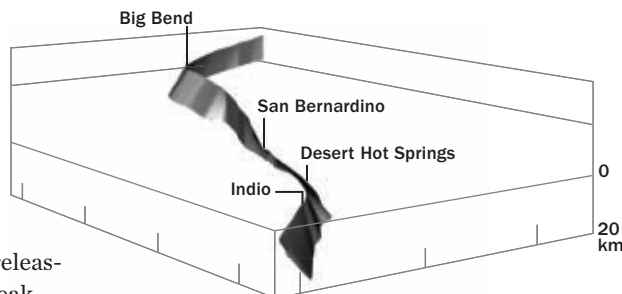
“The dipping geometry may allow for significantly larger earthquakes,” says

Roland Burgmann, a geophysicist at the University of California, Berkeley. Tilted faults pack more surface area into a given depth, potentially releasing more energy when they break.

Scientists took advantage of magnetic rocks that abut parts of the San Andreas to help reveal the fault's orientation. In computer simulations developed by Fuis' team, only a tilted fault could explain patterns in the magnetic fields produced by these rocks.


Measurements of seismic waves created by small quakes and man-made explosions, which travel at different speeds depending on a fault's orientation, helped to fill in the picture in other places, as did data showing differences in gravity's pull along the fault.

In its northern reaches, the fault leans to the southwest. As it snakes to the south, the San Andreas becomes



**This simulation of part of California's San Andreas Fault (gray ribbon) reveals it leaning first to the southwest and then to the northeast as it snakes through the southern part of the state.**

vertical in the Mojave Desert. Closer to Mexico, it dips to the northeast, the scientists found, cutting into Earth's crust at an angle of 37 degrees near San Bernardino, Calif.

Forecasts designed to predict how hard different places will shake during a massive rupture in the southern San Andreas — which hasn't happened since 1857 — might change when these new angles are taken into account. 

## Sea ice decline increases snow

Arctic melting linked to severe Northern Hemisphere winters

By Devin Powell

Global warming may be responsible for the Northern Hemisphere's recent bout of severe winters. As Arctic sea ice melts, it funnels cold air toward the equator and sets the stage for snow.


“When we have a dramatic reduction in sea ice, we end up with more snow,” says climate scientist Jiping Liu of the Georgia Institute of Technology in Atlanta, coauthor of a study published March 13 in the *Proceedings of the National Academy of Sciences*.

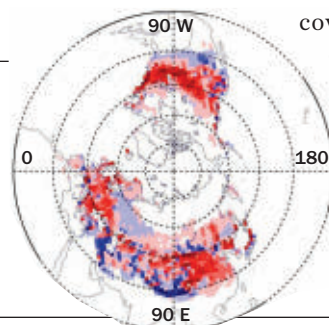
Despite rising global temperatures,

extreme winters have blasted much of the Northern Hemisphere during the last decade. To explain this bitter cold and snow, some scientists have turned to natural climate fluctuations — including El Niño, a periodic warming of the eastern Pacific Ocean thought to portend warmer and drier winter conditions. But since some severe winters coincided with El Niño years, Liu's team looked instead to sea ice in the Arctic, a region that has been warming twice as quickly as the Northern Hemisphere average.

**Loss of Arctic sea ice cover from 1979 to 2010 could help explain more winter snow in parts of the Northern Hemisphere (redder regions).**

Satellite observations show that the amount of autumn sea ice declined by 27.3 percent from 1979 to 2010. Years with less autumn ice tended to be followed by more winter snow in many parts of the Northern Hemisphere. The researchers' computer simulations suggest that losing 1 million square kilometers of ice can increase snowfall by 3 to 12 percent in some places, including parts of the United States, Europe and China.

Liu and his team “confirm a link between sea ice cover and snow cover,” says Ralf Jaeger, a climate scientist at the Alfred Wegener Institute for Polar and Marine Research in Potsdam, Germany. “That is something I always expected but was not able to prove.” 



# Humans



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## Pi master relates secrets of recall

Record holder turned digits to images for use in stories

By Bruce Bower

All it took was intensive practice and a knack for storytelling for a Chinese man to figure out how to have his pi and recite it, too — beyond 60,000 decimals.

The man who set a world's record in 2005 by reciting 67,890 decimals of pi learned to associate number pairs with images of people and objects, scientists report in the June *Cognitive Psychology*. From those images, 23-year-old Chao Lu concocted stories that corresponded

to blocks of 500 to 1,000 numbers, say Yi Hu of East China Normal University in Shanghai and K. Anders Ericsson of Florida State University in Tallahassee.

As Chao Lu delivered a heaping slice of pi to Guinness World Record judges for 24 hours and four minutes, a tale containing more than 60 chapters ran through his head. “That’s up there with the Bible,” Ericsson says.


Several thousand hours of practice over seven years with an efficient memory strategy enabled Chao Lu’s achievement, says psychologist Elizabeth Valentine of Royal Holloway University of London. No special mental or memory abilities were required, in her view, although scientists disagree about the extent to which practice makes perfect.

In the new study, Hu and Ericsson

asked the pi master to describe his thinking as he memorized 100- and 300-digit lists. His recall immediately afterward ranged from 95 percent to 100 percent.

Chao Lu described generating mental images for number pairs from 00 to 99, such as a classroom for 94 and stones for 17. From these cues he created stories.

The ultimate pi guy said that different stories containing common image sequences became confusing once he surpassed 10,000 decimals of pi. He then generated images for combinations of digit pairs. The second pair in a sequence was primary. So 1514 became a key (14) shaped like a parrot (15), whereas 1415 became a parrot with a key in its mouth.

Chao Lu’s memory feat was short-lived. Five years after his pi-rotechnics, he could recall only 39 decimals. 

## Jordanian huts date to Stone Age

Hunter-gatherers built shelters before rise of farming villages

By Bruce Bower

The remains of a couple of nearly 20,000-year-old huts, excavated in a Jordanian desert basin, add to evidence that hunter-gatherers built long-term dwellings 10,000 years before farming villages debuted in the Middle East.

These discoveries come from a period of social transition, when mobile hunter-gatherers hunkered down for months at a time in spots with rivers, lakes and plentiful game, say archaeologist Lisa Maher of the University of California, Berkeley and her colleagues. Discoveries in and around hut remnants at a Stone Age site called Kharaneh IV include hearths, animal bones, caches of pierced seashells and other apparently ritual items, Maher’s team reports online February 15 in *PLoS ONE*.

Graves containing human skeletons



**Remains of almost 20,000-year-old huts (dotted lines) suggest that Middle Eastern hunter-gatherers built long-term dwellings 10,000 years before farming villages appeared.**


were previously excavated beneath what have now been identified as hut floors covered by burned wood and shrubs that once served as walls.

Maher expects evidence of additional four- to five-person huts to turn up at the site, about the size of four U.S. football fields. Over a millennium, groups totaling between 50 and 100 people spent about

half of each year at Kharaneh IV, she says.

“This type of attachment to one place by ancient hunter-gatherers may have been similar to early farmers’ perceptions of their villages,” Maher says.

Ancient huts at Kharaneh IV join a handful of other Stone Age hunter-gatherer structures excavated in the Middle East. Remains of six brushwood huts at Israel’s Ohalo II site, along the shore of the Sea of Galilee, date to as early as 23,000 years ago. Those ancient huts were probably occupied year-round, based on plant and animal finds at that site, says Harvard archaeologist Ofer Bar-Yosef. In his view, those huts — but not the Kharaneh IV huts — were precursors of 14,500-year-old oval structures with stone foundations built at several Middle Eastern sites by the Natufians, the first foraging society known to inhabit permanent settlements.

New Kharaneh IV finds show that, by 20,000 years ago, “perishable brush huts were common from the lush Sea of Galilee basin into now-arid plains to the east,” says archaeologist Dani Nadel of the University of Haifa in Israel, who directs Ohalo II excavations. 



## Matter &amp; Energy

2,170,000  
atmospheresPressure where  
a new hydrogen  
phase was found27°  
CelsiusTemperature at  
which new phase  
was created

## Erase a memory, use some energy

### Lab experiment confirms link between information and heat

By Alexandra Witze

Anyone who has ever tried to forget a bad night knows that erasing a memory takes work. Physicists have now shown this is literally true, by measuring the heat released when a single bit of information is deleted.

The discovery confirms a 1961 prediction by the late IBM physicist Rolf Landauer. It links information and heat flow in ways that keep the universe from breaking the second law of thermodynamics. Elaborations on Landauer's idea may also prove useful in building miniature computers that don't overheat.

"Here you have two quantities which seem to have nothing to do with each other, at least at first sight, and Landauer tells you that they are interconnected," says physicist Eric Lutz of the Free University Berlin. "That's a big deal."

Lutz, who led the new work while at the University of Augsburg in Germany, and his colleagues describe the findings in the March 8 *Nature*.

Landauer calculated that erasing a bit of information always releases at least a tiny amount of heat. At room temperature, that minimum heat loss is about 3 billionths of a trillionth of a joule.

To measure that number, Lutz went to the laboratory of Sergio Ciliberto at the French National Center for Scientific Research in Lyon. There the scientists created a one-bit memory with a floating silica bead and a double well, where the bead could rest in one well (representing a 0) or the other (1). By lowering the barrier between the wells and tilting them, the researchers could coax the bead to jump from one well to the other. They could also erase its memory by resetting it to state 1, regardless of which state it started out in.

Next the scientists carefully measured the speed at which the bead moved from

one well to the other, which allowed them to calculate the heat given off by that shift. "This is the first experiment showing that this tiny limit does exist," says Lutz.

Understanding heat's release by erasure can help scientists anticipate problems with overheating in ever-smaller computing devices. More fundamentally, Landauer's principle helps explain the thermodynamics law requiring entropy, or disorder, to always increase over time.

A 19th century thought experiment by Scottish physicist James Clerk Maxwell envisioned a demon sorting cold and hot molecules into two chambers. By separating hot (fast) molecules from cold (slow) ones, such a demon could convert information about molecular speeds into energy, seemingly decreasing entropy.

## A new phase for hydrogen found

### High-pressure studies reveal sign of possible fourth form

By Alexandra Witze

Squeezing hydrogen at extreme pressures changes it into a mix of honeycombed atoms layered with free-floating molecules — the first new phase of the element found in decades.

If confirmed, the discovery will be only the fourth known phase of hydrogen.

"I think we have pretty bulletproof evidence that there is a new phase," says Eugene Gregoryanz of the University of Edinburgh, leader of the team that will report the work in *Physical Review Letters*.

Gregoryanz and colleagues squished room temperature hydrogen to some of the highest pressures ever. At around 2 million times the pressure of Earth's atmosphere, the scientists saw distinct

But Landauer's principle requires "Maxwell's demon" to use up energy whenever discarding information about the molecules already sorted. Without an infinite memory, the demon would have to erase enough information (using energy each time) to keep the law intact.

"When you erase that memory, bring it back to that original state, all the accounts get squared," says John Bechhoefer, a physicist at Simon Fraser University in Burnaby, Canada.


Bechhoefer has been using a different particle trap to demonstrate Landauer's principle; he thinks he may be close. "So far we've observed the basic effect," he says. His team is still working out some small discrepancies, though.

With the verification of Landauer's principle, the quest now turns to exploring it in other realms, such as the quantum world. "I hope this is the first of a long series of experiments," Lutz says. ■

changes in some properties, such as how light scatters into different wavelengths when shined through the hydrogen.

The change is dramatic enough to reflect some underlying fundamental shift, Gregoryanz says, representing the long-sought "phase IV" of hydrogen.

Analysis of the scattered light suggests phase IV contains both hydrogen molecules and free atoms. Chris Pickard, a theorist at University College London, says it is probably arranged in hexagonal sheets of atoms separated by unbound molecules. In a 2007 paper, Pickard and a colleague calculated that such a structure might exist for hydrogen at these pressures. The Edinburgh experiments are "exciting certainly for me," Pickard says, since they confirm his prediction.

But the new finding will probably attract close scrutiny. Last fall, scientists in Germany reported turning hydrogen into a metal at similar pressures and temperatures but have faced a flurry of criticism over how they interpreted their findings (*SN: 12/17/11, p. 9*). 



## Some corals live on after a breakup

After rough waters shatter embryos, cells grow as clones

By Susan Milius

Choppy waters and even mellow surf can knock drifting coral embryos to bits. But it takes more than shattering to kill these resilient young animals. The fragments turn out to have the power to keep on growing as clones.

Many corals start life adrift in open water, forming when eggs and sperm released by settled parents float to the sea surface and mingle. In the central Great Barrier Reef, the new embryos often face at least somewhat rough water on about half of the spawning nights. Lab tests mimicking these conditions split apart 45 percent of coral embryos just starting to divide, says Andrew Negri with the Australian Institute of Marine Science in Townsville. Yet the remnants contained plenty of survivors that remained small but matured normally, Negri and institute colleague Andrew Heyward of Perth report in the March 2 *Science*.

“A pretty cool observation,” says coral biologist Nancy Knowlton of the Smithsonian Institution’s National Museum of Natural History in Washington, D.C. “What makes it neat is not that the developing embryos can clone per se, but they are likely to do it under natural circumstances.”

Undamaged, older larvae of sea stars and brittle stars (as well as other echinoderms) sometimes clone themselves. In these animals, however, the very youngest larvae get some protection from their environment. Right after fertilization, a membrane forms around the echinoderm embryo as cells start to divide. Corals, in contrast, start naked.

Many coral species release their buoyant bundles of sex cells during highly



synchronized mass spawnings. “It looks like upside-down, pink rain,” Negri says.

To test very young corals under realistic conditions, Negri and his colleagues focused on moderate winds greater than 11 knots (12.7 miles per hour), which nudge water into waves at least 30 centi-

meters high. The researchers poured young embryos from that height — twice. Studying the survivors, researchers found a mix of embryo sizes as smaller remnants kept on dividing. Like their intact brethren, if a smidge littler, these cloned bits developed into brisk swimmers and then selected places to settle down for some reef-building adulthood.

Finding normal development despite disaster opens up a new range for experiments, says Negri. Coral versions of human twin studies might compare some environmental effects on genetically identical individuals, or environmental tests might determine the vulnerabilities of youngsters of different sizes. The discovery also raises evolutionary questions about the possible advantages of cloning for sea-tossed corals. After roughly 240 million years, the coral lineages certainly have had time to evolve a protective membrane, he says. ■

## Ray-finned fish can regrow limbs

Vertebrate ancestors may have had similar capability

By Susan Milius

The discovery that a long, skinny fish can regrow a fin in a matter of weeks suggests that ancient vertebrates had considerable regenerative powers.

Two species of bichir from Africa can regrow amputated bony fins with remarkable accuracy, says developmental biologist Luis Covarrubias of the National Autonomous University of Mexico in Cuernavaca. Among the most ancient of the living lineages of ray-finned fishes, the *Polypterus* bichirs share traits such as paired lungs with both modern amphibians and very early four-limbed vertebrates.

The venerable fishes’ powers suggest that early vertebrates shared substantial

limb regeneration capability during the ancient evolutionary transition from fins to feet, Covarrubias and his colleagues contend in the March 6 *Proceedings of the National Academy of Sciences*. Those first steps toward life on land took place at least 375 million years ago.

Biologists would love to understand why regeneration appears to have faded away in the course of evolution, or how it arose in the first place. “The real question is not why regeneration was lost but why it was ‘won,’” Covarrubias says.

Only select groups of vertebrates living today can to varying degrees replace a lost limb, including axolotls and some other amphibians and some other fishes.

“Zebrafish are great at fin regeneration,” says Ken Poss of Duke University, who studies them. Their fins contain mostly ray bones that form the way fish scales do. Bichir fins, however, grow considerable fleshy tissue as well as bones of the type in the internal skeleton. Their comeback fins may prove useful for comparing regeneration systems, Poss says.

"The real question is not why regeneration was lost but why it was 'won.'" —LUIS COVARRUBIAS

## Sawfishes don't live up to name

Spiked snouts used mostly for sensing, slashing prey

By Susan Milius

Sawfishes use their spiked snouts as a combination sword, antenna and serving spoon — but not much at all as a saw, scientists have found.

Figuring out how the fishes use their whopper snouts has been tricky, says Stephen Kajiura of Florida Atlantic University in Boca Raton. Most of these rare and endangered relatives of sharks and rays live in murky waters or have been trained to captive-feeding regimens in big aquarium displays.

But Barbara Wueringer of the University of Western Australia in Crawley got a rare chance for a more natural look at a freshwater sawfish, *Pristis microdon*, in tanks in Australia just after the fish were

collected from the wild. "Now we actually have some empirical evidence" for what the saw does, Kajiura says.

What didn't show up was any kind of sawing motion. Instead the fish were more likely to slash their saws in sword-like swipes that impaled prey dangled in open water, the researchers report in the March 6 *Current Biology*. The saw lets its owner fling or whack prey to the bottom, pin it and then, like a cook arranging food on a plate, manipulate the catch so it can be swallowed headfirst.


The ability to whack prey from a distance gives sawfishes an advantage over predators that have to get their mouths over something before nailing it, notes fish ecologist Michael J. Miller of the University of Tokyo's Atmosphere and Ocean Research Institute in Chiba, Japan.

The saw can sense as well as snag, picking up the displacement of moving water and the weak electric fields that give away the position of prey. Wueringer set up metal rods creating electric fields



**Sawfishes use their snouts to slash at prey and to sense moving water and the weak electric fields that betray the locations of prey.**

in the water and found that setting off an electric signal with no prey fish attached still prompted the sawfish to try to bite.

This experiment clarifies that just sensing an electric field is enough to trigger a sawfish attack, says neuroscientist Carl D. Hopkins of Cornell University, who has studied the electric world of fishes. "It really is an amazing story." 

## Plant grown from an ancient fruit

Squirrel's stash spent 30 millennia in Siberia's permafrost

By Devin Powell

A flower that last bloomed while mammoths walked the Earth has been reborn, regenerated from a piece of fruit frozen in Siberian permafrost.

It's the oldest flowering plant ever grown from preserved tissue, scientists report in the March 6 *Proceedings of the National Academy of Sciences*. David Gilichinsky, who led the team at the Russian Academy of Sciences' research institute in Pushchino, died just before the paper was released.

The fruit, radiocarbon-dated to about 31,800 years

ago, came from a recently excavated cache of provisions that a squirrel stuffed into a burrow 38 meters underground. Tissue scraped from the fruit and bathed in nutrients grew into fertile plants with healthy seeds that sprouted in soil.

"It is remarkable that under deep freeze, fruit tissues ... can remain viable for such a long time," says UCLA biologist Jane Shen-Miller. "This is like regenerating a dinosaur from tissues of



**Scientists grew this flowering plant from bits of a fruit preserved in Siberian permafrost for more than 31,000 years.**

an ancient egg."

At first the reconstituted plants, identified as the extant species *Silene stenophylla*, looked exactly like their modern relatives. But when flowers appeared, the white petals of the reborn plants were narrower and less separated than those of the modern species.

The hardiness of an ancient plant's frozen tissue is good news for Norway's Svalbard Global Seed Vault and other projects freezing seeds to safeguard against the extinction of modern plants. "No one knows how long [frozen seeds] are viable for, but freezing is basically the format for all seed conservation attempts nowadays," says Sarah Sallon, director of the Louis L. Borick Natural Medicine Research Center at the Hadassah Medical Organization in Jerusalem. Several years ago she helped grow a date palm from a 2,000-year-old seed unearthed in Israel (*SN*: 7/5/08, p. 13). 



# Body & Brain



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## Taste of fructose revs metabolism

Pancreas cells pump more insulin in response to sugar

By Rachel Ehrenberg

Scientists have a greater appreciation of fructose's full flavor. The sugar, which is found predominantly in fruit, honey and high-fructose corn syrup, tickles taste cells found on the pancreas. The interaction can crank up the body's secretion of insulin, which may be a concern for people prone to diabetes, researchers report in the Feb. 21 *Proceedings of the National Academy of Sciences*.

Experiments with mouse and human cells and with living mice reveal that fructose activates the same proteins in pancreatic cells that the tongue uses to taste sweets. When these cells are exposed to glucose — the sugar that is the body's main source of energy — and then get a hit of fructose, the cells pump out more insulin than with glucose alone, the researchers found.

"This is really beautiful mechanistic work," says nutrition and metabolism expert Kathleen Melanson of the University of Rhode Island in Kingston. The research adds to a growing body of evidence demonstrating that taste cells are not just the province of the tongue, she adds.

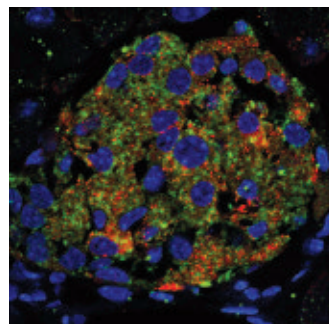
Insulin is a master regulator, keeping the right amount of glucose in the blood. So it makes sense that fructose alone doesn't trigger insulin secretion, says cell biologist and physiologist Björn Tyrberg of Sanford-Burnham Medical Research Institute in Orlando, Fla. If fructose triggered insulin release on its own, glucose levels in the blood could get dangerously low. "The system seems to be elegantly made to keep a balance," says Tyrberg, who led the new work.

Fructose has recently taken some heat for whacking metabolism out of balance.

One issue is where it enters the metabolic assembly line: Most sugars join the process at a point where a supervisory enzyme can control the flow of goods. But fructose comes in farther down, where

it can lead to an overproduction of fat. And because fructose on its own doesn't stimulate the same insulin response that glucose does, the hormone isn't doing the other things it usually does, like moderating appetite.

The sugar content of high-fructose corn syrup is typically 55 percent fructose; the rest is glucose. Molecules of sucrose, or table sugar, consist of



**Insulin-producing pancreatic cells (red) have surface proteins (green) that can taste fructose, which boosts insulin production in some instances.**

a fructose linked to a glucose.

In general, people should keep an eye on their intake of all sugars, Melanson says. The quantities of fructose found in a spoonful of honey or an apple aren't of concern, "but our metabolic pathways aren't designed to handle Big Gulps." ■

## Sleeplessness agitates the brain

Boost in electrical activity may explain why we need shut-eye

By Laura Sanders

Sleep deprivation makes the brain groggy, but as waking hours mount nerve cells actually grow increasingly jumpy, a new study shows.

This amped-up state may explain why seizures and hallucinations can accompany all-nighters. More generally, the results help clarify what goes wrong in a brain deprived of shut-eye.

"It's an important finding," says neuroscientist Christopher Colwell of UCLA. "Sleep deprivation is an area of huge interest because most of us do not get enough sleep."

By subjecting six people to a night of sleep deprivation and measuring their brain responses, Marcello Massimini of the University of Milan and colleagues found that people's brains become more reactive as waking hours accumulate.

To look for signs of altered brain function, the team delivered a jolt of magnetic current to the participants' skulls that kicked off an electrical response in the nerve cells. Electrodes recorded the strength of this electrical response in the frontal cortex, a brain region that's involved in making executive decisions.

After a night of sleep deprivation, participants' electrical responses were

stronger than they were the previous day, the scientists report online February 7 in *Cerebral Cortex*. This overreaction disappeared after a night's sleep.

The results offer support for a theory of why people sleep: During waking hours, the brain accumulates connections between nerve cells as new things are learned. Sleep then sweeps the brain of extraneous clutter, leaving behind only the most important connections.

Enhanced excitability in the brain may explain why sleep deprivation can trigger seizures.

The new results also have an intriguing link to depression. For some people, sleep deprivation can quickly reverse symptoms of depression, an effect that may be due to the brain's boosted excitability, Massimini says.

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# furryfriendsforever

Humans aren't the only animals who benefit from having someone to count on

By Susan Gaidos



A good friend will make you laugh, defend you in an argument, cheer you on when you're doing well and cheer you up when you're feeling sad. Best buds can be good for your health, too. Maintaining close relationships means less stress and a longer life.

And you don't even have to be human.

Just as with people, animals of other sorts can benefit from having a BFF. New studies show that animals with someone they can count on — to get them out of a scrape, share food or deliver a kind gesture — are more likely to reproduce and are better at fighting disease.

Such findings suggest that the need for a trusted, dependable companion goes way back in time. If so, friendship may confer evolutionary advantages.

"It's beginning to look like a strong,

evolutionarily ancient phenomenon that's shared by many social species," says Dorothy Cheney, a biologist at the University of Pennsylvania in Philadelphia who has studied primate relationships for four decades.

Many of the behaviors that hint at animal friendships have been observed in the field. Studies of monkeys, horses and chimpanzees reveal that individuals are selective about whom they spend time with or feed near. Some male chimpanzees are more likely to hang out together, groom each other, share meat and accompany one another on hunts or border patrols. Female baboons will groom some peers more than others, and are more likely to come to the aid of someone who recently groomed them.

Further studies find that female baboons closely bonded to a few other

females have more surviving offspring and often live longer. Similar results have been found in elephants, dolphins and rodents, as well as in horses and chimps.

With these friendly findings in mind, researchers are working to tie together animals' behavior and physiological responses over time in hopes of better understanding the benefits of having a buddy. Recent work shows, for example, that a social-bonding hormone makes monkeys more generous with others. Other studies are turning to genes to try to understand why some animals win out when it comes to popularity.

Finding all the factors that promote friendship might ultimately provide clues to the origin and evolution of traits that have allowed humans to form close social ties, scientists say.



"These animals know so much about each other's relationships, and it's conceivable that this type of social cognition is very important in being able to establish and maintain bonds," Cheney says. "Which would suggest that there is real evolutionary advantage to, in a sense, being a social wire and being highly motivated to know about each other."

## Got your back

Scientists have long known that animals form bonds. Primates and horses that spend more time in close proximity will generally be friendlier and less aggressive with each other. Chimps and elephants share food, comfort the injured and appear to grieve at the deaths of peers.

Still, for decades the prevailing view was that most interactions occur between closely related individuals. Bonds formed between unrelated animals were supposedly only transient, designed to gain some immediate benefit. Scientists now know that isn't true. Studies of dolphins, horses, lions and chimpanzees show that even unrelated animals often form stable bonds lasting for years. And evidence indicates that one animal may do something costly to help a nonrelative, while receiving a benefit later.

Such exchanges, known as contingent cooperation, operate daily in human relationships, says biologist Liza Moscovice of Binghamton University in New York. "You might buy coffee for your coworkers, but you expect that at some point they're going to buy coffee for you too," she says.

Though it remains unclear whether nonhuman animals keep track of all the favors they give and receive, experiments suggest that contingent cooperation plays a big role in their relationships. In 2010, Moscovice and Cheney, along with others, showed that a shared positive experience can increase the odds that one individual will help the other at another time.

Among the female baboons studied, the primary way of bonding is through grooming. Grooming entails sitting with

another and methodically cleaning her fur, a task that provides an immediate benefit to the animal being groomed. "It's like getting a hug," Moscovice says.

Grooming has an up-front cost in terms of the time taken away from foraging or resting. But donors might be able to rely on a grooming partner for support if caught in the middle of a fight soon after the exchange, previous studies have shown. Moscovice says having an extra ally or two can be a huge benefit in baboon society, where dominance hierarchies produce inequalities in access to food and resources, and threats and tiffs break out frequently.

Friendship is especially beneficial for animals without relatives to help them out. Among baboons, the strongest social bonds are found between mothers and daughters, followed by sisters and other female relatives, including aunts, nieces and cousins.

In strictly evolutionary terms, relatives cooperate because it promotes survival of their shared genetic material. That genetic link may explain why when screaming for help, a female baboon can rely on her family members for support.

"Relatives generally help regardless of whether they've groomed or interacted recently," Moscovice says. "In this case, it's not contingent cooperation because relatives basically help across the board."

To see if good deeds are reciprocated among nonrelatives, even after a considerable amount of time has elapsed, Moscovice and her colleagues set up an experiment. The scientists recorded

the vocalizations, or grunts, of female baboons, often delivered to challenge another individual and to recruit aid. After collecting a library of grunts from many individuals, the researchers waited until two unrelated females had groomed and then separated. The team then played the groomer's "help" call to the other baboon and recorded her response. A control experiment, using the same recordings and same groups of animals, played a female's "help" call to the other female following an aggressive exchange. The scientists also tested a small number of relatives to compare the outcomes.

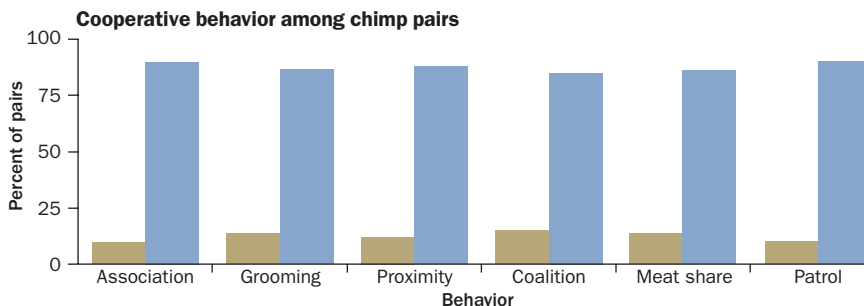
The findings, published in 2010 in the *Proceedings of the National Academy of Sciences*, showed that females who had recently received grooming from a non-relative almost always moved toward the speaker, as if to seek out the grooming partner in need of help. Help calls played after an aggressive encounter did not elicit such interest.

In contrast, relatives' decisions about helping each other did not relate to the recent encounters. The findings suggest that female baboons take into account past interactions when choosing to support an unrelated individual.

Moscovice says it makes sense that the evolution of friendship might be based on contingent exchanges of aid, while this would not be necessary for the evolution of cooperation among relatives.

Similar observations have been made in chimps, where an unrelated bystander will step up and support another, if the chimp in need of help is a

**Hobnobbing chimps** Male chimpanzee pairs that engaged in friendly behavior more often than expected by chance were more likely to be distantly related (blue) than closely related (tan). The findings suggest chimps are motivated to cooperate with nonrelatives, not just close kin.



SOURCE: K.E. LANGRABER ET AL/PNAS 2007

friend. John Mitani, a behavioral ecologist who has been observing chimpanzees in Uganda's Kibale National Park since the mid-1990s, says his studies show general patterns in who sides with whom.

"When male chimps form coalitions, they take sides, but they don't do so randomly," says Mitani, of the University of Michigan in Ann Arbor. "They take sides with individuals who will later turn around and help them."

Such alliances are formed around the idea "you scratch my back and I'll scratch yours," rather than kinship, he says. In 2009, Mitani showed that 22 of 28 male chimps in a single group formed their longest, closest bond with an unrelated animal, with some friendships lasting a decade or more.

Zoologist Elissa Cameron of the University of Pretoria in South Africa has found similar behavior among wild, unrelated female horses in New Zealand: The mares form long-term alliances, in part to keep aggressive stallions at bay.

The fact that an animal would risk injury on behalf of another, even though they are not related, suggests that these friendships are extremely important to the animals, Moscivice says.

In a recent book, *Friendship: Development, Ecology, and Evolution of a Relationship*, anthropologist Daniel Hruschka of Arizona State University in Tempe argues that human friendships offer an evolutionary advantage because people can't always get what they need from their kin.

## Whiff of kindness

But people, and perhaps other animals, make friends for another reason too: Because it feels good. Sharing time with a friend is not only relaxing, but it can also have a positive effect on health and well-being.

Though it's difficult to assess exactly why one critter is helping another, scientists are finding ways to sort this out.

One way to "interview" an animal is by looking at its hormonal profile, to see what is upsetting and what causes delight.

Catherine Crockford of the University of St. Andrews in Scotland, who studies chimpanzees in Uganda's Budongo Forest, is looking for hormonal links related to stress or social bonding in the chimps as they engage in various behaviors with others. Moscivice is also using this approach to study wild female bonobos. By looking at how levels of certain hormones, such as oxytocin, change as the animals go about their routine business, the researchers hope to pinpoint interactions that promote social bonds.

Oxytocin is best known for its role in childbirth and breast-feeding and

its promotion of mother-infant attachment. But oxytocin is also secreted during other forms of pleasant touch, such as massage or sex, and has been shown to stimulate bonding in animals such as prairie voles. Though scientists have yet to figure out how oxytocin fosters bonding, studies show that it promotes feelings of relaxation and well-being, and serves to enhance behaviors that reflect trust and generosity in humans.

In a series of experiments, Duke University neuroscientist Michael Platt

showed that oxytocin may promote generosity in monkeys as well. Platt's team trained a group of rhesus macaques to associate certain colored shapes on a computer screen with either a reward to self, a reward to another monkey or no reward at all. Last year, the scientists showed that, when given a choice between rewarding someone else or giving no reward at all, monkeys choose to reward the other more frequently if the recipient was seen on a day-to-day basis.

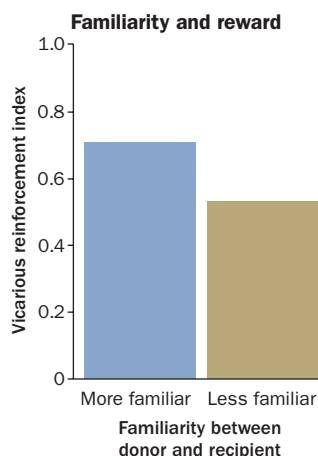
In an experiment reported in January in *Proceedings of the National Academy of Sciences*, the scientists found that a male monkey given a whiff of oxytocin became increasingly generous with his rewards to others, even if he wasn't chummy with them. In both experiments, the scientists also tracked the monkeys' gaze, to see where their attention was focused. Reward-giving monkeys spent more time gazing at the face of the recipient immediately after sending the juice reward. Platt says the findings suggest that observing a monkey receiving a reward may bring some kind of vicarious reward back to the giver.

The scientists now plan to expand their studies, looking at the neural circuits involved in reward-related brain activity in the animals. Such work may help reveal whether giving another monkey a reward creates a positive experience similar to receiving one. If so, the findings may point to neural wiring that promotes social bonding and altruistic behavior.

## Facebook for animals

Vicarious rewards aside, some individuals are natural social networkers, while others are not. In her book *Baboon Metaphysics*, Cheney relays the story of Ruby, a young, low-ranking but gregarious baboon who lost all her kin in a leopard attack. Because kin are the lifeblood of social support in female baboon society, a low-ranker such as Ruby might be left with little access to food and other resources.

Despite lacking the skill to set up a Twitter account, likable Ruby managed to build a network of followers by taking advantage of her social opportunities.



## Rewarding a friend

In an experimental setup, rhesus macaques were more likely to deliver a juice reward to a second monkey if the two saw each other frequently. A higher vicarious reinforcement index indicates more rewards.

SOURCE: STEVE CHANG

She spent hours grooming one particular high-ranking baboon, Sylvia, and managed to climb up the hierarchical ladder, gaining access to the best food and the most desirable resting places.

Ruby's story illustrates how factors such as personality or temperament may play into animals' ability to form relationships, Cheney says. Temperament may also influence ability or willingness to reconcile after a disruption or fight. Cheney says that when two female baboons scrap over some bits of chow, the aggressor will often walk up to the opponent afterward to hug her or offer a friendly grunt. Studies of stress-related hormones conducted by Cheney's group showed that such gestures helped the opponent relax.

Platt and his group, who study animals in the wild as well as in the lab, recently initiated a large-scale study to look at temperament, as well as genetic and other individual characteristics, in a population of rhesus macaques on an island just off the coast of Puerto Rico. The thousand or so monkeys, living in a handful of groups, have free rein over the island. Platt's team is collecting blood samples from the animals to look at natural variations in hormone levels, including oxytocin. By extracting DNA, the researchers will create genetic profiles of various individuals and collect information on genes known to be relevant to social behavior in humans.

Combining the genetic information with observations in the field, the researchers plan to measure the "sociability" of different animals. To do so,

## Bonding by animal

Baboons, chimps and other primates have a reputation for being buddy-buddy, but evidence for social awareness shows up in a range of other species.



**African elephants** maintain mother-daughter and sisterly bonds for decades. Some research suggests that when kin aren't around, relationships with unrelated females suffice.



**Dolphins** form alliances for mating. Males who cooperate for access to a female also rub each other with their pectoral fins and swim and surface in synchrony.



**Hyenas** can recognize third-party relationships: Research shows spotted hyenas are more likely to attack a rival's relative after a fight than during agreeable times.

the team drew up a list of 50 different behaviors to observe, including affable gestures such as grooming or sitting next to one another, and hostile moves such as biting, scratching or chasing.

Platt says the study could reveal how specific behaviors bind monkeys in a social network. "It's a sort of Facebook for monkeys," he says. "We're looking at who are the popular monkeys, who shares friends with whom."

## Connections count

Studying the biological mechanisms that come into play as animals cooperate, says Moscovice, may help explain how the capacity for friendship and social behavior arose and endures among humans.

"Contingent cooperation is the first step, I would say, because if you don't start to take risks to help others, how do you ever get to a level of close affiliation and unconditional support?" she says.

Crockford agrees that cooperation is crucial both for making and maintaining a close bond. "People are always looking for the things that essentially make life feel good, and I think this sort of ties back to the cooperation," she says.

All together, findings from recent studies suggest that the desire to have a trusted companion is a deep need in mammals, humans included, Crockford says. "Knowing this about mammals is sort of a reminder to us, that we can eat as much good food as we want or have as much money as we want, but if we don't have at least one or two close relationships that we can depend on, life is going to be more difficult for us." ■

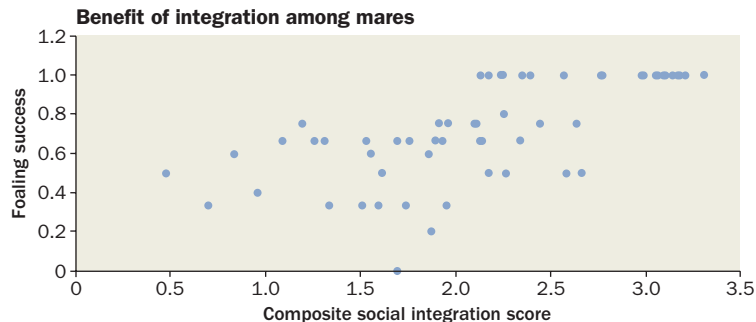
## Explore more

■ Robert Seyfarth and Dorothy Cheney. "The evolutionary origins of friendship." *Annual Review of Psychology*. January 2012.

**Friends and foaling** Among 56 unrelated New Zealand horses studied over four years, mares that spent more time with other mares and initiated more grooming tended to have more foals. Higher levels of this form of "social integration" also decreased harassment from male horses. The researchers conclude that friendship can have direct benefits, even outside primate groups.



SOURCE: E.Z. CAMERON ET AL/PNAS 2009





**M**eeting the Almighty takes hallucinatory talent and training. And Hannah, a member of the Vineyard Christian Fellowship, has got it down.

She talks with God every day. Sometimes she imagines that God is walking beside her, although no vision of the Almighty appears. On other occasions, Hannah goes on what she calls “date nights” with God. She buys a sandwich, finds a secluded bench and imagines that the big guy is sitting next to her. In both cases, imagination occasionally gives way to a sense of truly hearing God speak.

During these divine experiences, Hannah gets in touch with her unconscious mind, an undercurrent of thoughts

and feelings she regards not as her own but as those of the Holy Spirit.

“I recognize that it’s not me, but God inside me, that I’m having a conversation with,” Hannah told Stanford University anthropologist Tanya Luhmann. “Which makes this relationship way more complicated ... trying to imagine some real but not real figure outside of my own self.”

Luhmann spent more than four years interviewing evangelical Christians in Chicago and Palo Alto, Calif., for her 2012 book *When God Talks Back*. Her conversations with Vineyard members, including the young woman given the pseudonym Hannah, are part of an ongoing effort to try to understand how

ordinary people can meet God through spiritual hallucinations.

Researchers studying hallucinations often focus on people with schizophrenia and other psychotic ailments who experience incessant, unwanted and distressing hallucinations. But emotionally stable, well-functioning individuals can have unusual sensory experiences too.

Luhmann’s evidence suggests that this regular-folks brand of hallucinating is much more common than most people think, and understanding such hallucinations could offer new insights into how the mind works. People who effortlessly get caught up in imaginary worlds, nature and music are more likely to have hallucinations, for example. Luhmann

# VISIONS FOR ALL

People who report vivid religious experiences may hold clues to nonpsychotic hallucinations

By Bruce Bower



has also identified ways that, through practice, such hallucinatory abilities can be enhanced.

“Given the right training in how to pay attention to one’s mind, it’s easy to go on a walk with God,” Luhrmann says.

Nonpsychotic individuals do have hallucinations, other researchers agree. But, they argue, anyone who experiences hallucinations more than a few times in a lifetime probably falls on the functional end of a psychotic continuum and could be at risk for future psychosis. If true, the claim may bode ill for one Vineyard member.

## Hallucination nation

Most of the more than 30 evangelical Christians interviewed by Luhrmann recalled one or a few times when they heard God’s voice or had a holy vision. But hallucinatory experiences don’t affect just the religious.

Surveys conducted over the last century find that 10 to 15 percent of U.S. and British adults report having been startled by briefly hearing a voice when alone or seeing something that could not be seen by others. About three-quarters of bereaved adults acknowledge having heard, seen or otherwise sensed their departed partners. People everywhere, including millions of Americans, have waking nightmares in which they lie frozen, eyes wide open, tormented by hallucinations of demons or other evil presences that sit on their chests as breathing becomes difficult (*SN*: 7/9/05, p. 27).

Westerners usually keep these experiences secret for the same reason that Vineyard congregants tend to stay tight-lipped about God talk outside of church — because they know that people who have hallucinations are often assumed to be mentally ill.

Elsewhere in the world, people openly discuss their hallucinatory experiences. In many non-Western cultures, such as Thailand’s Buddhist society, troubled minds are viewed as open to manipulation by ghosts and other forms of invisible, supernatural energy, Luhrmann says. In an upcoming issue of *Religion*

**Hearing voices** A recent study looked at what characteristics of auditory hallucinations were shared and which differed among healthy participants and psychotic patients. Members of both groups hallucinated at least once a month. Scientists are not yet sure whether hallucinations in the two groups should be treated as the same phenomenon.

SOURCE: K. DAALMAN ET AL./J CLIN PSYCHIATRY 2011

Shared characteristics	Differing characteristics
<ul style="list-style-type: none"> <li>■ Perceived location of voices</li> <li>■ Number of voices</li> <li>■ Loudness of voices</li> <li>■ Who the voices belonged to</li> </ul>	<ul style="list-style-type: none"> <li>■ Frequency of the hallucinations</li> <li>■ Negativity of the content</li> <li>■ Control over the hallucinations</li> <li>■ Age at onset</li> </ul>

and *Society*, Stanford anthropologist Julia Cassaniti and Luhrmann report that Thai college students and villagers often report having had waking nightmares, run-ins with ghosts and other supernatural encounters during periods of personal turmoil.

Luhrmann refers to congregants’ vivid encounters as well as other culturally driven hallucinations as sensory overrides, to distinguish them from the psychotic type of experiences.

Sensory overrides depend on a person’s capacity for getting caught up in his or her own imagination, or in nature, music and other worldly objects of interest, Luhrmann proposes. This tendency is called absorption, and she tests for the characteristic using a questionnaire developed in 1974 as a measure of susceptibility to hypnosis.

Luhrmann argues that sensory overrides emerge from healthy brains that reorganize and stitch together external information based on expectations about what’s supposed to be out there. Given a perceptual system that seamlessly fills in the blanks of an uncertain world, those who trust their imaginations or know how to focus deeply on their thoughts and feelings occasionally see or hear things that no one else does.

In an effort to explain how modern people come to know God via sensory overrides, Luhrmann has turned up evidence that absorption forms a mental bridge from the act of praying to seeing or hearing the divine. “Absorption-

related sensations of God’s presence are rare, brief, can be trained and are viewed as reassuring by those who report them,” she says.

In the March 2010 *American Anthropologist*, Luhrmann and her colleagues reported that the way 28 Vineyard members responded to an absorption questionnaire predicted whether they experienced God as a person through prayer. Those who scored high on absorption portrayed God as someone they talked to easily, laughed with, got angry at and who talked back from time to time.

After affirming nearly all 34 absorption questions, one volunteer told Luhrmann, “The man who created this scale lived inside my head.”

Not so for congregants with low absorption scores, who didn’t like praying because God never seemed to speak to them.

A prayer-challenged participant wrote next to one absorption item, “There are such people?”

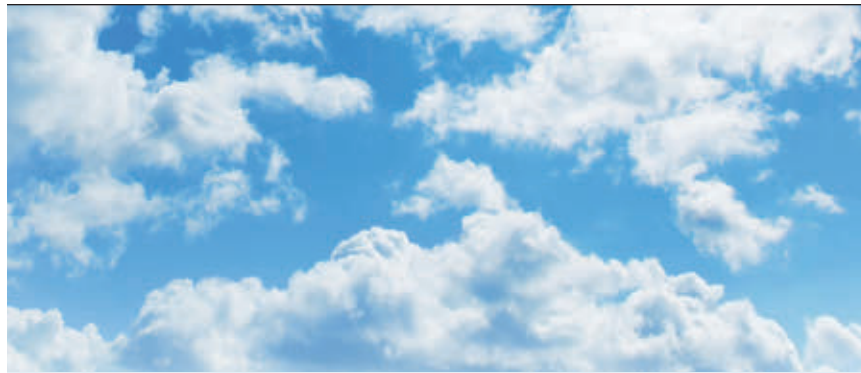
Crucially, the volunteers who endorsed at least half the absorption questions were far more likely than the others to report sensory overrides, such as hearing

God’s voice, feeling the Almighty’s touch or glimpsing an angel’s wing.

“The capacity to treat what the mind imagines as more real than the world one knows lies at the heart of experiencing God,” Luhrmann says. An aptitude for absorption can also influence experiences outside of startling religious shout-outs. It enables, for instance,

**10 percent**  
Portion of people in the West thought to hallucinate at least once in their life

**25 percent**  
Portion of hallucinators in one study who met the criteria for psychosis



**Caught up in the mind** The Tellegen Absorption Scale was described by its conceivers as a measure of a person's "openness to absorbing and self-altering experiences." In its original form, the test had 34 true/false questions (some below); today, researchers sometimes allow participants to reply on a four- or five-point scale. Participants are instructed not to consider experiences they have had under the influence of alcohol or drugs.

- If I wish, I can imagine that my body is so heavy that I could not move it if I wanted to.
- I can sometimes recollect certain past experiences in my life with such clarity and vividness that it is like I am living them again or almost so.
- I like to watch cloud shapes change in the sky.
- If I wish, I can imagine (or daydream) some things so vividly that they hold my attention as a good movie or story does.
- I sometimes "step outside" my usual self and experience an entirely different state of being.
- When listening to organ music or other powerful music, I sometimes feel as if I am being lifted into the air.

SOURCE: T. LUHRMANN ET AL./AMERICAN ANTHROPOLOGIST 2010

temporary escape from one's troubles by reading a book and entering an imaginary world.

### All-access deity

A rare breed of otherwise healthy folks seem to take absorption to the extreme. Luhrmann calls this brand the "Joan of Arc" pattern, a reference to the 15th-century French girl who said that she heard and sometimes saw two saints and the archangel Gabriel every day. These emissaries of God purportedly told Joan to lead the king's army against England and gave her battle strategies — eventually leading to her capture and death.

Luhrmann met one Vineyard member who exhibited this pattern. This calm, well-respected churchgoer with a good job, whom Luhrmann calls Jane, constantly heard God talking to her. Jane said she heard "a little voice" as a child that she couldn't make sense of. The voice fell silent for a while until she joined an evangelical church as a young adult. God then spoke to her often while

she prayed and at other times, providing counsel and encouragement.

Jane probably inherited a genetic propensity for absorption and for unusual sensory experiences that can contribute to schizophrenia in people with other brain and emotional vulnerabilities, Luhrmann suggests. "But that doesn't mean that she is ill."

Luhrmann thinks of schizophrenia as a collection of traits — including disorganized thinking, blunted emotions, impulsiveness and hallucinations — that get stirred into a toxic brew by environmental factors such as harsh and traumatic experiences growing up.

Many psychiatrists suspect that a genetic predisposition, combined with prenatal brain damage and the psychological turmoil of young adulthood, orchestrates schizophrenia.

Given a relatively benign upbringing and a steadfast temperament, hearing God's daily pronouncements made Jane feel good, as well as useful at church. But Jane's case highlights a divide that

exists between Luhrmann and other researchers. While Luhrmann regards the young woman as one of many mentally healthy folks who experience hallucinations, others view Jane as part of an understudied segment of the population consisting of people who function well despite displaying psychotic symptoms capable of flaring into mental illness.

Sensory overrides probably stand apart from psychotic hallucinations, but Jane's hallucinations signal a vulnerability to schizophrenia, says psychiatrist Iris Sommer of University Medical Center Utrecht in the Netherlands. In fact, an unappreciated number of people who work and live on their own experience hallucinations and other psychotic symptoms that are signs of a susceptibility to mental illness, she says.

Sommer regards sensory overrides as rare illusions among the healthy, such as a Catholic seeing a Mary statue cry or a wife who hears her late husband call her name. Schizophrenia symptoms, in contrast, take precious few breaks. Signs of mental deterioration usually appear around age 20, when patients find that they can't handle adult jobs and relationships. Many of those who seek treatment have heard friendly voices since childhood, as Jane has, says Sommer. Those same voices turn threatening in young adulthood, and patients often develop paranoid delusions.

"If Joan of Arc had lived a little longer, she may have undergone the same transition," Sommer suggests. Joan of Arc was burned at the stake at age 19.

Jane, now in her late 20s and holding down a good job, still stands a decent chance of eventually descending into psychosis, in Sommer's opinion.

Some adults harness hallucinations successfully for several years — say, a charismatic leader of a religious sect — before psychosis flares and requires treatment, Sommer says. Conversely, some psychotic patients that she has treated have tamed their hallucinations enough to live independently.

Sommer's clinical observations fit with surveys conducted in England and Wales by psychologist Louise Johns of



the Institute of Psychiatry in London and colleagues. Johns finds that 4 percent of the white population reports recent hallucinations that she believes signal a vulnerability to psychosis. She regards that figure as a conservative estimate. "Some people who hear God through prayer may have a vulnerability to psychosis, although there are many people who experience hallucinations and don't develop psychosis or need mental-health care," she says.

Preliminary evidence indicates that childhood sexual abuse and other traumas boost hallucination proneness, possibly by causing people to become psychologically detached from their emotions, bodies and surroundings, Johns says.

Sommer's team has studied 111 people who hallucinate at least once a month but have no psychiatric or brain disorders. Many work as mediums, psychics and spiritual healers. Volunteers described hearing voices as loudly and as vividly as 118 patients with schizophrenia and related disorders, the researchers reported in the March 2011 *Journal of Clinical Psychiatry*. But healthy individuals generally heard nice or neutral voices, whereas patients heard insults and commands to kill themselves.

Brain scans of 21 individuals from each group, taken while they said they were hearing voices, revealed similar activity for those with and without psychosis. Language production and comprehension areas of both hemispheres sprang into action, consistent

with participants silently talking to themselves, Sommer and her colleagues reported in a paper published online last year in *Schizophrenia Bulletin*.

Studies conducted by other researchers with small numbers of hallucinating volunteers suggest that when people hear voices out of nowhere, their brains are failing to identify internal thoughts as self-generated, Sommer says. In other words, neural activity reflects a mental state in which imagined statements are interpreted as coming from someone else. Confusion about the source of one's own thoughts could apply to sensory overrides as easily as to psychotic hallucinations, Luhrmann says.

### Trained visions

However minds and brains instigate hallucinations, cultural training may lie at the heart of sensing the immaterial, Luhrmann says.

Consider that different religions ascribe special meaning to different senses. Protestants emphasize hearing as appropriate for experiencing God, as do evangelical Christians and Muslims. Members of these faiths typically hear God's voice but don't see God. Catholics and Hindus privilege sight as a holy

channel and more often have supernatural visions.

Many non-Western cultures assume that one person's mind can be occupied by another's mind, or by supernatural forces. Sensory overrides appear to occur more easily among people in these societies, such as the Thai Buddhists studied by Cassaniti.

Cultural encouragement to focus carefully on inner thought, a characteristic of Islam, also prompts sensory overrides. And a study by Luhrmann has shown that evangelical Christians can develop a capacity for absorp-

tion by learning to focus on inner thoughts and feelings while praying. After a month of practicing this kind of prayer, many congregants reported that they had heard God's voice for the first time.

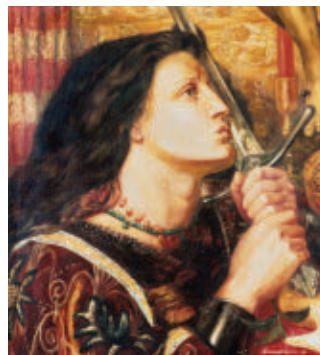
"Anthropologists and psychologists don't know much about the effects of cultural training on how people think about their own minds," says anthropologist Rita Astuti of the London School of Economics and Political Science, who studies a fishing community in Madagascar. Members of that community frequently report being temporarily possessed by invisible spirits.

Ways in which cultures promote everything from spirit possessions to hearing God's voice also remain largely unexplored. Luhrmann predicts investigations of the religious faithful will yield further insights into what personal characteristics other than absorption spark hallucinations.

She also thinks that regardless of what scientists turn up, Hannah will continue to enjoy date nights with God as much as ever. ■

### Explore more

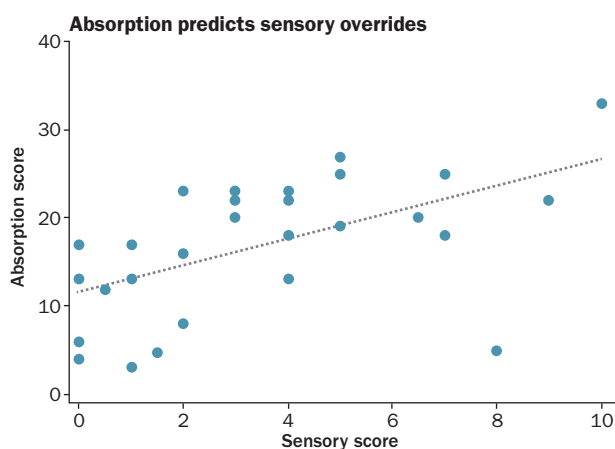
■ Tanya Luhrmann. *When God Talks Back*. Knopf, 2012.



**Some researchers believe Joan of Arc would have developed psychosis had she not been burned at the stake at age 19.**

### Fully absorbed

Members of a Christian group who scored higher on the Tellegen Absorption Scale were more likely to say they experience God in a sensory way—whether by seeing, hearing or feeling the touch or presence of the divine.



# Bits of reality

Not just for codes and computers,  
quantum information holds clues to the nature  
of the physical universe

By Tom Siegfried

**A**sk any physicist to name the top two theories of the 20th century, and you'll almost always get the same automatic answer: Einstein's relativity and quantum mechanics. But lately a few 21st century thinkers have hinted that maybe the third-place theory should move up a notch. In the wake of the computer revolution, information theory might deserve to displace relativity in the rankings.

That revisionist perspective reflects a late 20th century twist in the story of that century's theories: the surreptitious merger of quantum theory with information science. Their origins had been entirely independent. Quantum mechanics arose in the 1920s as the math for describing the odd behavior of atoms and electrons; information theory came along two decades later, as formulas for quantifying communication over telephone lines. For decades the two theories led separate lives in fields of study far removed from one another. While physicists expended their intellectual energy on uniting quantum mechanics with relativity (a quest that continues, still without success), information scientists graduated from telephones to computers with only occasional concern for quanta. But then in the 1980s and '90s, quantum and information science met, married and produced

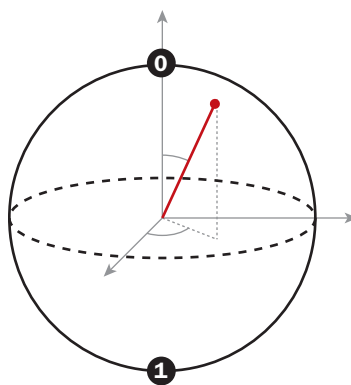
offspring — specifically, the intellectual enterprise known today as quantum information theory.

Initially, quantum information snared the attention of physics fans for its possible uses in sending secret codes and creating superfast computers. Those and other potential quantum technologies continue to occupy scientists' time at research centers around the world, from Canada to Austria to Singapore. But theorists pursuing quantum information's secrets are more motivated by the quest to acquire a deeper understanding of physical reality, and perhaps to grasp more fully the nature of quantum mechanics itself.

"We always stress how interesting are the applications" of quantum information, says theorist J. Ignacio Cirac. "But actually if you work in this field, you don't care so much about these things. What you see is that the science that is being done is really fantastic."

## Computing reality

At the heart of quantum information science is a novel representation for information known as the qubit. It's the quantum analog of the 1s and 0s, or "bits," processed by ordinary computers. But a qubit is infused with quantum magic, allowing it be both a 1 and a 0 at the same time. This "superposition" of identities gives quantum information extraordinary power.



## Quantifying qubits

A unit of quantum information, or qubit, can be represented as a point on the surface of a sphere. The angles formed by the radius to that point can be used to calculate the odds that the qubit will become 0 or 1 when measured.

Qubits can, for instance, transmit coded messages with absolute secrecy, typically in the form of particles of light, or photons (*SN*: 8/16/08, p. 24). Messages sent as a string of qubits, encoded in the orientations of photon vibrations, are secure because any attempt at eavesdropping would alter the message in a detectable way.

Such quantum-secured systems are already commercially available, and may someday be a commercial necessity because of another quantum information application: quantum computing. For certain problems, computing with qubits held in a quantum memory can solve mathematical problems so hard that a standard supercomputer couldn't find the answer within the lifetime of the universe. One such hard problem is finding the prime factors of very big numbers. Codes based on such problems, which now protect most electronic financial transactions, would be worthless in a world with full-scale quantum computers. (No need to worry about your credit card security just yet, though. Breaking today's codes would require a quantum computer handling thousands or more qubits; the record for today's prototypes is merely 14.)

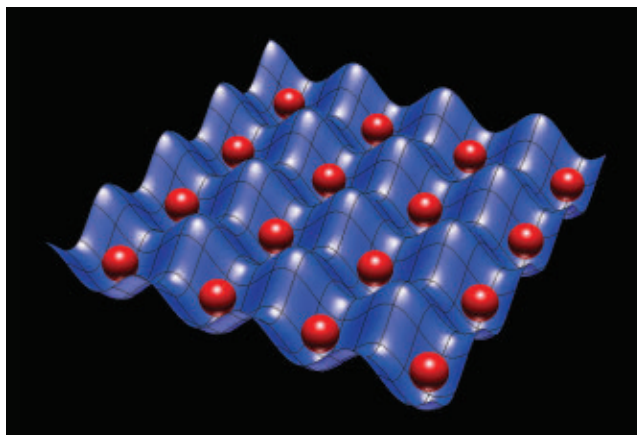
Quantum computers wouldn't be worth much for general number crunching. They would work only for problems that could be posed in the form of an algorithm amenable to the way quantum weirdness can cancel out wrong answers, allowing only the correct one to survive. But a sufficiently sophisticated quantum computer would be able to simulate molecular systems governed by quantum mechanics. You could harness that power to foretell the outcome of chemical reactions, for instance, without the bother of test tubes. Such computing ability could aid the design of new industrial materials or help develop powerful drugs with fewer side effects.

"Of the currently understood algorithms, the one that seems most promising for applications is simulation of a quantum system," says Caltech physicist John Preskill. "We don't currently envision that you'll be sending your e-mail on a quantum computer. On the other hand, quantum games might be a blast."

But for all these wonders, quantum computers and other quantum information processing systems are not mere investment speculation opportunities. They are tools for scientists to dig deeper into reality's foundations. Quantum information could reveal nuances about the interface between mathematics and the physical world.

Cracking codes, for instance, involves solving the very hard math problem of finding the prime factors of a big number, hundreds of digits long. But the fact that a quantum-computing algorithm can solve such a problem — as discovered by the mathematician Peter Shor in 1994 — has deeper implications than just financial eavesdropping.

"Factoring is a hard problem classically," says Preskill, "but Shor's algorithm shows that it is an easy problem quantumly. And so it seems the boundary between what problems are hard and what problems are easy is different in our physical world — because it's a quantum world — than it would be if the



**To solve certain hard problems beyond the ability of ordinary computers, quantum computers need to process bits of quantum information, or qubits. One proposed method would store the qubits in the form of rubidium atoms (red) held in place by an "optical lattice" (blue) created by laser beams.**

world were classical." In other words, quantum information processing reveals something about math's relation to physical reality that prequantum scientists couldn't have imagined.

Or at least that's what quantum scientists believe. Proving that the physical world really does allow quantum solutions to some hard math problems requires actually building a large-scale quantum computer. "We hope to be able to verify that these extraordinary computational resources in quantum systems really are part of the way nature behaves," Preskill noted recently in Vancouver at the annual meeting of the American Association for the Advancement of Science. "We could do so by solving a problem that we think is hard classically ... with a quantum computer, where we can easily verify with a classical computer that the quantum computer got the right answer."

Factoring would be one example of such a problem — very hard to solve, but easy to check to see if the answer you get is right. But other hard math problems probably exceed even a quantum computer's capabilities. "Some problems are quantumly hard," says Preskill. Knowing which problems are hard for quantum computers would offer insight into what kinds of mathematical computations are actually possible in the physical universe.

One computational claim challenged by quantum computing, MIT computer scientist Scott Aaronson points out, is a long-held belief called the extended Church-Turing thesis. It basically states that anything feasibly computable by a physical device is also computable by an idealized "universal" computer known as a Turing machine.

"This is a falsifiable claim about the laws of physics," Aaronson said at the AAAS meeting. It expresses the belief that if physical laws are like computer code, any reasonable programming language for nature's laws could emulate another one.



"This would say that any reasonable laws of physics that someone could write down, they can all reasonably simulate any other laws," Aaronson said.

But Shor's factoring algorithm contends that quantum computers could do things a Turing machine couldn't. So either quantum computing is actually impossible (not likely, as that would imply some flaw in quantum mechanics itself), or the Church-Turing thesis is incorrect as a statement about the physical world. Unless somehow there exists an unknown way for an ordinary computer to simulate quantum physics. "No one has proved that there isn't one," said Aaronson. "But this would be an astounding mathematical discovery."

### Quantum roots

An equally or more profound discovery would be identifying the physical principle that requires reality to obey the rules of quantum mechanics in the first place. In the beginning, the quantum pioneers simply figured out the math that works — a math that requires the weirdness of multiple possible realities (*SN: 11/20/10, p. 15*). Inquiring into the underlying reason why such weird math worked so well was long considered foolish. A standard response to junior physicists who raised such questions was "shut up and calculate."

But in recent decades, the quest to find a physical principle from which quantum mechanics can be built has become more popular, and quantum information has been at the heart of many such efforts. Much of the work along these lines was inspired by the late physicist John Archibald Wheeler, who believed that quantum physics — and existence itself — might have its roots in aspects of information theory. His slogan "it from bit" summarized the view that reality somehow emerges from cosmic information processing.

Several efforts to derive quantum math from basic principles have echoed the it-from-bit philosophy. Last year, for instance, Giulio Chiribella of the Perimeter Institute for Theoretical Physics in Waterloo, Canada, and collaborators from Italy showed a way to derive quantum mechanics from a set of five axioms plus one postulate, all rooted in information theory terms (*SN: 8/13/11, p. 12*).

"In this approach the rules by which information can be processed determine the physical theory, in accordance with Wheeler's program 'it from bit,'" Chiribella and Italian colleagues Giacomo Mauro D'Ariano and Paolo Perinotti wrote in *Physical Review A*.

Their system is built on axioms such as "causality" — in essence, the notion that signals from the future cannot affect the present. In other words, the odds of an experiment turning out one way or the other do not depend on a future choice of which measurements to perform. Another axiom, called "ideal compression," asserts that the information in a system

always can be condensed into an encoded form that could then be decoded to reproduce all of the original information.

All five axioms in this approach reflect basic aspects of ordinary information, no quantum weirdness necessary. "These axioms represent standard features of information processing that everyone would, more or less implicitly, assume," Chiribella and colleagues wrote.

Their postulate, however, departs from the nonquantum classical world by introducing what they call the "purification" principle. That principle is something like a law of conservation of information, contending that all the information a quantum system contains can be recovered by reversing all its interactions with its environment. In practice, of course, keeping track of every interaction of a system with its environment isn't possible. But as a principle, it implies the ability to know all the information there is to know about a whole system yet remain ignorant of some of its parts. Therein lies the key to quantum weirdness, and that postulate plus the other information-

theoretic axioms yields the quantum math that has long perplexed anyone who has tried to understand where it comes from.

### Relatively simple

Chiribella and colleagues' axiomatic system is not the only one to reproduce the formulas of quantum physics, though (but they claim theirs is the first to do so using only principles that can be expressed in terms of actual physical operations). And none of the various approaches satisfy everybody, anyway. Some physicists (Wheeler was among them) believe that the physical principle underlying quantum physics should be crisp and clear and even in retrospect, perhaps, obvious.

Christopher Fuchs, a quantum physicist at the Perimeter Institute, argues that the secret principle (or principles) at the core of quantum mechanics ought to be similarly simple to the two pillars of Einstein's theory of relativity: The speed of light is constant, and the laws of physics do not depend on how you are moving. Axioms that need paragraphs of explanation do not meet this crisp-and-clear test. Fuchs still appreciates information's role in quantum theory, but he does not believe that Wheeler's "it from bit" is the right story.

"I suspect quantum theory is mostly about information," Fuchs said in a recent interview. "But there is going to be some piece remaining behind that you really can't pin down as being a statement about information. Instead I expect it to be a statement about the character of the world.... The distillate that remains, the part that can't be given an information-theoretic reason, will be our first glimpse into what quantum reality is all about." ■

**Some physicists believe that the physical principle underlying quantum physics should be crisp and clear and even in retrospect, perhaps, obvious.**

# Cell Phone Inspires Chicago Doctor to Design Affordable Hearing Aid

## Outperforms Many Higher Priced Hearing Aids

Reported by J. Page

**CHICAGO:** A local board-certified Ear, Nose, Throat (ENT) physician, Dr. S. Cherukuri, has just shaken up the hearing aid industry with the invention of a medical-grade, affordable hearing aid. **This revolutionary hearing aid is designed to help millions of people with hearing loss who cannot afford—or do not wish to pay—the much higher cost of traditional hearing aids.**

**"Perhaps the best quality-to-price ratio in the hearing aid industry" – Dr. Babu, M.D.  
Board Certified ENT Physician**

Dr. Cherukuri knew that hearing loss could lead to depression, social isolation, anxiety, and symptoms consistent with Alzheimer's dementia. **He could not understand why the cost for hearing aids was so high when the prices on so many consumer electronics like TVs, DVD players, cell phones and digital cameras had fallen.**

Since Medicare and most private insurance do not cover the costs of hearing aids, which traditionally run between \$2000-\$6000 for a pair, many of the doctor's patients could not afford the expense. Dr. Cherukuri's goal was to find a reasonable solution that would help with the most common types of hearing loss at an affordable price, not unlike the "one-size-fits-most" reading glasses available at drug stores.

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He evaluated numerous hearing devices and sound amplifiers, including those seen on television. Without fail, almost all of these were found to amplify bass/low frequencies (below 1000 Hz) and not useful in amplifying the frequencies related to the human voice.

### Inspiration from a Surprising Source

The doctor's inspiration to defeat the powers-that-be that kept inexpensive hearing aids out of the hands of the public actually came from a new cell phone he had just purchased. **"I felt that if someone could devise an affordable device like an iPhone® for about \$200 that could do all sorts of things, I could create a hearing aid at a similar price."**

### Affordable Hearing Aid With Superb Performance

The high cost of hearing aids is a result of layers of middlemen and expensive unnecessary features. Dr. Cherukuri concluded that it would be possible to develop a medical grade hearing aid without sacrificing the quality of components. The result is the MDHearingAid PRO®, starting well under \$200. **It has been declared to be the best low-cost hearing aid that amplifies the range of sounds associated with the human voice without overly amplifying background noise.**

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*"I have a \$2,000 Resound Live hearing aid in my left ear and the MD HearingAid PRO in the right ear. I am not able to notice a significant difference in sound quality between the two hearing aids."*

— Dr. May, ENT physician

*"We ordered two hearing aids for my mother on Sunday, and the following Wednesday they were in our mailbox! Unbelievable! Now for the best part—they work so great, my mother says she hasn't heard so good for many years, even with her \$2,000 digital! It was so great to see the joy on her face. She is 90 years young again."*—Al Peterson

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## That's Disgusting

Rachel Herz

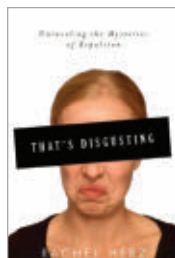
Casu marzu is made in Sardinia by adding fly larvae to sheep's cheese and allowing the concoction to rot. It is eaten with thousands of little maggots still squirming inside it.

Disgusting? Not to the Sardinians who find it delicious with a nice strong glass of red wine. And it's the same for many other sights, sounds and smells: What's disgusting is in the queasy stomach of the beholder. Herz, a research psychologist specializing in the sense of smell, set out to understand the science behind disgust after being tapped to judge the National Rotten Sneakers Contest in Montpelier, Vt., and finding it not as bad as she had expected. She becomes the reader's brave guide to all kinds of topics that are normally avoided.

First Herz surveys what kinds of things disgust people, and then she tries to explain why by exploring disgust's physiological basis (people with

damage to some brain areas don't feel it, for example) and behavioral research on how people develop and respond to disgust.

Disgust is the only basic emotion that is largely learned (young children don't feel or recognize it), and Herz argues that it may be the most recently evolved. Disgust, research sug-



gests, evolved from fear and took hold because of its ability to help protect people from their top predators, pathogens. From there, it has been elaborated upon by associations and connections in the brain, such that today all sorts of violations (ketchup on ice cream) can trigger disgust. But these feelings can be harnessed, Herz says, and in the end her lesson on disgust has a lot to say about how we as humans feel about ourselves. — *Erika Engelhaupt* W.W. Norton & Co., 2012, 274 p., \$26.95

treatment for a nonfatal liver disease. His death temporarily shuddered the field to a halt. Lewis clearly lays out how far gene therapy has come since then. Among other things, scientists have found better viral vectors to deliver the new genes, so that the patient's body does not go into immune overload.

Much of this progress has been pushed forward by the anxious parents of children suffering from rare genetic disorders such as the brain-destroying adrenoleukodystrophy best known from the movie *Lorenzo's Oil*. From the hallways of patient conferences to the National Institutes of Health library in Bethesda, Md., Lewis adroitly sketches the heartbreaking world of families searching for a cure.

And while her reporting steers clear of unfounded optimism, her message is ultimately a positive one: Gene therapy is here to stay. Soon, Corey Haas, not Jesse Gelsinger, will be the name most people remember. — *Alexandra Witze* St. Martin's, 2012, 323 p., \$25.99

## The Forever Fix: Gene Therapy and the Boy Who Saved It

Ricki Lewis

Gene therapy, long heralded as the savior of those suffering from rare genetic disorders, has a lot to thank Corey Haas for. Haas was 8 years old when, in 2008, doctors injected engineered viruses into his eyes in an attempt to cure his hereditary blindness. It worked, and that success swept away shadows that had haunted gene therapy for nearly two decades.



Genetics writer Ricki Lewis uses Haas' story to book-end the checkered history of gene therapy—the idea of replacing a defective gene with a working one in order to knock out disease. In theory, it sounds clever. In practice, it has been fiendishly difficult. Most notably, 18-year-old Jesse Gelsinger died in a 1999 clinical trial of a gene therapy



## The Life of Super-Earths

Dimitar Sasselov

The astronomer who coined the term “super-Earth” reviews the hunt for these possibly life-holding planets. *Basic Books*, 2012, 240 p., \$25.99



## How Not to Be Eaten

Gilbert Waldbauer

Insects' ingenious means of avoiding becoming lunch are examples of evolutionary one-upmanship in action. *Univ. of California*, 2012, 221 p., \$27.95



## Across Atlantic Ice

Dennis J. Stanford and Bruce A. Bradley

A pair of archaeologists explore the earliest days of the first humans in North America and suggest these people may have had European roots. *Univ. of California*, 2012, 336 p., \$34.95



## Vesuvius

Gillian Darley

This history of the famous Italian volcano examines its role as a cultural icon through the ages. *Harvard Univ.*, 2011, 245 p., \$22.95



## Wired for Culture

Mark Pagel

A biologist examines the development of human culture and argues that evolutionary history has shaped humankind's social tendencies. *W.W. Norton & Co.*, 2012, 416 p., \$29.95

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## A Boy Scout's salute

I am a Boy Scout doing the Communications Merit Badge. I am supposed to write to the editor of a magazine and express my opinion.

I've always loved the Atom & Cosmos section because I'm very interested in particle physics and on the other end of the scale, cosmology. "Earth-y orb found in habitable zone" (SN: 3/10/12, p. 14) describes a planet 22 light-years away from Earth that could potentially have life on it. It really is fascinating to think that there are other civilizations out there in space all searching for other forms of life.

Another topic that I love reading about is black holes. Being someone who knows the tip of the iceberg about things like black holes, it's really mind-boggling to read the works and findings of brilliant scientists in such a comprehensible way. Schools don't teach this sort of material, and these science topics are what I love to learn about. It

really is a blessing to be captivated by almost any article in *Science News*.

**Matthew Kotila**, San José, Calif.

## Which came first, lung or bladder

In "African lungfish walk in water" (SN: 1/14/12, p. 12), the author comments that primitive lungs "probably evolved from the air bladders found in fish." Since it might very well be just the opposite, instead of this phrasing I think it better to simply acknowledge the evolutionary homology [relatedness] of air bladders and lungs. The air bladders seen in modern ray-finned fishes are very different in their anatomical details from lungs. It is plausible that the "lung" (or lungs, depending on species) of modern lungfishes — virtually identical morphologically to the lungs of tetrapods — represents the ancestral (or primitive) condition seen in some of the now-extinct "transitional" fishes alluded to in the article.

**Kevin Lumney**, Sunbury, Ohio

*The reader makes a good point. It is possible that lungs and swim bladders evolved separately. As evolutionary biologist Neil Shubin of the University of Chicago says, these kinds of structures arise "via similar processes, but it is unclear whether one is derived from the other."* — Editors

## Correction

An entry in the 90th anniversary issue of *Science News* (SN: 3/24/12, p. 25) incorrectly stated that atomic timekeeping was reported in 1947. The entry should have said that the U.S. National Bureau of Standards reported quartz timekeeping accurate to a millionth of a second in 1947. The first atomic clock was actually reported in 1949, also by that agency ("Atoms control new clock," SN: 1/15/49, p. 35).

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## Measure Your Giant Carefully And His Size Will Shrink

The American public may scoff a bit at fairies, but it would like very much to believe in giants.

At least, so it appears from the thin but steady stream of letters received at the Smithsonian Institution.

Every month in the year brings these letters. They come from people eager to tell that they have found the bones of a race of seven or eight foot giants that stalked about the countryside in the ancient times.

If you come across something that looks mightily like a giant, therefore, pause and consider these points on the anatomy of giants vs. ordinary mortals, as explained by Dr. Ales Hrdlicka, the Smithsonian's curator of physical anthropology:

"The estimate of stature," he explains, "is usually based on the thigh bone of a man of ordinary size. But the person unfamiliar with human anatomy does not know that the upper joint of the femur is several inches higher in the sacral region than would appear from superficial examination of the living body. The finder makes a hurried comparison of the length of the fossil thigh bone with his own, applying the specimen usually to the front of his body, and from this calculates roughly the size of his hypothetical 'ancient giant.'"

The Smithsonian will tell you, at any rate, that there was no prehistoric race of giants — or pygmies either — among the wonders of America's past.



The femur of a species dubbed *Homo floresiensis* (bottom) is much smaller than the same bone in *Homo sapiens*.

### UPDATE

## Ancient oddballs in Indonesia

To date, *Homo sapiens* (aka modern humans) are the only people known to have ever resided in the Americas. Any fossil evidence pointing to a new, unknown class of Western Hemisphere hominids would be a huge surprise — probably requiring scientists to reconsider human evolutionary history and the peopling of the planet.

But such surprises do occur, if rarely. In 2003, for example, researchers uncovered a partial skeleton of a half-size *Homo* species on the Indonesian island of Flores (*SN*: 10/30/04, p. 275). The team reported that the skeleton belonged to a female adult who probably stood 3 feet, 6 inches tall and weighed as little as 35 pounds. Because her brain size would have been similar to that of a chimpanzee, and because of other anatomical differences, the ancient lady was pegged as a member of a new species, not a pygmy version of *H. sapiens*.

Most puzzling for anthropologists, the recovered fossils dated from 17,000 to 95,000 years ago, meaning the new species — dubbed *H. floresiensis* — lived alongside *H. sapiens*. *H. floresiensis* also appeared to make sophisticated stone tools.

Backlash came swiftly. The new hobbitlike hominid didn't fit within the existing framework of human evolution. Soon after the Flores fossils were announced, another team argued that the partial skeleton came instead from a modern human with a genetic growth disorder. A condition called microcephaly, for example, could have made the head smaller than usual. The argument has shifted back and forth, back and forth since. A report published last August found that the proportions of the hobbit skull fit within the range of microcephalic *H. sapiens* (*SN Online*: 8/8/11).

Because getting DNA from the Flores bones is extremely difficult, there's no end to the debate in sight. No doubt anyone who makes claims about ancient giants or hobbits elsewhere on Earth would face a similar fight. — *Elizabeth Quill*

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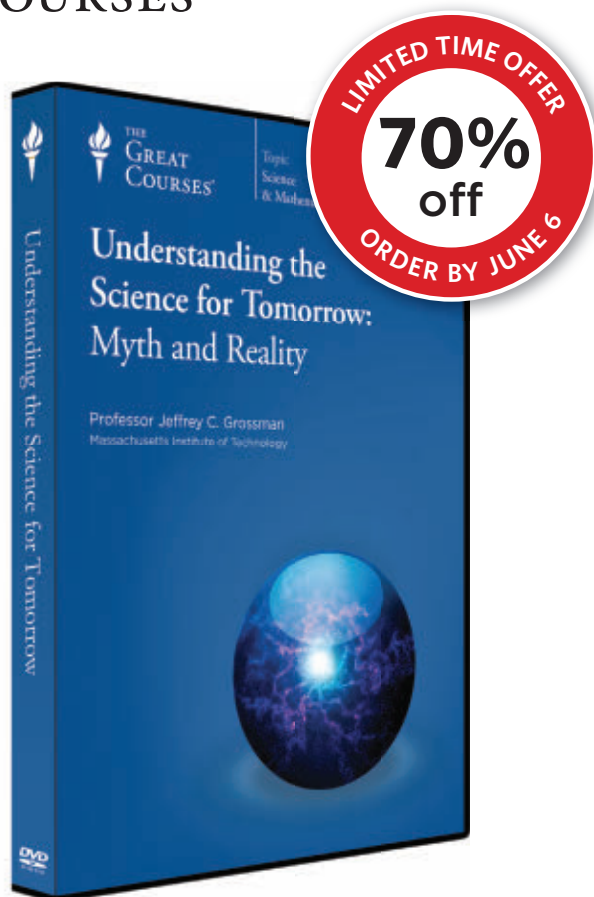
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