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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ JULY 19, 2008

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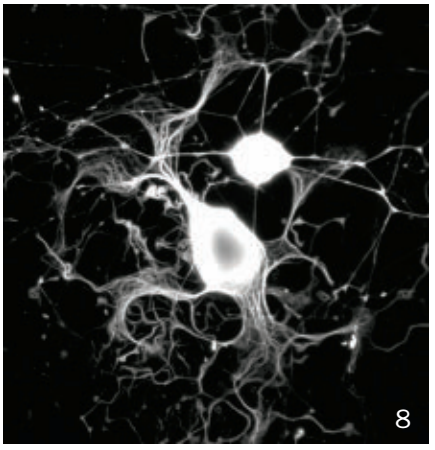

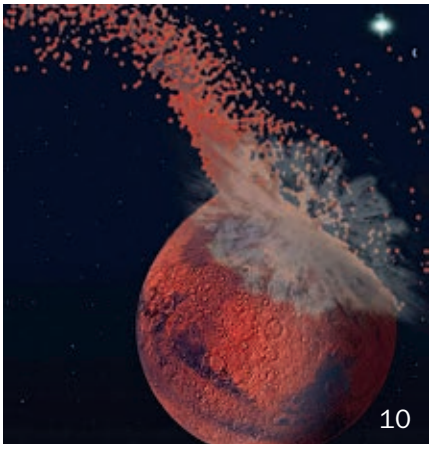

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ScienceNews

In the News

Features

Departments

On the cover:
A technician working on the Large Hadron Collider travels its tunnel on a bike. Others use motorized carts.
Photo: Maximilien Brice

ScienceNews
MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

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Science News (ISSN 0036-8423) is published biweekly, for $54.50 for 1 year or $98.00 for 2 years (international rate $80.50 for 1 year or $161 for 2 years) by Society for Science & the Public, 1719 N Street NW, Washington, DC 20036. Preferred periodicals postage paid at Washington, DC, and an additional mailing office.

Subscription Department: P.O. Box 1205, Williamsport, PA 17703-1205. For new subscriptions and customer service, call 1-800-552-4412.

Postmaster: Send address changes to Science News, P.O. Box 1205, Williamsport, PA 17703-1205. Two to four weeks' notice is required. Old and new addresses, including zip codes, must be provided.

At the LHC, physics will collide with reality

In a couple of months or so, scientists will celebrate the beginning of a new era in physics when the Large Hadron Collider opens for business outside Geneva. The LHC will be the world's most powerful atom smasher, colliding protons at sufficiently high energies to produce particles more massive than any ever previously produced on the planet.

If such particles exist.

As Ron Cowen describes in this issue (Page 16), LHC scientists are eager to find clear evidence for the existence of the Higgs boson, a particle that would seal the last crack in the standard model of particle physics. If the current understanding of subatomic particles is correct, the Higgs simply must exist. It's as sure a bet as the existence of the ether was at the end of the 19th century.

Back then, of course, the Michelson-Morley experiment showed that the ether didn't exist after all, revealing some serious deficiencies in prevailing ideas about light and motion. There's always a chance that physicists will be shocked again by a failure to find the Higgs.

But in a way, that wouldn't be as bad as finding the Higgs and nothing else. As Nobel laureate Steven Weinberg told Ron, that's everybody's worst fear. It would merely ratify the current theory without providing any new clues to all the problems the current theory can't solve, such as the nature of the dark matter lurking unseen in the cosmos and the identity of the repulsive force that drives the universe to expand at an accelerating rate.

Failure to find the Higgs would inspire physicists to seek an entirely new approach to understanding matter, energy, space and time. So the $8 billion spent on the LHC wouldn't be wasted, even if it finds nothing.

A better payoff, though, would be the discovery of the Higgs plus other particles, presumably the "superpartners" of the known particles. Most experts would wager that such superparticles exist, differing from their ordinary alter egos in spin and mass. Finding them at the LHC would verify decades of theoretical study and strongly hint that superstring theory, championed by many and derided by others, is on the right track.

Better yet, the LHC might turn up unsuspected phenomena, utter surprises that will invigorate a new generation of physicists to forge a more profound picture of reality than theorists have so far drawn. Not only would that excite the nonscientific world and perhaps improve the prospects for future funding, it would provide fodder for future features in *Science News*.

—Tom Siegfried, Editor in Chief

Turning the Odds in Your Favor

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Probability as a Reasoning Tool

Professor Michael Starbird knows the secret of making numbers come alive to nonmathematicians. He picks intriguing, useful, and entertaining examples, with questions such as: When did the most recent common ancestor of all humans live? How much should you pay for a stock option? What do you do on third down with long yardage?

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$$p \times 5 + (1 - p) \times 6 = p \times 7 + (1 - p) \times 1$$

$$(1 - p) \times 5 = p \times 2$$

$$5 = p \times 7$$

$$p = \frac{5}{7} = 0.714$$

which the expected value is infinity; something has to be wrong, but can you guess what it is?

About Your Professor

Professor Michael Starbird is a distinguished and highly popular teacher with an uncommon talent for making the wonders of mathematics clear. He is Professor of Mathematics and a Distinguished Teaching Professor at The University of Texas at Austin, where he has received the President's Associates Teaching Award, the Jean Holloway Award for Teaching Excellence, and the Friar Society Centennial Teaching Fellowship.

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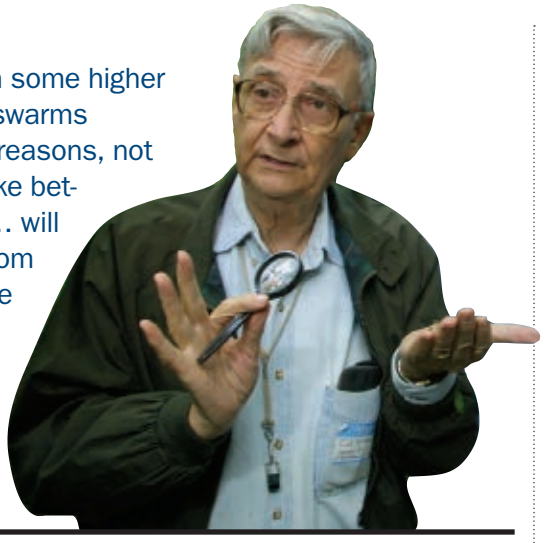
Scientific Observations

"We do not float above the biosphere in some higher spiritual or technoscientific plane. Life swarms around us, and even in us.... For many reasons, not least our own well-being, we need to take better care of the rest of life. Biodiversity ... will pay off in every sphere of human life, from medical to economic, from our collective security to our spiritual fulfillment."

—EDWARD O. WILSON, WRITING IN THE FOREWORD TO *SUSTAINING LIFE: HOW HUMAN HEALTH DEPENDS ON BIODIVERSITY*, A COLLECTION OF SCIENTIFIC ESSAYS PUBLISHED IN JUNE.



Science Past: 50 Years Ago

From *Science News Letter*, July 19, 1958

RUSSIANS TEST ACCELERATOR— Russian scientists reported the first results of experiments with their atom-smasher, the world's largest, to the 1958 Annual International Conference on High Energy Physics in Geneva, Switzerland. Their studies showed the hard core of a proton, a fundamental particle of the atomic nucleus and a building block for all matter, shrinks at high energies. Using their atomic accelerator at close to its full power of ten billion electron volts, they bombarded a target of protons with a beam of protons.... None of the Russians in the 19-man delegation would comment concerning their proposed 50 billion electron volt (Bev) accelerator. One reason is believed to be the difficulties Soviet scientists have had in getting their ten Bev machine to work properly. Although it could now be operated at its full power, the beam intensity would be extremely weak.

Science Future

July 19

Randy Olson's new mockumentary *Sizzle: A Global Warming Comedy* premieres in Hollywood. Visit **www.sizzlethemovie.com**

August 6–14

The 33rd International Geological Congress will be held in Oslo. Visit **www.33igc.org**

October 31

The Aztec World opens at The Field Museum in Chicago. Visit **www.fieldmuseum.org/exhibits/temporary_exhib2.htm**

SN Online

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COMMENT

Go online to find references from this issue's Comment author Dudley Herschbach, winner of the 1986 Nobel Prize in chemistry, for his column (p. 32) discussing infusing liberal arts education with scientific ideas.

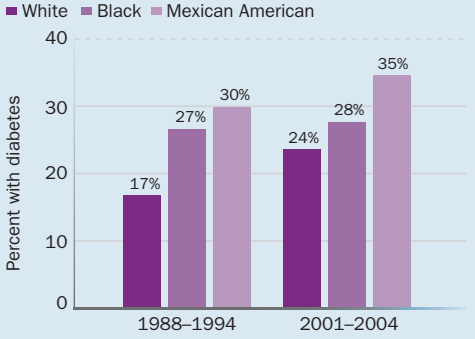
MATH TREK

What's Edgar Allan Poe got to do with game theory? Inspired by a game theory "riddle" in Poe's short story "The Purloined Letter," economists Kfir Eliaz and Ariel Rubinstein ran dozens of simple, even-and-odd guessing games, similar to a game described by Poe. They showed that Poe (and not game theory) was right in cases in which human psychology played an important role, but that when this element was minimized, game theory prevailed in predicting winners. Julie J. Rehmeyer describes the study and its results and implications in a recent post of her weekly online column.

Science Stats

DIABETES ON THE UPSWING

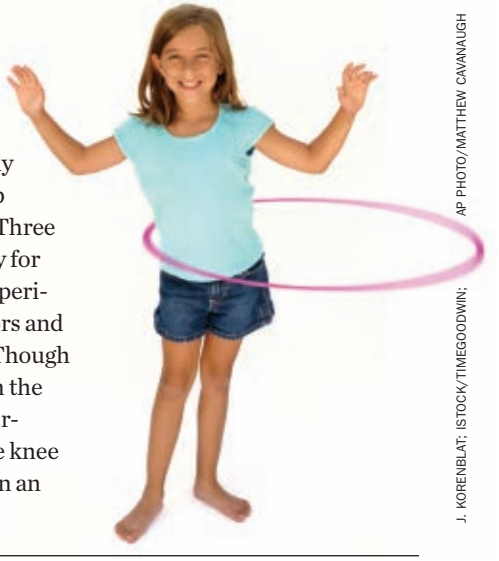
Percent of people age 65 or older with diabetes by race in the United States



SOURCE: CDC/NCHS

How Bizarre

It's all in the hips. Or is it? University of Ottawa researchers decided the complex task of hula hooping needed more attention, so they set out to study the coordinated movements that keep the plastic ring from dropping down. Three volunteers—who could spin smoothly for 20 seconds but had no competitive experience—were attached to motion sensors and stood on plates that measured force. Though the volunteers moved their middles in the same way, each gave the hoop lift differently. A burp in the ankle or jerk of the knee both kept the hoop up, the team says in an upcoming *Human Movement Science*.



J. KORENBLAT; ISTOCK/TIMEGOODWIN; AP PHOTO/MATTHEW CAVANAUGH

“Something big smacked into Mars and stripped half the crust off the planet.” —FRANCIS NIMMO, PAGE 10

In the News

STORY ONE

Brazil’s Pirahã grasp numbers without words

Study challenges theories linking language, thought

By Bruce Bower

One is the loneliest number that you’ll ever do, especially if you don’t even have a word for it. That’s the situation of the Pirahã people, denizens of Brazil’s Amazon rainforest who have no term for the number one or for any other exact quantity, a new study finds.

Until now, researchers have not demonstrated the absence of a way to express the number one in any language, according to a team led by Massachusetts Institute of Technology cognitive scientist Edward Gibson.

Yet Pirahã individuals can still identify the number of items that an experimenter places in front of them, Gibson’s team reports. The new findings challenge the long-standing idea that number words enable people to think about and recognize exact quantities of items.

“These results suggest that number words do not change our underlying representations of number, but instead are a cognitive technology for keeping track of the exact size of large sets over time and in different contexts,” says coauthor Michael Frank of MIT. The new study was published online and will appear in an upcoming *Cognition*.

What’s in a name? A Pirahã man participates in a counting experiment that, researchers say, indicates that his language contains no number words, even for the number one.

GIBSON

The team first examined whether the Pirahã employ counting words, as was described in a 2004 study conducted by psycholinguist Peter Gordon of Columbia University. Gordon concluded that the Brazilian tribe has words for *one*, *two* and *many* (*SN: 12/10/05, p. 376*). However, Daniel Everett of Illinois State University in Normal, a longtime Pirahã researcher and coauthor on the new study, initially questioned Gordon’s results.

The new study explores Everett’s contention that no words for exact numbers exist in the Pirahã language. For each of six adult Pirahã volunteers, a researcher placed one wooden thread spool on a table and added spools one at a time until reaching 10 spools. For each quantity, the experimenter used the Pirahã language to ask volunteers “How much is this?” Four of the same volunteers then performed this exercise as the researcher removed one spool at a time from a set of 10 spools until one remained.

Participants used the same three words for dramatically different ranges of quantities when dealing with increasing or decreasing numbers of spools. For increasing quantities, these words roughly corresponded to *one*, *two* and *many*. For decreasing quantities, these three words were used to denote from one to six spools, from four to 10 spools and from seven to 10 spools.

These results indicate that the three Pirahã words refer to general quantities, such as *few*, *some* and *more*, Frank says. Many other foraging groups, as well as the Pirahã in Gordon’s study, have been reported to have words for *one*, *two* and *many* based only on responses to increasing numbers of items. Some of those »

For today's top science news, visit SN Today at **www.sciencenews.org**

groups may, like the Pirahã, reveal an absence of number words when responses to decreasing quantities are considered, Frank proposes.

In a second experiment, 14 Pirahã adults reproduced exact quantities of objects despite lacking number words. Participants facing a line of one to 10 spools almost always chose the same number of uninflated balloons to put in a matching line. Still, the same individuals often muffed tasks that required them to track and remember precise amounts, such as choosing a matching number of balloons after watching an experimenter drop spools one at a time into a can.

Pirahã	Various English translations		
	GORDON 2004	EVERETT 2005	GIBSON 2008
hói	one/small	small size or amount	few/fewer
hoí	two	larger size or amount	some
baágiso	many	cause to come together/many	more

Number words are cultural inventions that greatly enhance the ability to monitor the exact sizes of large groups of objects, the researchers propose. Speakers of languages with number words thus find it easy to recall and re-create the number of spools dropped into a can.

To some extent, this idea challenges the nearly 70-year-old argument of Edward Sapir and Benjamin Whorf, both Yale University anthropologists. They proposed that the structure of a language conditions the ways its speakers think about the world. Thus, speakers of different languages view critical aspects of the world in different ways. The Sapir-Whorf hypothesis has attracted much criticism, especially over the last 15 years, from researchers who regard the mind as a collection of evolved thinking devices that operate independently of language.

Scientific opinions vary widely on what the new study shows about numerical thinking among the Pirahã. Gibson's team makes a good case for the absence of Pirahã words that represent exact quantities, including a word for *one*, remarks psychologist David Barner of the University of California, San Diego.

Barner's own studies indicate that English-speaking children don't immediately realize that singular nouns, such as *a banana*, represent the numerical equivalent of *one banana*. At 2 years of age, youngsters understand that *one* refers to single items but assume that *a* means *at least one*, he says. As they learn about terms such as *some* and *all*, children gradually adopt *a* as a stand-in for *one*, Barner suggests.

Harvard University psychologist Elizabeth Spelke agrees that the Pirahã lack number words but questions whether they exhibit an underlying knowledge of precise amounts as proposed by Gibson's team. "The prize question, whether exact number concepts such as *seven* depend on number words and verbal counting, is still open," Spelke says.

Pirahã volunteers may have matched appropriate numbers of balloons to sets of spools by using a non-numerical rule of thumb, such as "for each thing on your side, there's a thing on my side," she suggests. Frank acknowledges that possibility.

Columbia's Gordon agrees with Spelke and adds that the new data fit with his earlier contention that the Pirahã use words that approximately mean *one*, *two* and *many*. He likens such usages to the English phrase *a couple of*. This phrase typically refers to two items but sometimes gets applied to slightly larger quantities.

In Gibson's study, the common meaning of *two* was triggered in Pirahã volunteers if they heard it used immediately after the term for *one*. Thus, in the ascending spool count, participants only used *one* to refer to a single spool and the term *two* to refer to a pair of spools or sometimes to larger quantities, Gordon asserts. In the descending count, the *two* term preceded the *one* term, leading to confusion and a more variable use of the terms, he says.

In upcoming studies, Gibson's team plans to assess whether the Pirahã understand that if one object is added to or removed from a large number of identical objects, then the quantity has changed. The researchers also want to see how the Pirahã use quantifying terms such as *all* and *none* to deal with increasing and decreasing amounts of items. For now, count on Brazil's Pirahã villagers to stimulate further scientific debate about the link between numbers and language. ■

Back Story Theories on language and thought

Franz Boas

A century ago, Boas proposes that the culture and worldview of a people are reflected in language.

Edward Sapir

Boas' student, Sapir furthers the argument that language and thought are linked.

Benjamin Whorf

Whorf joins Sapir to propose that language determines thinking patterns.

Noam Chomsky

In the '50s, Chomsky argues for an innate grammar common to all languages, challenging Sapir and Whorf's idea.

Daniel Everett

Everett claims the Pirahã language, with no words for numbers or colors, brings many theories into question.

COLUMBIA UNIV.; CANADIAN MUSEUM OF CIVILIZATION, MARIUS BARBEAU PROJECT; MADID/YALE UNIV. LIBRARY; DONNA COVENEY/MIT; D. EVERETT

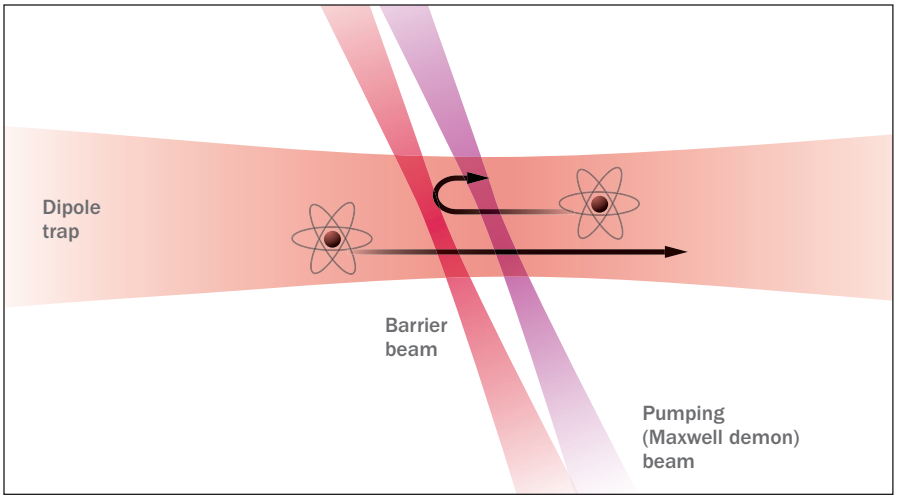
Matter & Energy

450 picokelvin Lowest temperature recorded for matter, reported in 2003 from a lab at MIT

One-way gate mimics 'demon' to trap atoms

Barrier could cool gases to very low temperatures

By Davide Castelvecchi



Parallel laser beams let atoms pass through in only one direction, as if a demon were guarding a microscopic gate. Atoms in their lowest-energy state approach from the left and go through, but atoms from the right become energetically excited and bounce back from the barrier beam.

Like the entrance to hell in Dante's *Inferno*, this gate is one-way only. Physicists have created a laser barrier that lets atoms through only in one direction — mimicking the "demon," proposed by James Clerk Maxwell in a thought experiment, that selectively opens or closes a microscopic gate to let some atoms through but not others.

The method could cool gases to temperatures close to absolute zero, making new kinds of experiments possible. "It's a very nice demonstration of the one-way barrier concept," comments Gabriel Price of the University of Texas at Austin. The laser barrier concept was first set forth in 2005 by Mark Raizen, also of UT–Austin, and his collaborators as a way to cool gases to extremely low temperatures.

Normally, collecting a gas into a smaller volume ends up increasing the gas's temperature, while letting the gas expand lowers it. But the laser barrier stuffs the gas into a smaller volume with only a minute increase in its temperature, Daniel Steck of the University of Oregon in Eugene and his colleagues report in the June 20 *Physical Review Letters*.

Researchers could then let the gas expand and get colder than the temperature at which it started, even approaching temperatures just above absolute zero.

Steck's team first trapped a gas of rubidium atoms using laser light, essentially creating a box with walls made of electromagnetic fields. The researchers added two parallel laser beams that cut through the trap, dividing it in half. The beam on the left acted as a barrier, while the beam on the right played the demon.

The researchers tuned the barrier beam to a frequency that would make it interact with the outermost electron in each rubidium atom. When those electrons were in their lowest-energy state, the beam would let the atoms through. But if the electrons were in a slightly higher-energy orbit — an "excited state" — the beam created a repulsive force that made the atoms bounce back.

Initially, no atoms were excited. Atoms approaching the beams from the left would go through the "barrier" unimpeded. But atoms approaching from the right would first have to cross the demon beam. That beam kicked (the technical term is "pump") the atoms' outermost electrons into their higher-energy state. So they were turned back when they reached the barrier beam.

The pumping beam acted like a demon closing a gate only when atoms tried to cross from right to left. "Eventually, all atoms will get stuck on one side," Steck says. Unlike Dante's gate, though, this one led to a colder place.

While other cooling methods work only on particular elements, the barrier technique could cool a wide variety of atoms and molecules down to less than one ten-thousandth of a kelvin, Steck says. Such cooling allows physicists to study exotic states of matter, and could be helpful for building new kinds of atomic clocks.

A similar cooling trap was described in the March 7 *Physical Review Letters*. A Texas team that included Raizen and Price achieved a similar result with a more complicated setup that included a magnetic as well as an optical trap, with a barrier beam between.

In 1871, Maxwell described the thought experiment of an all-knowing demon that could control which particles could cross a gate between two chambers. Such an entity would have been able to sort particles and thus put more order into the universe.

But the second law of thermodynamics says that the total amount of disorder is to forever increase. In fact, physicists have demonstrated that in order to lower the disorder inside the chambers, any demon will have to produce disorder elsewhere.

In Steck's case, the demon's secret is rather subtle. Like all lasers, Steck's pumping beam is an orderly arrangement of photons, all traveling in the same direction. And a photon increases the energy level of a rubidium atom by scattering off of it. "But the scattered photon goes in a random direction," Steck observes. So while the atoms get a little more order in their lives, the pumping laser ends up with a little less. ■

STECK

Body & Brain

For longer versions of these and other Body & Brain stories, visit **www.sciencenews.org**

Scientists find molecular key to paradoxical pain

Study pinpoints trigger of burning by anesthetics

By Ashley Yeager

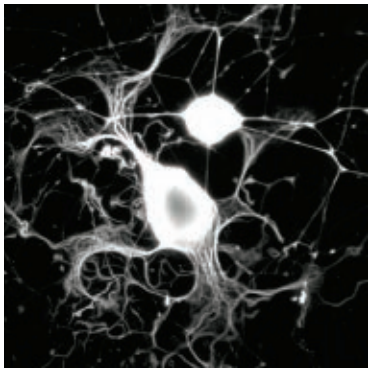
100 ... 98 ... 97 ... 96 ... 95 ...

"Relax. Keep counting," the anesthesiologist says to the patient, who is having her hip surgically replaced. "You won't feel a thing."

Though the woman can no longer feel the dull ache in her hip, she can feel a prickly burning in her arm where a general anesthetic drips intravenously into her veins. It is a sensation she doesn't remember the doctor telling her about, she thinks, as she forces herself to mouth a few more numbers.

94 ... 93 ... 92 ...

For years, patients have reported a burning feeling at the site of a general anesthetic injection, or in the lungs when inhaling gaseous forms of the drugs, which put a patient into an unconscious sleep. But doctors could not pinpoint where the pain response originated.



Some general anesthetics trigger sensory neurons like the ones shown here.

Now scientists have confirmed the patient perspective and identified the pain-promoting trigger associated with anesthesia. What's more, some anesthetics can also increase pain after surgery by adding to swelling of the tissue being operated on, a team of scientists from Georgetown University in Washington, D.C., reports in the June 24 *Proceedings of the National Academy of Sciences*.

The ion channel protein called TRPA1 is present on sensory neurons, found in most body tissues. Anesthetics activate this protein, also called the mustard-oil receptor, causing nerves to fire electrical signals. That message tells the brain that something painful is happening.

"Probably what is most significant for people to know is that this activation of a pain channel actually adds to post-surgery inflammation, so what we didn't know before was that you could exacerbate swelling of surgery-damaged tissue with general anesthetics," says Georgetown neuroscientist Gerard Ahern, who oversaw the new study with lead author and Georgetown postdoctoral researcher José Matta. "I don't think anyone has ever considered that before."

Until now, scientists did not understand how anesthetics activate and sensitize pain-response neurons in the peripheral nervous system. So anesthesiologists have not known how to reduce the drugs' painful side effects. The findings may lead to development of new anesthetics or increased use of the few anesthetics that don't add to post-surgery pain and inflammation.

"Now that we know the mechanism that triggers these ill side effects ... we can get closer to finding a single agent, a single general anesthetic to use rather than a bunch of drugs together," says Tim Hales of George Washington University in Washington, D.C., a neuropharmacologist not involved in the research. "The fewer drugs we have to administer, the safer it is for the patient. That single anesthetic is the ultimate, long-term goal."

Studying the inflammatory effects of different anesthetics in humans will also help doctors determine whether the pain of more inflammation is worth the benefit of healthier tissue healing, says Robert Pearce, chair of the anesthesiology department at the University of Wisconsin–Madison.

NEWS BRIEFS

Testing for sound bones

X-ray technology is the gold standard for measuring bone density, but cheaper ultrasound scans can provide useful density measurements, a new study in the July *Radiology* finds. Idris Guessous of Emory University in Atlanta and colleagues in Switzerland tested ultrasound on one heel each of 6,174 women ages 70 to 85. The researchers classified participants as having a good score or a poorer one. Over the next three years, roughly 6 percent of those with poor ultrasound scores broke a bone compared with less than 2 percent of the others. —*Nathan Seppa*

Wishful thinking

SAN FRANCISCO — Guys who receive a shot that might or might not be growth hormone are more likely than women to believe it's the real thing, a new study finds. And men who got fake shots actually scored higher on a jumping test than they did in previous tests, Ken Ho of the University of New South Wales in Sydney, Australia, reported June 17 at a meeting of the Endocrine Society. The study team is still evaluating the participants who received real growth hormone to see whether they benefited. —*Nathan Seppa*

Vessel rescue

The drug losartan may prevent lethal damage to the aorta in people with a genetic disorder called Marfan syndrome, preliminary findings suggest. From 2003 to 2006, Johns Hopkins University researchers identified 18 children with severe Marfan syndrome, including steadily widening aortas in the slow process of forming aneurysms near the heart. Enlargement of the aorta slowed in every one of the patients given losartan or a similar drug, the researchers report in the June 26 *New England Journal of Medicine*. —*Nathan Seppa*

MAX DELBRÜCK CENTER FOR MOLECULAR MEDICINE

Energy deficit interrupts periods

Athletic girls face hormone imbalance from too few calories

By Nathan Seppa

SAN FRANCISCO — Roughly one-fourth of high school and college female athletes stop having periods at some point, far more than the 2 to 5 percent rate in women overall, surveys have shown. A new study reveals a hormone imbalance that might help doctors identify girls at risk of losing their monthly cycle.

A stoppage of periods, amenorrhea, results in temporary infertility and can reduce bone density. Previous research indicates that amenorrhea strikes girls and young women who exercise extensively but have a calorie intake that doesn't satisfy their bodies' needs, leading to what scientists call a state of "energy deficit." Amenorrhea results from internal priorities, enforced by hormones, that allot the athletes' nutrients. Researchers say that the body's reproductive system loses out in a tug-of-war for calories.

Amenorrhea, a stoppage of periods, shows up in girl athletes who don't get enough calories to meet their bodies' needs.

The new study looked at blood levels of two appetite-regulating hormones, ghrelin and leptin, in 40 female athletes and 18 non-athletic females, all 12 to 18 years old. Ghrelin is known for stimulating appetite and leptin for signaling satiety, but the study suggests they also influence estrogen manufacture and secretion.

About half the athletes had amenorrhea. These girls also had higher ghrelin levels and lower leptin levels compared with the athletes who were still having periods, says study coauthor Madhusmita Misra, an endocrinologist at Harvard Medical School and Massachusetts General Hospital in Boston. That means changes in ghrelin and leptin may throw off production of estrogen or other reproductive hormones necessary for having regular monthly cycles, says Misra, who presented the findings June 16 at a meeting of the Endocrine Society.

The researchers also found that the girls with amenorrhea had significantly poorer bone density than the others.

While the infertility is easily reversed, the reduction in bone density poses a greater problem. "These might be girls who will be at risk later in life," says Nanette Santoro of the Albert Einstein College of Medicine in New York.

DNA packaging runs in families

Epigenetic shifts also continue throughout life

By Tina Hesman Saey

If you find yourself becoming more like your parents, don't blame it just on your genes. Epigenetics may be responsible too.

Epigenetics refers to changes to DNA that don't alter the genes themselves but nudge their level of activity up or down, much like a thermostat controls heating or cooling. Controlling gene activity is important for guiding development and maintaining health.

A team of scientists reports in the June 25 *Journal of the American Medical Association* that one form of epigenetic modification, called DNA methylation, changes throughout an individual's life and that families tend to have similar patterns of change.

"These are fascinating findings because the standard model for epigenetics has been that DNA marks are immutable once set down as part of development," says J. David Sweatt, director of the McKnight Brain Institute at the University of Alabama, Birmingham. Sweatt was not involved in the current study. "The new findings ... strongly support the emerging idea that the epigenome is dynamically regulated over the lifetime of a person, perhaps in response to environmental signals, life experiences and as part of the normal aging process."

Such changes have been proposed to contribute to diseases, including cancer, that don't appear until late life, but, before now, there was little evidence to show that epigenetic settings change as a person ages, says Andrew Feinberg, director of the Center for Epigenetics at Johns Hopkins University in Baltimore, and an author of the new study.

Feinberg and his colleagues examined DNA methylation in 111 people from Iceland and 126 people from Utah. Each participant contributed two DNA samples, collected years apart.

Some of the people increased overall methylation of their genes as they aged. Others reduced methylation. The number of people who increased methylation was about the same as the number of people who decreased methylation, Feinberg says. That could account for why an earlier study that averaged methylation levels in groups of people instead of following individuals over time failed to find epigenetic changes associated with aging.

CATHRINE WESSEL/CORBIS

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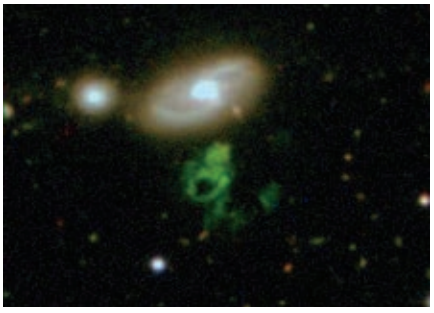
School teacher spots green blob

Mystery object appears to be a starless dwarf galaxy



After seeing an uncorrected version of this image, a school teacher alerted astronomers.

By Janet Raloff

Within a few weeks, astronomers are expected to formally report the discovery of an intensely hot, green ring of gas. They'll make a Dutch primary school teacher an honorary coauthor to credit her for first drawing their attention to this apparently starless dwarf galaxy. It's unlike any celestial object known.

Neighboring a massive spiral galaxy known as IC 2497, the newfound object radiates with an intensity and temperature higher than could be accounted for by ordinary starlight, observes astronomer William Keel of the University of Alabama in Tuscaloosa.

He reports that analyses of the object's emissions, earlier this year, suggest that it is being "lit by the ultraviolet light and X-rays from a quasar that has vanished in the last 100,000 years." The quasar's telltale ghostly radiance, or light echo, indicates the blob is very warm — probably 16,000° to 20,000° Celsius.

Quasar-light echoes have been witnessed ricocheting within small clouds, notes Chris Lintott of the University of Oxford in England. But none has ever illuminated a galaxy-sized object, as is being done here. That is among the features making this new object "weird," Lintott says — even "unique."

Last July, he and other astronomers at several universities invited the public to visit a website named Galaxy Zoo and help catalog never-before-seen distant galaxies. The false-color images had been collected as part of the Sloan Digital Sky Survey.

Within a month, Hanny van Arkel, of Heerlen, the Netherlands, signed on. A few days later, she recalls, a strange deep-blue object in one photo made her do a double take. She reported the mystery blob — which, in true color, is deep green — and it soon became affectionately known as Hanny's Voorwerp (Dutch for "object").

Hanny's Voorwerp has proven so strange that astronomers have since been feverishly requesting observing time on telescopes around the world to learn more about it. Indeed, word arrived on May 30 — van Arkel's 25th birthday — that the Hubble Space Telescope would train its eye on this prize for seven orbits next year.

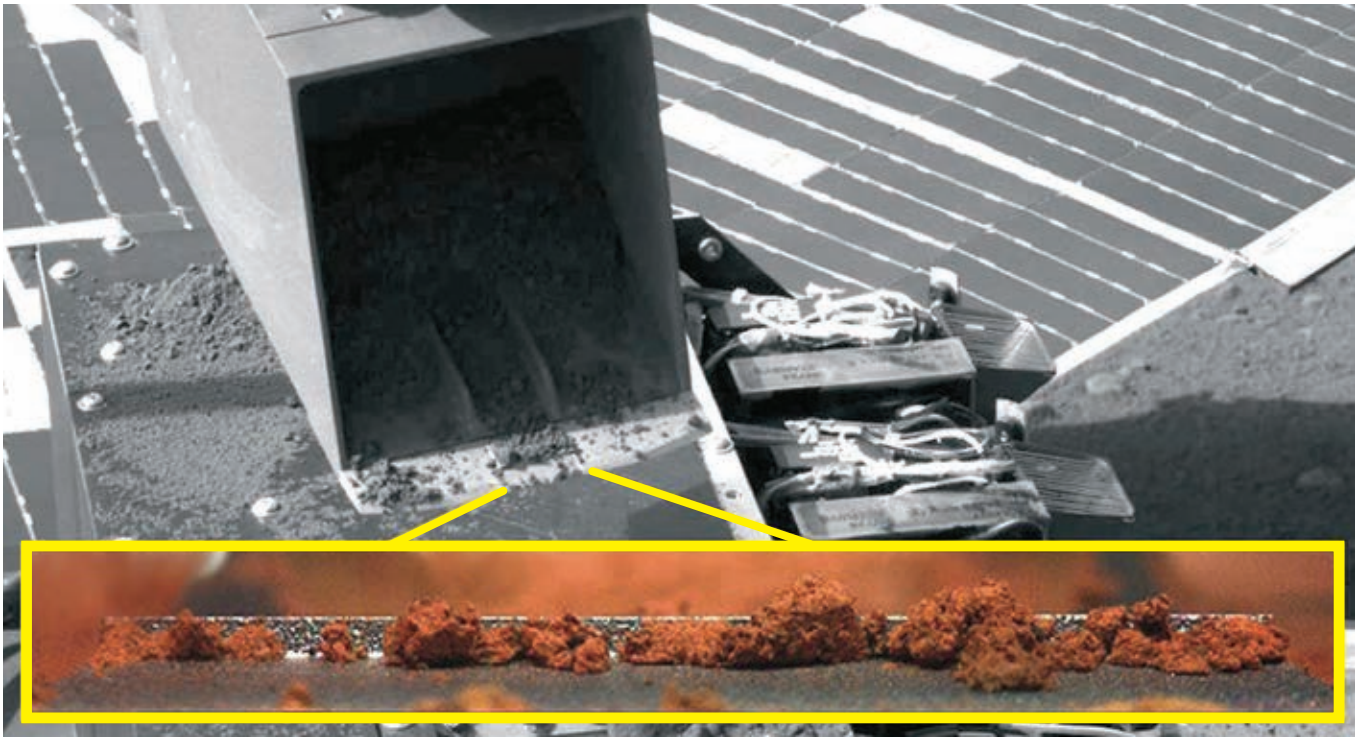
In its first year, the Galaxy Zoo project turned up plenty of other weird objects as well, Lintott reports, such as "this wonderful object called a 'blue banana.'" He is clueless about what it might be, but he says that "at some point I've got to spend a few days trying to find out."

Crows Lintott: "This is what I used to think astronomers did. We found something weird, looked at it with everything we could get our hands on and then worked out what it is." ■

M. MARINOVA ET AL./CALTECH; GALAXY ZOO TEAM, ISAAC NEWTON TELESCOPE

Impact may have scarred Mars

Mars has two faces: a northern hemisphere with smooth, low ground and a southern hemisphere with a high elevation and many craters. "It's one of the really striking things about the planet," says Steven Squyres of Cornell University. Now, three papers in the June 26 *Nature* offer an explanation. "Something big smacked into Mars and stripped half the crust off the planet," says Francis Nimmo of the University of California, Santa Cruz, lead author of one of the studies. In 1984, Squyres and astrogeologist Don E. Wilhelms suggested that a single impact caused the dichotomy in the Martian surface. The new studies support this idea. By mapping surface elevations, crustal thickness and variations in gravitational pull, MIT's Jeffrey Andrews-Hanna and colleagues uncovered a gigantic scar — a pockmark covering about 40 percent of the planet's surface. "Finding this elliptical boundary is a smoking gun," Andrews-Hanna says. Only an impact could make such a shape, he adds. Working independently, two modeling groups simulated slamming different-sized objects into Mars (image shown) to pinpoint the "sweet spot" conditions that could gouge out such a scar but not melt the planet's entire crust. Their findings fit well with the MIT report. —*Ashley Yeager*



Lander hints at water, nutrients on Red Planet

Phoenix continues to dig and analyze soil samples

By Ron Cowen

The first analyses of Martian soil scooped up last month by the robotic arm on NASA's Phoenix Mars Lander support the notion that liquid water has flowed on the Red Planet.

A cubic centimeter of Martian soil — about the volume of a sugar cube — delivered to one of the miniature laboratories on the lander revealed several water-soluble elements and inorganic compounds, including sodium, potassium chloride and magnesium, reported Samuel Kounaves of Tufts University in Medford, Mass. Kounaves leads the lander's wet-cell lab experiment, which adds water to samples in order to detect soluble substances.

"We have found what appears to be the requirements — the nutrients — to support life [on Mars], whether in the past, present or future," he said during a telephone press briefing on June 26. The findings, he added, are one more piece of evidence showing the presence of salts created by "some sort of liquid action at some point in the history of Mars."

"We were all flabbergasted by the data we got back," Kounaves said. He noted that the composition of material analyzed by the wet-cell laboratory appears strikingly similar to that of the dry valleys in Antarctica on Earth.

The analysis also revealed that the soil is alkaline, between pH 8 and 9, which surprised some researchers, Kounaves said.

A separate analysis of the first soil sample heated to 1,000° Celsius in one of Phoenix's tiny ovens — the first time any parcel of a planet other than Earth had been artificially heated to such high temperatures — showed that the grains contain carbon dioxide and water vapor.

"The soil has clearly interacted with water in the past," said William Boynton of the University of Arizona in Tucson.

The Phoenix Mars Lander's robotic arm (pictured above) collected small clumps of Mars' fine, red soil (inset). Analyses of the soil in one of the lander's miniature ovens revealed that the planet may have once possessed the liquid water required for life.

"We don't know whether that interaction occurred in this area in the northern polar region or might have happened elsewhere and been blown to this area as dust." Boynton leads the team operating the Thermal and Evolved Gas Analyzer, a set of eight single-use ovens.

Phoenix's signature robotic arm has been scooping soil for chemical analyses since the craft landed safely in the planet's arctic region on May 25.

In another first, the robotic arm scraped icy soil in the Wonderland area on June 26. The arm flattened the layer where soil meets ice, exposing the icy surface below the soil.

The next step is to scoop ice samples into Phoenix's analytical instruments. Scientists want to find out whether that ice may have been liquid in the past and could have offered a haven for microbial life on the Red Planet. ■

JPL/NASA, U. OF ARIZONA, MAX PLANCK INSTITUTE

Life

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Vanilla's genetic flavor is bland

Low diversity suggests difficulty in fighting off pests

By Rachel Ehrenberg

Scientists have now tasted the genetic makeup of *Vanilla*, the orchid whose pods bestow flavor on ice cream, perfume and rum. And they found it's pretty plain.

Genetic diversity in *Vanilla planifolia* is "very, very, very low," says Pascale Besse, a plant geneticist at the joint research center PVBMT Cirad and the University of Réunion who led the research, which appears in the July *American Journal of Botany*. Besse and colleagues examined a stretch of genetic code in more than 300 vanilla plants from Réunion Island, Madagascar, French Polynesia, Mexico, Central America and Brazil.

The findings are worrisome, the researchers say. The blandness of the plant's DNA suggests that cultivated vanilla is a monoculture, lacking the genetic variation that would help in a face-off with pests or disease.

But even with Plain Jane DNA, there is consistent physical variation among the surveyed orchids — differences in leaf shape and size, pod shape, stem thickness and self-fertility, the researchers report. This physical variation in vanilla plants, without the variation at the genetic level, suggests some intriguing things might be going on — perhaps epigenetic modifications that don't actually alter the DNA code but can crank up the volume of certain genes while silencing others.

"This opens the doors to a lot of research," comments Ken Cameron, a botanist at the University of Wisconsin–Madison. "By many estimates, vanilla flavor and fragrance is the most popular on Earth — it's in thousands of products."

Cameron says other work has shown interesting chromosomal traits in vanilla, and the new study offers hope that the crop will survive into the future despite its lack of genetic diversity.

Tapping into the biochemical diversity, investigating hybrids and looking more closely at some of the other 50 to 90 related species could provide a lot of variation for breeders to work with.

Blossoms of the orchid *Vanilla planifolia* must be pollinated within 12 hours of opening or pods — and thus the beans — won't develop.

Environment drives fashion sense

Lady damselflies aren't just mimicking the male color

By Susan Milius

MINNEAPOLIS — It's not the sexual harassment. It's the sunshine. That's Idelle Cooper's new take on the evolutionary force driving female Hawaiian damselflies to dress like males. The slim bodies of male *Megalagrion calliphya* damselflies shine fire-engine red, says Cooper, of Indiana University in Bloomington. Species-wide, half the females have grass-green bodies, but the others sport the brilliant guy-red.

Male Hawaiian damselflies shine fire-engine red (bottom right). At low altitudes, green females are easy to distinguish from the males (top right). But as altitude increases, red females become more common and can be seen mating with red males (left).

I. COOPER; M. GRISONI

Such cross-dressing females show up among insects, lizards and birds. And biologists have typically suggested that this male mimicry reduces the relentless pursuit by sex-obsessed males.

These damselflies, though, may be adapting to their habitat rather than avoiding annoying propositions, Cooper reported June 23 in Minneapolis at the Evolution 2008 meeting.

While the males stake out territories on exposed streambeds, females stay in adjacent shrubbery, visiting the males for mating and egg-laying.

In sparse, high-altitude vegetation, Cooper found females in landscapes as sunny and exposed as male territories. There, both sexes are bright red. Her work also suggests that red pigments defuse potentially damaging free radicals in tissues exposed to sun.

The finding could lead to closer looks at other male-colored females, says Laura Sirot of Cornell University.

Earthworms keep house

These ecosystem engineers collect and plant ragweed

By Rachel Ehrenberg

Unlike Richard Scarry's Lowly Worm, real worms don't drive cars or go to school. But the wriggly creatures appear to live a more purposeful life than previously thought. Earthworms deliberately gather and bury ragweed seeds from around their burrows, reports a new study in the *Journal of Applied Ecology*.

The findings fit with recent work documenting how nonnative earthworms are changing northern U.S. forests. Though native worms were wiped out from the northern United States in the last glaciation — only persisting south of the ice sheet and permafrost — European worms arrived with settlers. The worms are slowly changing deciduous forests by eating through the leaf litter and "duff" that native plants need to thrive.

"Worms do a great job in gardens, it's true," comments Cindy Hale of the University of Minnesota Duluth. "But take the same organism and put it in a native hardwood forest that's evolved over 10,000 years earthworm-free, and the worms change everything about the ecosystem."

In the study, seeds that the worms buried grew into the healthiest plants, suggesting that the crawlers' activity could help not only ragweed thrive, but perhaps also help invasive plants gain a foothold in new territory, Hale says.

Weed ecologist Emilie Regnier of Ohio State University in Columbus and her colleagues conducted field experiments to determine how exotic European night crawlers, *Lumbricus terrestris*, affected the survival of the seeds of *Ambrosia trifida*, giant ragweed.

In addition to its prowess as an allergen, ragweed is a major weed of soybean fields and cornfields in the Midwest, Regnier says. This fact has puzzled scientists because ragweed seeds are usually quickly eaten by birds, rodents and beetles.

Worms collected and buried more than 90 percent of ragweed seeds from the surface of the soil around their burrows, the team reports. There were six times as many seeds in the worms' burrows as in the surrounding soil, and after one season, there was an average of 127 seeds per burrow. These night crawlers buried some seeds as deep as 22 centimeters.

The work enhances understanding of plant-animal interactions, Regnier says.

"We were astonished by how quickly the seeds were removed," she says. "We think of ants and mice and squirrels as being very important in dispersing seeds. Here's a new mechanism — they are burying them quite deliberately."

On their own, nonnative worms probably spread only 10 meters a year, but they move faster with human help. Leftover fishing bait should be thrown in the trash, Hale says, not dumped in the dirt. It's likely that the worms will keep moving west — not in a car with Lowly Worm — but with humans, the same way they arrived.

Chimp noises suit audience

Females' sex sounds depend on eavesdroppers

By Susan Milius

When a chimp has sex in the forest, will she make a sound?

Depends in part on who's listening, literally, says a scientist who spent months recording chimp sex sounds in the wild.

With lots of females within earshot, a female chimp typically doesn't give a call, says Simon Townsend of the University of St. Andrews in Scotland. With a largely male audience, though, she's more likely to make copulation squeaks or screams, rhythmic high-pitched sounds that could be spelled "eeeeee! eeeeee!"

And partners matter. Even if she is not fertile, she's more likely to vocalize when she's with a high-ranking male than with a low ranker. The benefit of this strategy could be that she avoids attacks from other females while confusing males about who's going to be the dad, Townsend and his colleagues propose in the June *PLoS ONE*.

"It's very elegant and quite novel," says Stuart Semple of Roehampton University in London. Past work looked at male reaction, so studying the effects of a female audience brings a new dimension. Also the new paper does not support a widely expected benefit of female calling, he says.

Just what benefits might drive animals to make these calls, often among the loudest in a species' repertoire, has long intrigued evolutionary biologists. Lions, elephants and plenty of other animals get noisy. An influential 1977 paper on elephant seals theorized that a loud female incites males to compete for her, attracting the attention of the top guy in the neighborhood.

Among chimps, Townsend found, females called only 36 percent of the time, and the pattern didn't fit the standard idea of male incitement. The females called less, not more, when they were with lower quality males, and the females called before, during and after ovulating.

So Townsend argues that the females give confusing signals about paternity, possibly enlisting the support of important males in case other females attack.

ISTOCK/ LEPETITKARSTEN

Humans

"The word for anger is not the same in Russian and in English, but the expression is." —PAUL EKMAN

Where funny faces come from

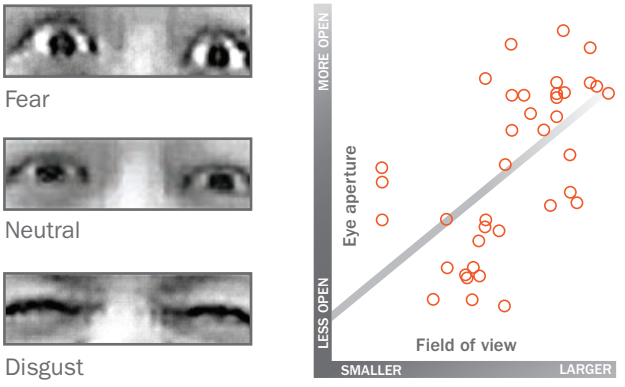
Looking afraid once served a different purpose

By Amy Maxmen

Faces say so much that Google's Gmail includes more than 20 emoticons to make up for the personal touches e-mail lacks. But those basic expressions, so important in conversation, didn't originate for communication's sake, psychologists say.

At least two emotional expressions, those of fear and disgust, first served to moderate sensations coming in from the outside world, researchers reported online June 15 in *Nature Neuroscience*. Terrified eyes widen and nostrils flare to monitor the surroundings, and the nose crinkles in disgust to impede nasty odors.

Darwin hypothesized that faces once acted to protect the beholder, like a flexible shield between the atmosphere and sensory receptors within the eyes, nose, mouth and ears. Yet until now, that idea hadn't been tested and most people have believed that expressions are just a way to communicate, says Adam Anderson, a cognitive neuroscientist at the University of Toronto who led the study.



Wide, frightened eyes correlate with a larger field of vision, and squinting, disgusted eyes see less. Both may be protective.

Researchers measured the field of vision for study participants who pretended to be freaked out or grossed out. When participants put on a fearful face, their eyes widened and they detected lights flashing above their heads. When acting disgusted, they squinted and couldn't see the flashing lights. Using MRI, the researchers measured how much air the participants inhaled during each facial expression. Air intake increased when people wore a fearful expression and decreased when they looked revolted. The results support the idea that fearful faces observe more of the surrounding environment while disgusted faces see less.

As communication arose in groups, facial expressions might have acquired a second, more vital role in sending signals to others, the researchers suggest. They reason that if expressions had originated for communication, expressions should be as variable as language.

"The word for anger is not the same in Russian and in English, but the expression is," agrees Paul Ekman, a psychologist at the University of California, San Francisco, who has studied facial expressions from more than 30 cultures.

The original functions of other nonverbal expressions remain elusive, Ekman says, noting that Darwin didn't even touch on the smile.

Girls could give preschool boys learning boost

Proportion of boys in the class doesn't affect girls

By Bruce Bower

Here's some news preschool boys don't want to hear: Those who attend classes with a majority of girls receive an intellectual boost by the end of the school year.

Conversely, preschool boys who attend majority-boy classes fall increasingly behind girls on measures of learning skills and other developmental feats. Yet class sex ratio has no effect on the girls.

These provocative but still preliminary findings come from the first large-scale investigation of how the sex ratio in preschool classes influences girls' and boys' mental, social and motor development.

"At the very least, the findings from this study suggest that educators should exercise caution if considering a move toward greater sex segregation in early childhood education," says psychologist and study director Arlen Moller of Gettysburg College in Pennsylvania.

Moller and his colleagues analyzed data collected as part of an effort to assess classroom needs in Rochester, N.Y. The team found that girls displayed generally good progress during the school year on teacher-rated measures of thinking skills, social abilities and motor proficiency, whether in classes of mostly boys or girls.

Boys developed more slowly than girls did on the same three measures, and especially on thinking skills, if they attended classes with a surplus of boys. In majority-girl classes, boys developed at the same rate as girls, the researchers say in a paper slated to appear in *Early Childhood Research Quarterly*. Moller plans to further examine reasons for the learning differences.

"This is an exciting topic, but it is too early to draw any conclusions because this area is so underexplored," remarks psychologist Lena Malofeeva of High/Scope Educational Research Foundation in Ypsilanti, Mich.

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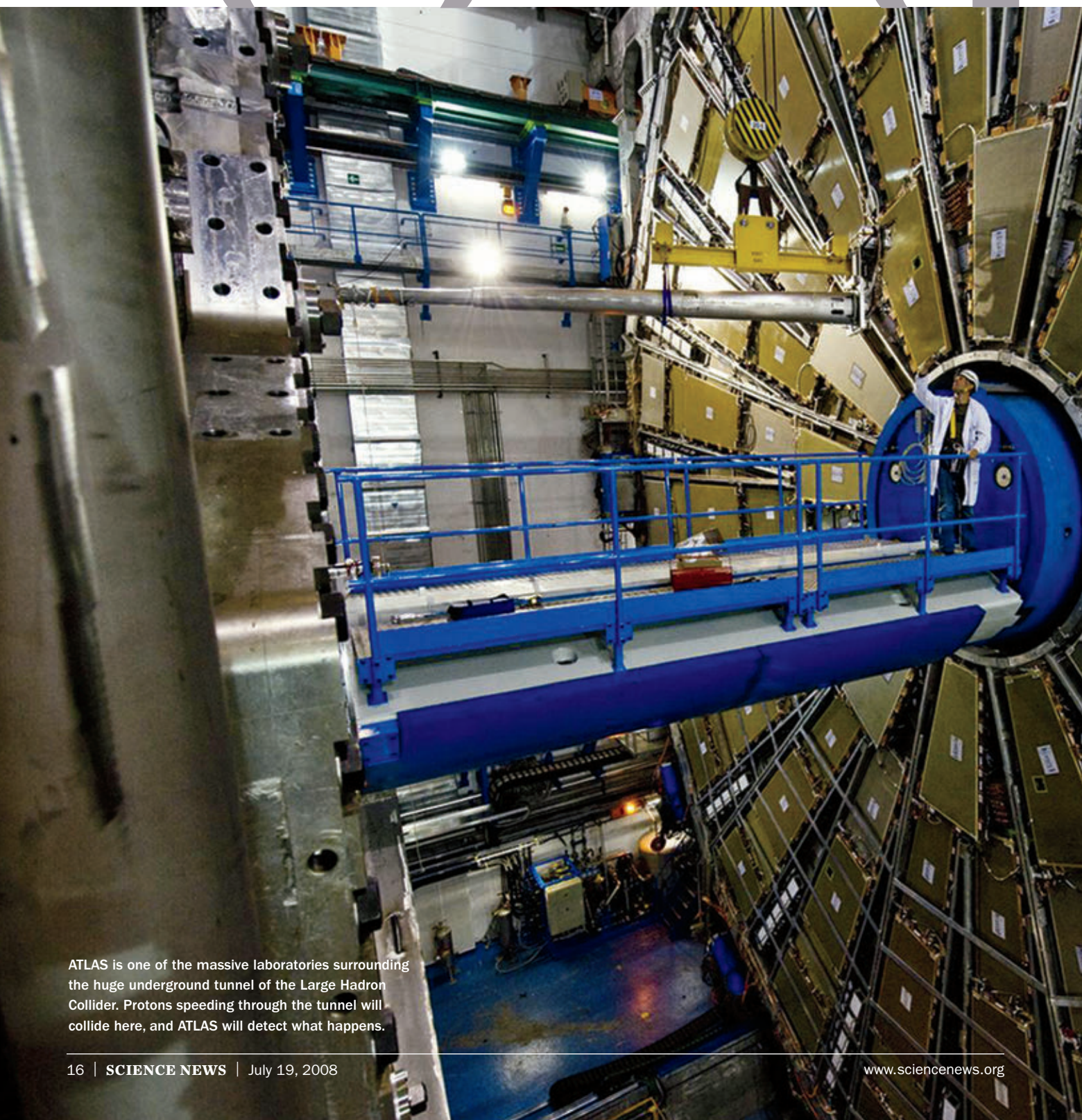

ATLAS is one of the massive laboratories surrounding the huge underground tunnel of the Large Hadron Collider. Protons speeding through the tunnel will collide here, and ATLAS will detect what happens.

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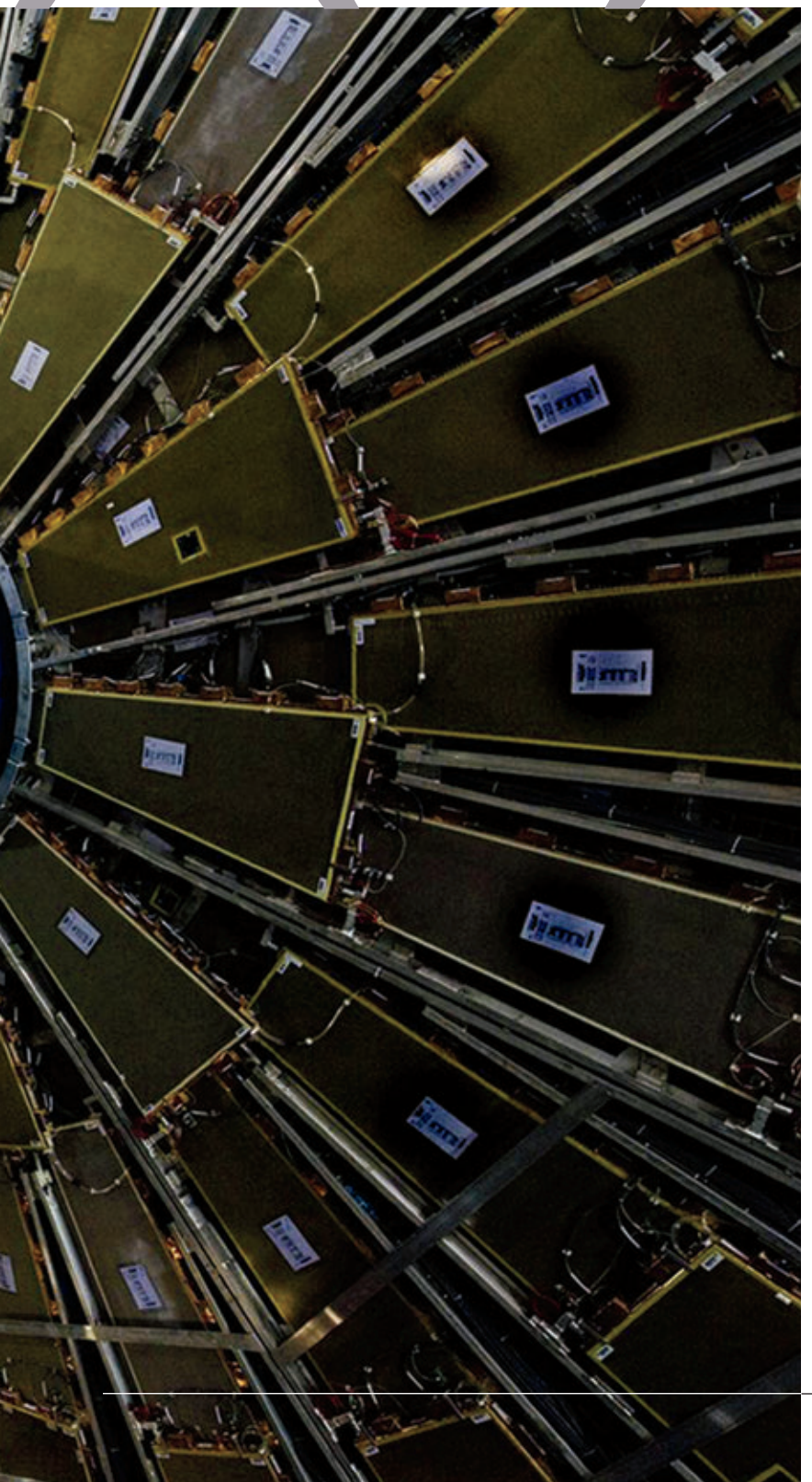


This fall, the massive Large Hadron Collider beneath France and Switzerland will switch on. Protons moving at almost the speed of light will collide with energies high enough, physicists hope, to solve matter's biggest mysteries.

By Ron Cowen

The hammering has stopped, the whining of power tools has abated. Only the hum of electronic detectors reverberates through the cavernous, eight-story space below the Swiss-Franco border that is stuffed with 9,300 magnets and enough niobium-titanium wire to stretch to the sun and back five times.

But by September, if all goes according to plan, two narrow beams of protons moving in opposite directions will begin making laps around the underground laboratory's 27-kilometer–long subatomic racetrack. The protons will pass from Switzerland to France without benefit of a passport, and smash into one another up to 600 million times a second.

The most violent of those collisions will generate the heat, energy and densities that existed just a trillionth of a second after the Big Bang. And like a movie in perpetual rewind, these primordial re-creations will repeat about once a second.

This is the Large Hadron Collider, or LHC, the mammoth atom smasher operated by the European Organization for Nuclear Research, better known by its French acronym, CERN. More than 15 years in the making, everything about the LHC is enormous, from the energies it generates — 14 trillion electronvolts — to the nearly 60 metric tons of liquid helium required to cool its magnets, to the 20,000 tons of metal it houses and to the staff of thousands of scientists involved. All this just to study the tiniest particles in the universe.

CERN

But more than the $8 billion price tag is riding on the LHC. Depending on what's detected, physicists may find out if they understand the fundamental building blocks of nature, or if "everything that physicists have been talking about for 45 years is wrong," says CERN theoretical physicist John Ellis.

More parochially, the success of the LHC may vault Europe over the United States as the champion in physics research. The United States once had plans to build an even more powerful — and more costly — accelerator, the Superconducting Super Collider, but that project was scrapped when Congress eliminated funding 15 years ago.

As revealed in Einstein's famous equation, $E=mc^2$, the enormous energies generated at the LHC will translate into large masses — and, particle physicists hope, a cornucopia of subatomic particles never before seen. Many are betting that they will see evidence of the elusive Higgs boson, a hypothetical particle first proposed in the 1960s that could help explain why some elementary particles have mass. Finding the Higgs would be the crowning achievement for what physicists call the standard model, a highly successful theory that unifies three of the four known forces in nature and groups the fundamental constituents of matter into two broad categories.

But researchers are hoping for more than a confirmation of the standard model. "I'm certainly not going to yawn if they find a Higgs boson; we'll break out the champagne and won't answer the phones for a week," Ellis says. "But that's somehow an expected discovery."

Physicists hope the LHC will lead them beyond the standard model — to signs of extra dimensions, curled up into volumes of space so tiny they're barely detectable; and to rapidly evaporating, microscopic black holes that the accelerator might forge.

And if scientists are really lucky, Ellis says, the experiments at LHC might double the scientists' pleasure, revealing a whole new set of elementary particles. According to a theory known as supersymmetry, every particle in nature has a heavier partner whose spin differs by a half integer. Supersymmetry would unite two seemingly disparate groups of particles.

On one side of the divide are the bosons, the particles that act as messengers for the four fundamental forces in nature. These include the photon, which communicates the electromagnetic force; the W and Z, which mediate the weak nuclear interaction; and the gluon, which transmits the strong nuclear force. On the other side stand the fermions, the particles that react to those forces — electrons, quarks and the like. Supersymmetry says that the two groups belong under the same umbrella, residing in one big happy family.

Moreover, the lightest supersymmetric particle, called the neutralino, could be a candidate for dark matter, the long-sought, invisible material that astronomers say must exist to keep galaxies intact and galaxy clusters from flying apart. There simply isn't enough ordinary visible matter to provide the requisite gravitational glue. The dark matter particles would provide the extra tug and account for more than 80 percent of the mass of the universe.

"That would be the fantastic breakthrough — that we would finally know what most of the matter in the universe is," says physics Nobel laureate Steven Weinberg of the University of Texas at Austin. "I don't think there's anything more exciting likely to come out of the LHC."

Meeting the experiments

Inside the LHC tunnel, the twin, hair-thin proton beams rev up to speeds approaching that of light. Steering them around the racetrack are 1,232 dipole magnets. Each magnet weighs 35 metric tons and is supercooled to 1.9 degrees Celsius above absolute zero.

For most of their journey around the ring, the beams travel in separate vacuum pipes, but at four points they collide. These are the hearts of the main experiments, known by their acronyms: ALICE (A Large Ion Collider Experiment), ATLAS (A Toroidal LHC Apparatus), CMS (Compact Muon Solenoid) and LHCb (Large Hadron Collider beauty).

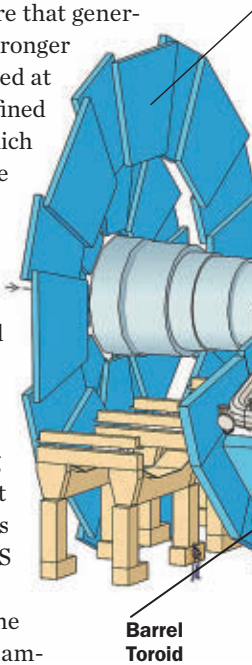
ATLAS and CMS, the largest, are the major players. Both ATLAS and CMS fully enclose the portals where collisions happen, leaving no gaps for particles to escape without detection. Although they can't flee, many of the particles rapidly decay into a spray of other, more stable members of the subatomic zoo. Like CSI detectives, scientists will measure the energy, mass and paths of those final particles to find out what happened in the collisions.

The cores of ATLAS and CMS — the parts closest to the collision sites — contain particle trackers made of silicon wafers. Charged particles traveling through the wafers create electrical signals that reveal their passage. The CMS experiment alone has enough wafers to tile an 8-meter–deep Olympic-sized swimming pool.

Just outside the wafers lie calorimeters, devices that slow down and absorb particles in order to measure their energies. Muons, the heavy cousins of electrons, are an especially precious commodity because they are both easy to detect and would be produced as end products in any reactions involving the Higgs boson.

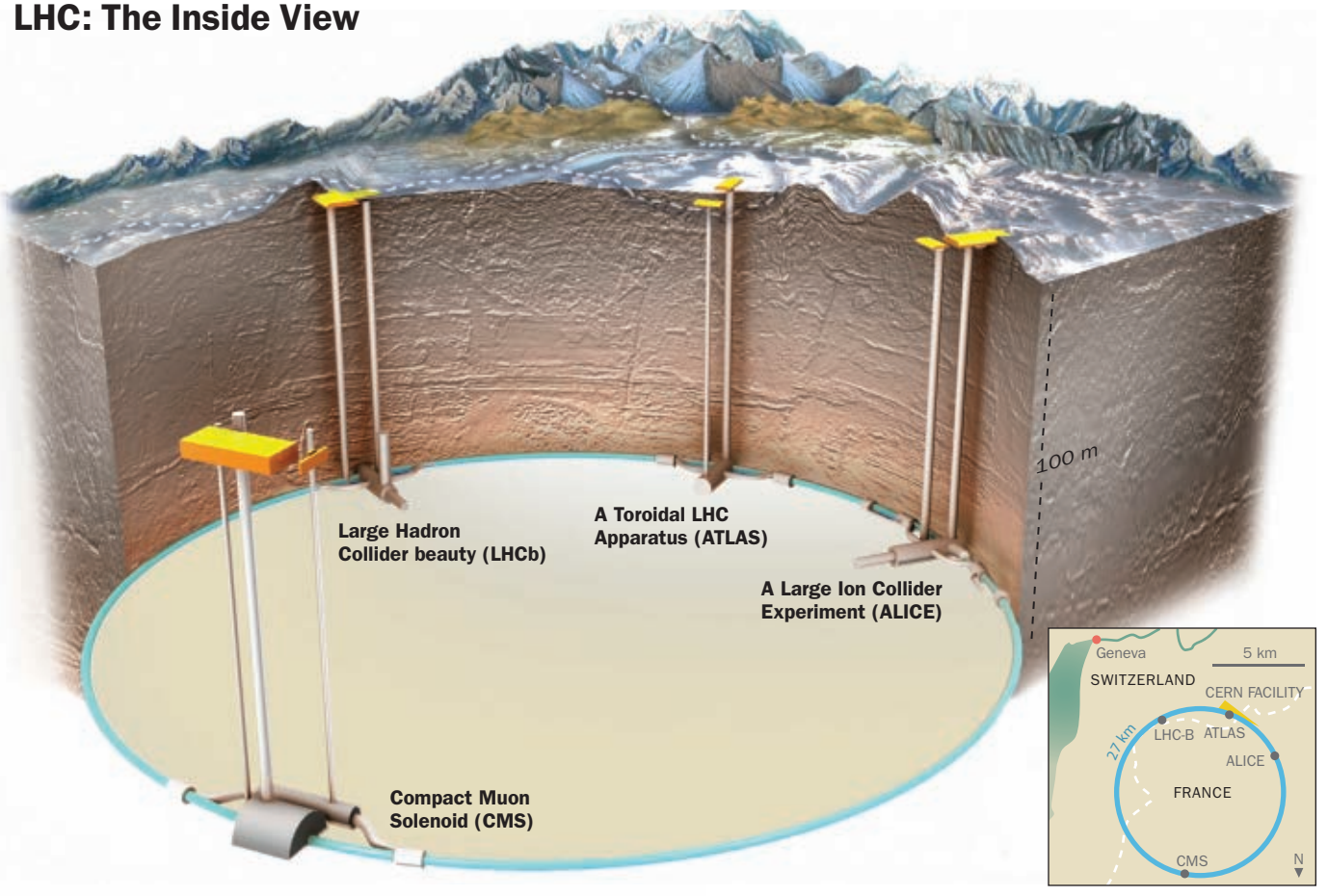
Both CMS and ATLAS have powerful magnets that curve the paths of charged particles. The amount of curvature reveals the particles' momentum and charge, allowing researchers to identify which charged particles are created directly or as a by-product of the collisions. CMS' magnet is in the shape of a solenoid, a cylindrical coil of superconducting wire that generates a field 100,000 times stronger than that of Earth (measured at the surface). The field is confined by a steel clamp or yoke, which accounts for the bulk of the detector's 12,500 tons.

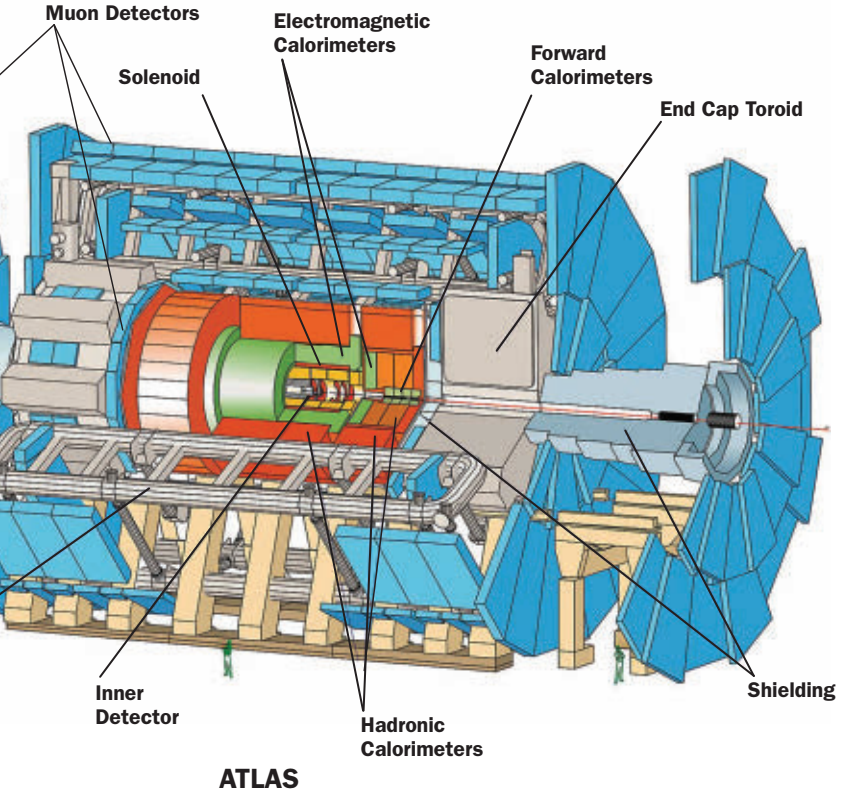
In contrast, ATLAS uses a doughnut-shaped magnetic system, consisting of a ring of eight supercooled coils. The design requires no yoke and allows ATLAS to be eight times the size of CMS — 46 meters long and 25 meters high — yet only half the weight, notes Fabiola Gianotti, an ATLAS researcher at CERN.



Though searching for the same particles, the two mammoth experiments are independent. CMS, located beneath France, has better precision for measuring muons and

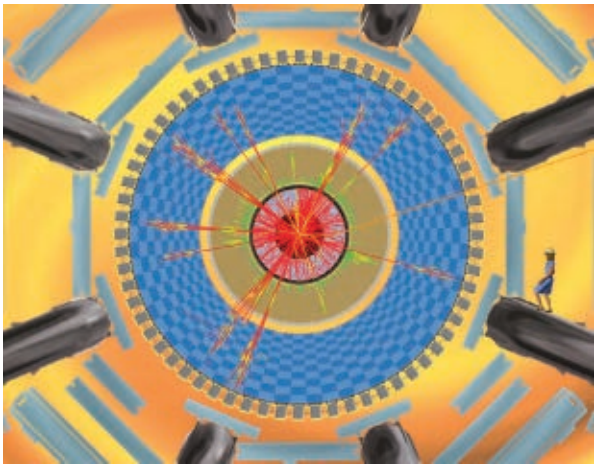
LHC: The Inside View





ATLAS

The Large Hadron Collider is just that: large, as shown by the illustration above. In it, protons (which are in the hadron category of particles) will collide at speeds nearing that of light. Each of four main laboratories along the 27-kilometer LHC tunnel is designed to detect different outcomes of the high-energy collisions. The ATLAS laboratory, illustrated lower left with drawings of people for scale, surrounds the tunnel and is almost half as long as the collider is deep. Its eight magnetic coils will distort paths of particles created in the collisions as a way to identify which particles are produced. A simulation of this collision and its possible outcomes is shown below.



CLOCKWISE FROM BOTTOM RIGHT: CERN; CERN; SAMAR SHOOL

electrons, while ATLAS, located beneath Switzerland, excels at detecting the shower of elementary particles created when quarks fragment, Gianotti says.

Together, quarks and gluons, the particles that bind quarks together, are the elementary constituents of particles such as the proton. And in some sense, it's not the protons that really collide in the LHC, but the quarks and gluons they contain. "What we measure is not the individual quarks or gluons but the results of their [breakup], as they decay into other particles," Gianotti says.

Evidence for extra dimensions

Both ATLAS and CMS will also explore the ghostly realm of hidden dimensions. Particle physicists tend to think of subatomic particles as point masses, but string theory attempts to unify all forces and particles by viewing them as different vibrations of strands or loops called superstrings.

Although the superstrings are probably too tiny to observe directly, the theory makes several predictions, including the existence of seven hidden dimensions of space. These dimensions would be tightly compacted or curled up. But through the production of new particles that might move or wind around these extra dimensions, ATLAS and CMS experiments will have the sensitivity to detect extra dimensions one-ten-billionth the size of an atom.

If this theory of extra dimensions is correct, the LHC could become a factory for making microscopic black holes.

In Einstein's theory of gravity, which assumes a universe confined to three space dimensions and one of time, black holes could be generated by an accelerator much bigger than Earth. But in an alternative theory, gravity leaks out into other, unseen dimensions — a possible explanation of why gravity appears to be so much weaker than the other forces in nature.

In this scenario, gravity is weak only if observed at long distances because the extra, hidden dimensions dilute its strength. Conversely, at the high energies and small scales probed by the LHC, gravity would become much stronger than it is in ordinary three-dimensional space, cramming enough matter together to form microscopic black holes as often as once a second.

Such black holes, according to research by Stephen Hawking in the 1970s, ought to rapidly radiate away their energy and evaporate in an instant, and would not be dangerous. As they nearly instantaneously evaporate, they would radiate distinctive sprays of elementary particles, which stand out in the LHC detectors.

The possibility of creating tiny black holes at the LHC is "quite a long shot," admits Steve Giddings of the University of California, Santa Barbara. But he's hoping that long shot comes through. "Not only would we learn things about gravity and the fabric of spacetime," he says, "but we would apparently have direct evidence for extra dimensions of space."

Getting fundamental

Two medium-sized experiments get to the heart of other fundamental questions about the universe. Physicists analyzing data from the LHCb will try to gain insight about why the universe has so much more matter than antimatter. Theory suggests that the cosmos began with equal amounts of both. But if matter and antimatter were mirror copies of each other, they would have annihilated, leaving behind only pure energy. Fortunately, an imbalance arose, allowing the tapestry of galaxies, the solar system and our own planet to coalesce.

LHCb examines the decay of B mesons, particles composed of a specific pairing of a quark and antiquark — the bottom antiquark and either an up or a down quark.

To catch the quarks, LHCb uses a 20-meter–long stack of detectors on a movable track that can intercept the spray of particles created during collisions. Studying how these quarks decay may reveal subtle differences between matter and antimatter. Rather than behaving as exact replicas of each other, the particles and antiparticles may exhibit slight distortions, akin to staring at a reflection in a wavy mirror.

ALICE will concentrate on a unique state of matter that existed just after the birth of the universe by studying collisions between lead nuclei. Lead atoms are first stripped of some of their electrons, creating positively charged ions. Those heavy ions are then accelerated to nearly the speed of light and forced to collide nearly head-on within the LHC, briefly creating hot, dense fireballs.

Within the fireballs, the neutrons and protons that make up the lead nucleus melt away, freeing quarks from their bonds with gluons. For a few precious moments, they form a new state of matter called the quark-gluon plasma.

In previous experiments at both CERN and Brookhaven National Laboratory in Upton, N.Y., scientists have caught glimpses of this plasma. But the ALICE experiment, operating at higher energies, should look in greater detail at the types and abundance of particles generated as the plasma cools. ALICE researchers hope to gain insight into how the universe created the cosmic zoo of particles immediately following the hot Big Bang.

All about the Higgs

Finding the Higgs is the driving force behind much of the research at the LHC. According to the simplest version of the standard model, every particle in the universe ought to be massless. Electrons, for instance, ought to weigh exactly the same as photons, the particles of light — absolutely nothing. That, of course, is not the case.

In the early 1960s, physicist Peter Higgs proposed that a hypothetical field, now called the Higgs field, permeates the universe like a cosmic vat of molasses. Many particles — but not all — would slow down as they propagated through the goo.

Slowing down is a critical step. That's because Einstein's theory of relativity draws a sharp distinction between particles that have mass and those that don't. Massless particles move at the speed of light, while massive particles never reach that ultimate of all speeds. So slowing down, according to relativity theory, is tantamount to acquiring mass. Electrons, protons, neutrons and the like bulked up because the Higgs field slowed them down, while photons somehow remained immune to the molasses and stayed weightless.

The Higgs field cannot be directly

SIMULATION FROM CERN; CHART BY J. KORENBLAT

Particle Zoo

Standard Model of Particle Physics

The standard model groups particles in two categories: particles that carry force and particles that make up matter. Each particle also has an antiparticle, such as an antiquark. Atomic nuclei are made of protons and neutrons, which in turn are made of quarks.

Supersymmetry

Supersymmetric particles — heavier companions for known particles — are theorized and not yet detected. They are likely candidates for dark matter, which is thought to make up most of the matter in the universe.

Particles that transmit forces

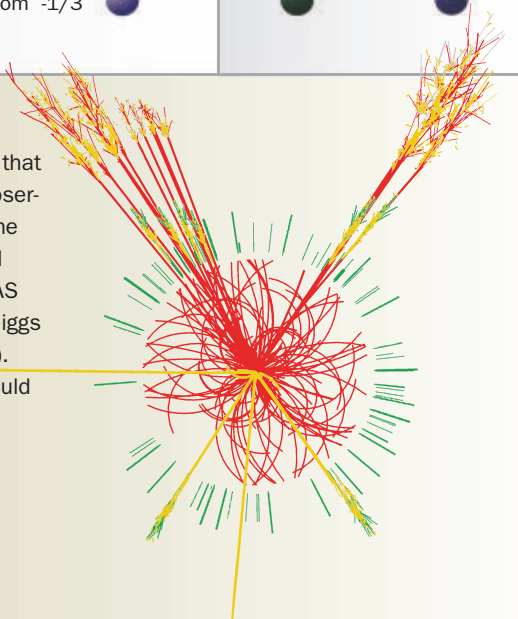
PARTICLE Force it carries		SUPERSYMMETRIC PARTNER
photon electromagnetic		photino
W, Z vector bosons weak		wino, zino
gluon strong		gluino
graviton gravity		gravitino

Particles that make up matter

LEPTONS Electric charge				SLEPTONS	
Light	electron -1		electron neutrino 0		
	muon -1		muon neutrino 0		
Heavy	tau -1		tau neutrino 0		
QUARKS				**SQUARKS**	
Light	up +2/3		down -1/3		
	charm +2/3		strange -1/3		
Heavy	top +2/3		bottom -1/3		

Higgs Boson

One tenet of the standard model is that no particle should have mass — observations show otherwise. Showing the existence of the Higgs boson would resolve this contradiction. The ATLAS experiment is tuned to detect the Higgs (a Higgs event is simulated at right). Confirming that the Higgs exists would solidify the standard model.



measured, but high-energy collisions like the ones possible at the LHC could excite the field. The decay of the Higgs boson would be the measurable signpost of that excitation. Theory suggests that the Higgs ought to lie in the mass-energy range that can be achieved at the LHC, Weinberg says.

"The Higgs boson is not a slam dunk, but it is something that is expected, and it's really important for the future of fundamental physics to see whether in fact it's found," he says.

But, Weinberg adds, "the greatest fear, I think, that the particle physics community has is that the LHC will find the Higgs boson and not find anything else. Because if that happens, we will simply have verified what is now the popular version of the standard model, and we won't have any experimental clues as to how to go beyond the model."

If the Higgs particle has a mass at the high end of its predicted range, about 115 billion to 200 billion electronvolts, it should be easily detected, its decay products standing out dramatically against the background of particle debris from other processes. But if the particle tips the scales at the lighter end, the signal will be trickier to discern, Weinberg says.

If the detection of the Higgs involves finding an extra, unaccounted-for signal in the collision debris, finding a supersymmetric particle requires finding a deficit.

The lightest supersymmetric particle is thought to have no charge and to interact only weakly, which is why it is a candidate for the invisible dark matter. "As such, these particles would not be seen in a detector, hence the energy it carries would be missed," notes Ellis. It's like the curious incident of the dog that did nothing in the nighttime, from the Sherlock Holmes story, he notes. It's what's missing that counts.

Whatever happens, says Weinberg, particle physics is about to awaken from some 30 years of slumber. Come September, the fun begins. ■

Explore more

■ News from LHC. Visit lhc.web.cern.ch/lhc/News.htm

Stranded A whale of a

Scientists generally agree that sonar can trigger strandings of certain whales, but no one really knows what leads these deep divers to the beach

By Rachel Ehrenberg

Off the eastern edge of Andros Island lies the Tongue of the Ocean, a hundred-mile, inky blue swathe of sea over the Great Bahama Canyon. Bounded on the south and east by the shallow sands of the Bahamas banks, the seafloor drops precipitously from 3 meters near shore to more than 2,000 meters farther out.

While the region boasts a colorful history of pirates and shipwrecks, scientists will head there this summer seeking treasure of a different sort: beaked whales, some of the deepest diving and least known animals on Earth. The research aims to solve one of the most contentious mysteries in marine biology today — the relationship between military sonar and stranded, dying whales.

In recent decades, a string of whale strandings have coincided with military testing that uses mid-frequency sonar to detect the low murmur of diesel and nuclear submarines. Beaked whales have washed up on the beach, sometimes with blood in their ears and eyes, but often with no obvious cause of death. After scientists first drew the connection between sonar and the strandings, environmental groups took note, embarking on a campaign to restrict sonar use in certain times and places. The hostilities reached a crescendo this winter in a U.S. federal court. A judge rejected the Bush administration's attempts to override a ruling that ordered the Navy to take measures to protect marine mammals while conducting sonar exercises. Now the Supreme Court is scheduled to hear the Navy's appeal this fall.

The wrangling over the stranded

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Much of what is known about Cuvier's beaked whales comes from stranded animals; the seldom-seen creatures are some of the deepest diving animals on Earth.

mystery

whales brings home how science can get lost in the scuffle between advocacy and policy. It also illustrates the highly charged nature of issues involving large, charismatic mammals. And then there's the attraction of simplicity — the Navy makes a tidy, singular foe. But there is no Moby Dick in this story.

Scientists agree that under certain conditions, sonar does trigger strandings of certain whales. But no one really knows why. Hypotheses, like fish in the sea, are plentiful. Sonar may be so forceful that it damages the whales' ears. Some researchers speculate that the sounds spur bubble formation in tissue, bringing on deadly embolisms. Or the sonar might distress and disorient the creatures, prompting them to surface too quickly and get the bends. Other researchers have suggested that certain frequencies of sonar might sound like killer whales on the hunt, stimulating beaked whales to seek shallower, safer waters.

Several research groups are trying to untangle what is happening, with the hope of developing strategies that minimize harm to marine life.

The National Oceanographic and Atmospheric Administration Marine Fisheries Service is partnering with the Navy to undertake some of the first controlled behavior experiments with beaked whales at a Navy Atlantic test center in the Tongue of the Ocean. Others are constructing computer models, looking at CT scans and studying beaked whale anatomy. There are efforts to compile stranding-related information in public databases.

In the meantime, providing policymakers and the public with advice on how to alleviate the problem has been stymied by holes in the data big enough to swim a whale through. *Ziphius cavirostris*, or Cuvier's beaked whales — the animals most associated with the unusual strandings — are understudied, elusive creatures. They spend little time in surface waters and, until the strandings, people rarely saw these whales at all. Then there are ethical and practical concerns with experiments that involve 2 ½–ton mammals that spend much of their time nearly a mile beneath the surface of the sea.

The mystery is compounded by several factors. No one knows where the whales are before they strand, so assigning safe distances from sonar is problematic. The strandings have been associated with specific geologic features, such as deep oceanic trenches near land, but by definition, stranded whales end up near or on land, so teasing out cause and effect is difficult. Because no one knows where and when a stranding will happen, experts might not arrive on the scene until days after the event. By then tissues are often decomposed, as are clues to the animal's death.

"One of the problems is we've really only had information on single exposures — one sound, one mammal," says Brandon Southall of the NOAA Fisheries Service, who is leading the Bahamas study. "We really need more data."

Some environmental groups and scientists argue that waiting for such data is folly. It is better to act quickly — perhaps by banning Navy sonar altogether — than it is to wait. But others express frustration at the bulldog approach, and at the time and money tied up in lawsuits that might be better spent on research. And while blame is slung in the courts, marine mammals face many threats beyond sonar.

"It is absolutely critical that we understand what is going on," says Darlene Ketten, a senior scientist at the Woods

Hole Oceanographic Institution in Massachusetts and a researcher at Harvard Medical School in Boston. "But when people ask, 'Why don't you shut down the Navy?' the answer is we're talking about five animals a year, and I have to balance that with over 100,000 deaths a year from fisheries interactions. I don't know that shutting down the Navy is going to do anything. And if you are worrying about noise in the oceans, how about the 3-decibel increase per decade from shipping?"

Scientists recognized a link between the use of mid-frequency sonar and strandings after several Cuvier's beaked whales washed up along the Mediterranean coast in 1996.

Signal from the noise

Scientists realized the link between whale strandings and mid-frequency sonar in 1996, several months after a stranding in the Mediterranean's Kyparissiakos Gulf. In early May, Cuvier's beaked whales began washing up along a 24-mile stretch of sandy beach. The spread of the 12 whales in time and space was unusual, but there was no smoking gun. The whales had stranded alive and appeared healthy — they had no obvious wounds, such as blunt trauma from a ship, and no signs of disease. A few animals appeared to be bleeding from their eyes, which prompted more questions than answers. There were various squid remains in the whales' stomachs — beaks, ocular lenses and flesh — suggesting that they had recently eaten.

"For a beaked whale to have been diving at depths great enough to find squids means they must have been healthy a few hours before they stranded," says Alexandros Frantzis of the Pelagos Cetacean Research Institute in Greece. The usual suspects — extreme weather, earthquakes, pollution, parasites, irregular geochemical or magnetic circumstances — were absent. "We had no idea what was happening," he says.

Several months later Frantzis discovered that around the time of the stranding event the NATO research vessel Alliance was performing "sound-detecting system trials" in the area of the strandings. Although the available data couldn't prove that the Alliance's sonar activities caused the event, the abruptness, timing and distribution of the strandings implicated sound, says Frantzis. He reported his conclusions in *Nature* in 1998.

In the 10 years since Frantzis' write-up, scientists have linked about a dozen stranding events to military sonar, depending on whom you ask. But whales have been stranding long before the advent of mid-frequency sonar use, which became widespread around 1963. Ketten, who has been compiling records of whale strandings, estimates that since 1950, fewer than 300 whale deaths can be attributed to naval sonar. Other researchers put that estimate at fewer than 100.

Ketten did necropsies on several of the beaked whales whose fatal strandings were concurrent with Navy sonar exercises. These include the oft-cited stranding in the northern Bahamas of nine Cuvier's beaked whales and three Blainville's beaked whales, a stranding of three Cuvier's beaked whales in Madeira and two strandings off Puerto Rico.

The evidence from Puerto Rico was inconclusive. The response team buried most of the heads — standard procedure in tropical areas — but one that destroys crucial soft tissue. Scans of the one intact head suggested it was an old male who had suffered prolonged infection.

Necropsies from the Bahamas and Madeira were more telling. Beaked and other toothed whales such as dolphins have a large pad of fat inside their lower jaw. Sound may enter the whale's head through the fat, which surrounds a very thin section of the lower jaw next to the middle and inner ears.

"There were no blown-out membranes, no broken middle ear bones," Ketten says, which would have suggested direct acoustic trauma to the ears. But in a few of the animals, blood had leaked from the brain case, pooling around the ear bones and the fat pad of the lower jaw. This suggested stress and possible pressure-related trauma, she says.

Researchers have raised other pressure-related hypotheses as well — unusual gas bubbles have been found in the tissues of beaked whales that stranded off the Canary Islands. The bubbles hinted at decompression sickness — what SCUBA divers call the bends — but later reports of dolphin strandings off the United Kingdom found similar bubbles in tissues, which led many scientists to deem the bubble evidence inconclusive.

It's been difficult for scientists to understand pressure-related injuries in animals built for the crushing pressure of the deep sea. These whales spend more than an hour at depths greater than 1,200 meters — more than three times the height of the Empire State Building. Down where

A. FRANTZIS

it is as dark as a starless night, the whales, like bats, hunt with their ears, not their eyes. Beaked whales have three times as many nerve cells devoted to hearing as people do, Ketten says. They use echolocation — emitting sounds that bounce off objects and return to the whale, giving a "picture" of prey shape, size and location.

"These are acoustic animals in the way that we are visual animals," Southall says.

Beaked whales also have a convoluted circulatory system that during dives sends blood to essential areas like the heart and brain, but cuts off flow to the extremities. Below roughly 70 meters the whales' lungs collapse, preventing gases from diffusing into blood and tissue where they could cause embolisms.

"These animals have been around 35 million years," says Ted Cranford of San Diego State University, who in April published in *The Anatomical Record* an analysis of how sound travels in and out of a beaked whale's body. "It doesn't make sense that a few nitrogen bubbles are going to cause chaos. Perhaps if the whales are at their physiological limit. But if it is nitrogen, why don't we see it affecting other deep divers?" he says.

This question bothers other researchers as well. Beaked whales are often seen around the Navy's testing site for mid-frequency sonar in the Bahamas. "So we know that marine mammals and beaked whales can live where there is sonar," Southall says. "It is not like a death ray where as soon as they hear it, they swim to the beach and strand."

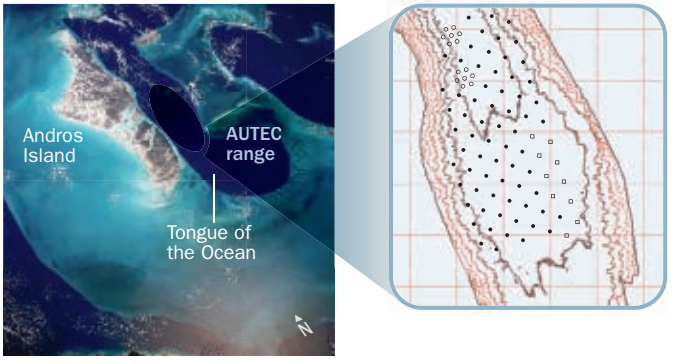
Sound science

The ambiguous data suggest to many researchers that the sonar-related strandings result from a perfect storm of environmental, physiological and acoustic conditions. A recent analysis by Gerald D'Spain of the Scripps Institution of Oceanography in La Jolla, Calif., and colleagues, hinted at the role of surface ducts — areas in the water where sound waves are trapped.

Sound travels about four times faster underwater than in air — about 1,500 meters per second versus 340 m/s on land. It slows in colder water, but increases with pressure, speeding up with the weight of the overlying water column. These factors, along with others such as the topography of the ocean floor and surface winds and weather, may mean sound sometimes creeps up on and startles deep divers.

Under certain conditions, as sonar sweeps an area, the pings and clicks could get trapped in a surface duct, making them less audible from below. If a beaked whale is down deep, it might not notice the sound until the ship is quite close, which could prompt the whale to surface. If the animal emerged to surface-duct depth, it would suddenly find itself in an intense, confusing zone of noise, D'Spain says.

Experiments planned by Southall's team for this summer in the Bahamas are designed to sift through these ideas and get at the peculiar set of circumstances that sends beaked whales to the beach. Using the Navy's 600-square-mile grid of interconnected, underwater microphones at the Atlantic Undersea Test and Evaluation Center, researchers will continue playback experiments that began last summer, exposing the animals to low levels of sounds and tracking their responses.



In the Tongue of the Ocean's AUTEC range, scientists are conducting some of the first controlled experiments on how whales respond to sonar using the Navy's interconnected grid of underwater microphones (inset).

B. SOUTHALL/NOAA

The team is also investigating the notion that beaked whales confuse sonar with a pack of killer whales, which emit noises in a frequency similar to the mid-range Navy sonar. Beaked whales' primary predators, killer whales and great white sharks, tend to hang out near the water's surface, notes Peter Tyack of Woods Hole, a member of the NOAA investigation team. If beaked whales think they hear the enemy, they might embark on repeated shallow dives for quick escape. Work by Tyack and colleague Walter Zimmer modeling nitrogen bubble growth suggests that if the dives are too shallow, the whales' lungs may not collapse, a physiological safety mechanism that doesn't kick in until the animals reach depths of 70 meters. Then even these deep divers might get decompression sickness, and visible bubbles might form in the whales' tissues, the researchers reported in *Marine Mammal Science* last fall and June 30 at the Acoustics '08 meeting in Paris.

Hampered by storms, last summer's first field season yielded data from only 10 tagged animals, six Blainville's beaked whales and four pilot whales, Southall says. Pilot whales, which are deep divers and frequent stranders, have similar biology to the beaked whales. But they haven't shown up in the sonar-associated strandings, so tracking them could reveal important behavioral differences, he says.

"We're seeing some avoidance," Southall says. "The animals become quiet and move away from the sound."

If the behavioral experiments reveal that the whales stop shallow diving as soon as the noise stops, the duration of sonar transmission could be limited, which might limit harm. Precautionary measures such as holding off from sonar exercises when surface ducts are likely to form may keep the creatures from becoming startled and disoriented.

When the Bahamas study is done, researchers may have enough data to solve the stranding puzzle and give policy-makers, the Navy and the courts sound advice on reducing harm to whales. ■

Explore more

- Discovery of Sound in the Sea. Visit www.dosits.org
- NOAA's Marine Mammal Health and Strandings Response Program. Visit www.nmfs.noaa.gov/pr/health/
- NOAA's Ocean Acoustics Program. Visit www.nmfs.noaa.gov/pr/acoustics/

Sick and down

To fight off an infection or illness, the body shifts into a slow-down mode that mirrors some symptoms of depression. In fact, scientists now think the immune response itself may even cause the mood disorder.

By Amy Maxmen

When one of psychiatrist Andrew Miller's patients asked about receiving the best drug available for treating hepatitis C, Miller said: "No way." The patient — in his early 20s and accompanied by his mom to the appointment — had no job, few friends and a history of depression. While Miller knows that hepatitis C patients often benefit from the new generation of immune-boosting treatments, he's keenly aware that those same immune therapies have a strong tendency to bring people down — and, in people predisposed to depression, dangerously down.

Certain immune proteins in the body appear to mess with the minds of otherwise healthy, but depressed people as well. Those who suffer from major depression have higher levels of cytokines, immune proteins the body makes to fend off infections and to patrol the body for disease, and which laboratories mimic. Excess cytokines have also been found lurking in the postmortem brains of suicide victims. "It raises the issue, how much of how we feel — how much of who we are as people — is dictated in terms of our immune system?" says Miller, a researcher at Emory University in Atlanta.

Though the connection between the body's immune response and depression has only gained firm support in the last five years, it's already catalyzing a revolution in antidepressant drug development. In hindsight, an emotional reaction to surging immune molecules does not seem so surprising. Cytokines are among the first immune proteins to respond to infection. Some direct swelling and fevers. Others order the body to rest, and so the sick take to the bed and decline party invitations, showers and even homemade dinners. The powerful molecules influence wants and needs by altering levels of substances like serotonin in the brain. Essentially, cytokines command the body to conserve energy when it's sick. "A little depressed behavior is a survival mechanism in that sense," Miller says. But when inflammation is artificially or erroneously triggered, prolonged sickness behavior may morph into depression and do more harm than good.

Figuring out the biology behind depression should help doctors combat the disorder, which strikes an estimated 14.8 million American adults each year, according to the National Institute of Mental Health. More than one in six individuals will experience major depression in their lifetime. And when depression coincides with chronic diseases like multiple sclerosis, cancer or diabetes, patients' conditions are less likely to improve.

Psychiatrists and pharmaceutical companies have noted the downpour of evidence linking inflammation to depression. Miller says he and his colleagues have considered creating a new diagnostic category: Major Depressive Disorder with Increased Inflammation. To combat this depression, he says, researchers must find a way to alter the body's immune response. It is a risky strategy but one that offers hope to the nearly 30 percent of all depressed patients who don't respond to the antidepressants currently on the market.

Jekyll-and-Hyde changes

Cytokines emerged as the primary suspects for what's since become known as inflammation-induced depression after Miller and others noticed that cancer patients became inexplicably upset during treatment with synthetic type 1 interfer-

JERRY COOKE/CORBIS

ons, cytokines that block viral replication in infected cells. One of these, interferon-alpha, is among the most effective drugs for patients battling cancer and the hepatitis C virus. Yet the treatment has become notorious for causing major depression and other behavioral changes in more than half of these patients, depending on the dose of the immune booster.

Miller describes a "Jekyll-and-Hyde–type change" in one of his patients after interferon therapy. Eight weeks into it, the patient dumped his girlfriend, began dressing in black and grew a goatee. And there was another woman, Miller recalls, who took a drastic downward turn. "One of my most positive patients had been battling cancer for years, yet four weeks into the cytokine therapy she was distraught," he says. "She told me, 'I love my husband and my children, but I don't want to be around them. I want to be left alone, and I don't know why.' "

As observations of sadness, irritability, insomnia, fatigue and loss of appetite — all classic symptoms of depression — mounted in patients treated with immune boosters in the 1990s, papers published nearly a decade earlier in veterinary journals resurfaced. Benjamin Hart had been writing about the behavior of sick animals since the mid-1980s. "Depression was the first sign we had that an animal was sick," says Hart, an animal behavior researcher at the University of California, Davis. In a seminal 1985 paper in the *Journal of the American Veterinary Medical Association*, he put forth the argument that animal malaise serves a purpose.

"People would call in and say that the dog is sleeping more than usual. They give the dog its favorite treat, and it only nibbles at it and then drops it, or they'd say the cat looks scruffy," Hart explains. "Cats usually groom all the time." He says that when he ran blood and urine tests on such animals, he usually discovered signs of bacterial or viral infection. Instead of assuming the pet acted sad because it wasn't feeling well, he suggested that the pet's behavior was part of its immune response. Fido's body forced the animal to devote its energy to battling illness, instead of to chasing squirrels.

Furthermore, since all mammals act similarly when sick, Hart suggested that the behavior had been inherited from a common ancestor who survived infection better than other animals who had not evolved the behavioral response.

In the 1990s, researchers in the Netherlands reported that patients with major depression showed signs of inflammation, with elevated levels of cytokines in their blood and cerebrospinal fluid. And in 2001, Robert Dantzer, now at the University of Illinois at Urbana-Champaign, injected rats with cytokines. Sure enough, Dantzer says, the rats lost interest in previous pleasures and activities: They didn't care for sugary water, they didn't run on the wheel and, when placed in a pool of water they swam lethargically, barely keeping their heads above water.

Miller compares this sickness behavior to "holing up in a cave." Although the animal has little drive to do much of anything, it does stay alert to major threats. "While in the cave, the organism rests but keeps one eye open," he says. That may explain why people with the flu, as well as people with depression, neither leave the couch nor get the deep sleep they crave.

Connecting body to mind

Like army generals, innate immune cytokines order inflammatory molecules to prepare for war when the body is under threat from invasive bacteria or viruses, or under perceived threat in the form of stress or chronic disease. In these situations, cytokine levels rise. "It's a good thing if you're running from a tiger," explained psychiatrist Dominique Musselman in May at a meeting in Washington, D.C., of the American Psychiatric Association. "You'd want to rev up your immune system to prepare for an injury." Nowadays, however, angry bosses, aggressive creditors and disappointed spouses have replaced vicious predators, she said. And as those stressors are less likely to bite, the subsequent immune response, which had evolved to heal injuries and fight infection, seems a vestige of the distant past.

"The fact that stress can activate the innate immune response has been a major breakthrough," Miller notes. Add this to one more piece of the puzzle: Stress often leads to depression. The immune system may explain why.

In mapping out the molecular pathway between elevated cytokines in the body and chemical changes in the brain, scientists aim to provide targets for drugs intended to treat depression caused by inflammation. In the last few years, researchers have identified primary suspects. Many cytokine proteins, including tumor necrosis factor-alpha, interleukin-6 and the type 1 interferons (IFN-alpha and IFN-beta), have been accused of being the principal perpetrators in sickness behavior. They respond rapidly to foreign intruders, circulate in the bloodstream and initiate a response in the central nervous system.

Cytokines manufactured in the body can send messages through the central nervous system to induce production of cytokines in the brain. That message may be relayed when cytokines sneak into the brain through leaky regions in the blood-brain barrier, a series of structures that block most substances. In the brain, cytokines activate inflammatory middlemen who tag-team their way to affecting emotion-regulating neurotransmitters. As neurotransmitter levels change, so can mood. "Among other things, we see a drop in levels of serotonin, the feel-good chemical," Miller says.

Attempts are underway to treat depression by blocking specific cytokines or the messages they send. A 2006 clinical trial funded in part by the biotech company Amgen found that depressed patients who suffered from psoriasis, an autoimmune skin disease associated with increased levels of cytokines, felt happier after taking the cytokine blocker etanercept (brand name Enbrel), which affects tumor necrosis factor-alpha. Another TNF-alpha blocker, infliximab (Remicade), is being tested for use in depressed patients who don't respond to antidepressants such as the selective serotonin reuptake inhibitors Prozac and Zoloft. Those results should be ready by 2010, says Charles Raison, a research psychiatrist at Emory University who heads the project.

Anti-inflammatory drugs like aspirin and ibuprofen haven't been shown to affect mood. But another anti-inflammatory, celecoxib (Celebrex), that more specifically blocks the inflammatory molecule COX-2, helped heal depression in a small clinical trial in Germany. Norbert Müller, a psychiatrist on that study from Ludwig-Maximilians-University Munich, suggests that a high dose of aspirin would be needed to inhibit COX-2 as strongly as celecoxib. And that, he says, "would provoke a high rate of side effects, mainly gastrointestinal pain and possibly bleeding."

Developing these types of treatments isn't easy, warns Dantzer. Compounds that interfere with immune responses have the dangerous potential to compromise the body's resistance to infection. The goal is to temper inflammatory molecules in the brain, not the body.

Researchers will have to identify safe points to alter along the molecular pathway that runs between bodily cytokines, molecular middlemen and neurotransmitters in the brain. "The further upstream you go towards the cytokines, the more far-reaching the effects on the body. If you move downstream to block cells that are activated by the inflammation, you may have a drug that is less toxic," Miller says.

> "The evidence is clear at this point that inflammation events can lead to a depressed mood. The issue is how often this is the case."
>
> **STEVEN MAIER, UNIVERSITY OF COLORADO, BOULDER**

Custom-made meds

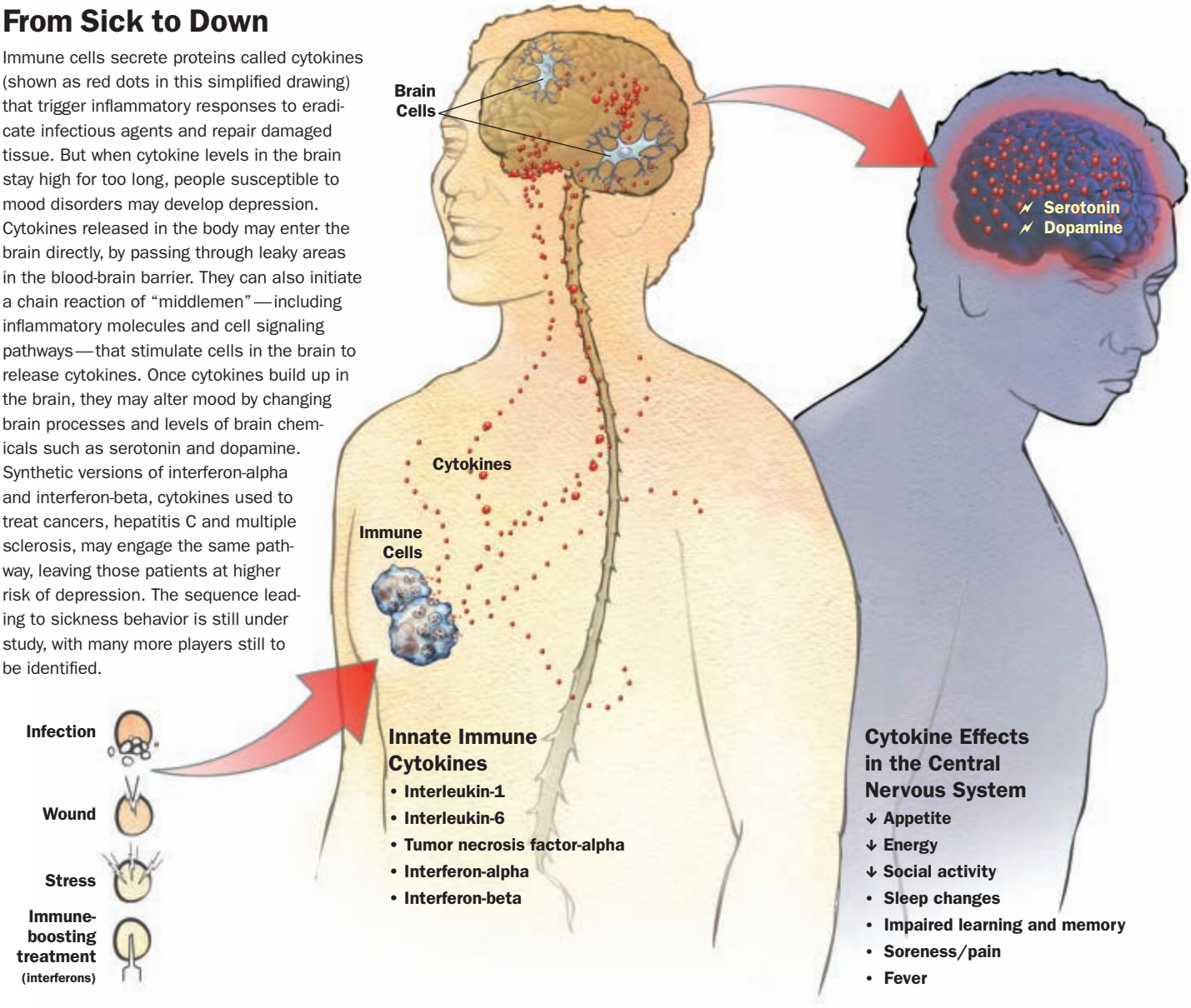
Another problem is identifying the cases in which the immune system is to blame. "The evidence is clear at this point that inflammation events can lead to a depressed mood," says neuroscientist Steven Maier of the University of Colorado at Boulder. "The issue is how often this is the case."

Not all people are sensitive to surges in cytokines. Some recover from the side effects of interferon therapy as gracefully as some lovers rebound from heartbreak. Variations in a couple of genes may help doctors to predict who is most susceptible to immune-related depression. Miller and collaborators found that patients with hepatitis C were more resistant to interferon-induced depression if they possessed a slight variation in the gene encoding the serotonin transporter 5-HTT, which is known to be involved in psychiatric disorders, as well as another small variation in a gene that codes for the cytokine interleukin-6. The fact that the interleukin-6 gene, involved with inflammation, has an emotional impact provides more evidence of how the body and mind interact, the researchers report in the May 6 *Molecular Psychiatry*.

Identifying these genes is part of a larger effort by doctors to tailor treatment to the individual. "Ideally there could be a drug where one size fits all, but that doesn't seem to be the case," Miller says. He thinks that while serotonin reuptake inhibitors like Prozac work for certain people, others might need an immunological approach to

From Sick to Down

Immune cells secrete proteins called cytokines (shown as red dots in this simplified drawing) that trigger inflammatory responses to eradicate infectious agents and repair damaged tissue. But when cytokine levels in the brain stay high for too long, people susceptible to mood disorders may develop depression. Cytokines released in the body may enter the brain directly, by passing through leaky areas in the blood-brain barrier. They can also initiate a chain reaction of "middlemen"—including inflammatory molecules and cell signaling pathways—that stimulate cells in the brain to release cytokines. Once cytokines build up in the brain, they may alter mood by changing brain processes and levels of brain chemicals such as serotonin and dopamine. Synthetic versions of interferon-alpha and interferon-beta, cytokines used to treat cancers, hepatitis C and multiple sclerosis, may engage the same pathway, leaving those patients at higher risk of depression. The sequence leading to sickness behavior is still under study, with many more players still to be identified.



AMADEO BACHAR

combat depression. "We want to bring to people's attention the interaction between factors," he says. "This is the idea behind personalized medicine."

Others agree that depressed patients unaided by standard treatments may be good candidates for an immune approach. "People who don't respond to those [therapies] seem to have increased levels of inflammatory markers," Raison says.

As logic, and misfortune, would have it, depression caused by inflammation is most prevalent in patients who have diseases associated with increased inflammation. Rates of depression are five to 10 times higher than average in patients with disorders that involve the immune system, including infectious diseases, cancer and autoimmune disorders, say Miller and Raison in a March report that appeared online in *FOCUS*. Inflammation is also a risk factor for diabetes and cardiovascular disease. When these diseases coincide with depression, patient outcomes can worsen.

Sickness behavior leads to grumbling under the covers. And grumbling under the covers hinders the hope and drive that patients need to follow doctors' orders. Depressed patents are more likely to skip appointments and stop taking their medication, Musselman said at the APA meeting. And depressed smokers are more likely to continue smoking after bypass surgery.

By treating those susceptible to depression early on, doctors may increase their patients' chances of surviving disease. "The idea," Maier says, "is to cut depression off at the pass." ■

Explore more

■ Robert Dantzer et al. "From inflammation to sickness and depression: when the immune system subjugates the brain." *Nature Reviews Neuroscience*. January 2008.

Feedback

"Having read of amnesia victims' inability to imagine a beach scene … I wondered whether they have normal dreams involving scenes and story lines."

For the record

We read with interest your article on superatoms ("Small, but super," *SN: 6/21/08, p. 14*) and would like to add a note on the experimental discovery. In the mid-1970s the late Walter Knight decided to investigate small metallic particles with a molecular beam apparatus. When Walt de Heer joined the group in 1979, Knight gave him the freedom to redesign the apparatus. De Heer built a new cluster source and a quadrupole mass analyzer with a range from 1–10,000 amu; clusters were ionized using a broadband UV arc lamp — all features that later proved to be essential for the discovery of electronic shell structure.

In fall 1983 Knight left for a sabbatical at Oxford. Keith Clemenger was performing polarizability measurements, Winston Saunders was optimizing the quadrupole mass analyzer for larger sizes and de Heer was measuring magnetic properties of small alkali clusters. Robust maxima progressively appeared in the abundance spectra Na_8, Na_{20}, Na_{40} and Na_{58}. By the time Na_{40} was observed, Clemenger speculated the features had an electronic origin.

In February 1984, we were confident of the reality of the electronic shell structure and the observation of Na_{92} finally left no doubt. We convinced Knight to visit in March. He solicited theoretical help from Marvin Cohen and graduate student Mei-Yin Chou, whose calculations verified the shell structure interpretation. The paper was written in April 1984 and appeared in the June 11, 1984 *Physical Review Letters*, p. 2141.

WALT DE HEER, ATLANTA, GA.
KEITH CLEMENGER, BEIJING, CHINA
WINSTON A. SAUNDERS, HILLSBORO, ORE.

Amnesia dreams

Having read of amnesia victims' inability to imagine a beach scene in "Thanks for the future memories" (*SN: 6/21/08, p. 26*), I wondered whether they have normal dreams involving scenes and story lines. It would seem that dreaming would be impaired in these people. If not, it would raise questions about why the imagining tasks are different when awake and asleep. If dreaming is impaired, it would be worth investigating how loss of such an apparently important function affects their waking hours.

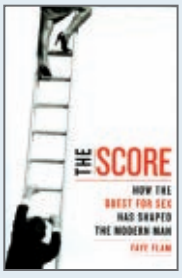
WALLACE MAGATHAN, MIAMI, FLA.

Eleanor Maguire says that her amnesiac patients report that they don't dream anymore. However, since their memories are impaired, Maguire says, they may have dreams but simply not remember having them. —SUSAN GAIDOS

The Score: How the Quest for Sex Has Shaped the Modern Man

Faye Flam

"What makes a man?" Flam, a science writer who pens a sex column for *The Philadelphia Inquirer*, seeks a scientific answer to this often-asked question. Her search takes her from a seduction boot camp for men to the labs of evolutionary biologists, sociologists and physiologists who study gender differences.



From mushrooms with 30,000 sexes to sea worms that compete to be the male, Flam surveys the natural world to explain why human males evolved the way they did, revealing a riotous diversity in the way life begets life. While human males have one X and one Y chromosome, for instance, the oddball male platypus carries five of each kind. Male squid inject females with sperm packages that burst out of her skin to fertilize the egg, while male sea urchins broadcast sperm into the ocean, never knowing whose eggs they may reach.

Flam contends that the fundamental reproductive imbalance between males and females shapes the way men seek love, take risks and view the world—and drives evolutionary strategies.

The Score sometimes flirts with gender essentialism, and the link between other male animals and modern man can often be tenuous. Men may prefer younger women, for instance, but male chimpanzees go wild for older females. While the book may not definitively say what makes a man, it offers a few entertaining clues, capturing the weird and the wacky without being fluffy. **—Tia Ghose**

Avery, 2008, 224 p., $24.95.

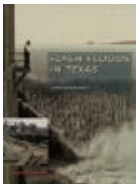
The Tomb in Ancient Egypt

Aidan Dodson and Salima Ikram

An illustrated tour of Egyptian tombs recounts the history and culture of ancient burial rites.

Thames & Hudson, 2008, 368 p., $50.

Flash Floods in Texas



Jonathan Burnett

The book details the 28 historic deluges that have hit the Lone Star State since 1900, with plenty of black and white photographs.

Texas A&M Univ. Press, 2008, 330 p., $35.

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Dudley Herschbach

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Seeding liberal arts courses with science parables

As a graduate student, more than 50 years ago, I heard Isidor Rabi make a fervent appeal to cultivate common ground, shared by science and liberal arts. Ever since, in my own teaching, I've strived to do what he urged: "Scientists must learn to teach ... in the light of the history of human thought and human effort, rather than as the geography of a universe uninhabited by mankind."

This theme was admirably exemplified recently in science festivals held in Cambridge, Mass., (April 26–May 4) and in New York City (May 28–June 1), melding science with art, music, literature and drama, and in an elegant essay by Brian Greene (*The New York Times,* June 1). Here I make a kindred appeal.

A liberal arts education worthy of the tradition surely must aim to integrate some science into our general culture. But this will continue to be strongly inhibited unless faculty undertake some cross-fertilization. Scientists could contribute to humanities courses what I'll call "seed parables," stories that convey both a few basic facts and, more important, perspectives and modes of scientific thinking that transcend any particulars. Suitable materials for developing such parables are plentiful, especially among reports from *Science News*!

Here's a sample parable: "Sex and the Single Methyl Group." For its first few weeks in the womb, the sex of a human fetus cannot be distinguished, whether it has XX or XY chromosomes. During about the seventh week, a genetically programmed switch kicks in. For a normal XY fetus, some already developing female structures then fade away and male structures begin to form. In rare cases (about one per 50,000 to 100,000), however, the switch is defective; the XY fetus continues on to become a woman, with external anatomy correct in all respects, although she is infertile. (Some XY women may have been barred from the Olympics.) Magnetic resonance experiments have shown that one type of defect in the genetic switch, encoded by the Y chromosome, occurs at a critical location; it is a missing methyl group, just a carbon atom with three attached hydrogen atoms. If that single methyl group were missing much more often, human males might be as outnumbered as male bees or ants.

Do not frown or gloat! Human females would not be viable if certain genes were fully expressed on both X chromosomes. To avoid that, such genes on one or the other X chromosome are deactivated — by methyl groups attached at strategic locations. Moral: respect is due even a mere methyl group! This parable should seed lively discussion in a variety of humanities courses (including one at Harvard called "Manliness").

Genuine science literacy requires understanding how scientific knowledge is attained, its nature and limitations.

Another sample: "Thomas Jefferson's Plow." Among the extraordinary range of his intellectual interests, Jefferson ranked science as his "supreme delight." He especially esteemed Isaac Newton, studied avidly the *Principia* and mastered geometry and calculus. When he undertook to design an improved plow, a key issue was the optimum shape of the moldboard, the part that peels back and turns over the sod as the plow cuts through the soil. That posed a calculus problem; Jefferson solved it and his plow remained the standard for a century. (On principle, he did not take out a patent; otherwise he would have died rich rather than bankrupt.) Moral: A mathematical tool Newton invented to analyze orbits of heavenly bodies found countless other applications, including plowing earthly furrows. As well as enhancing history or political science courses, this parable might peel open stimulating vistas for calculus students.

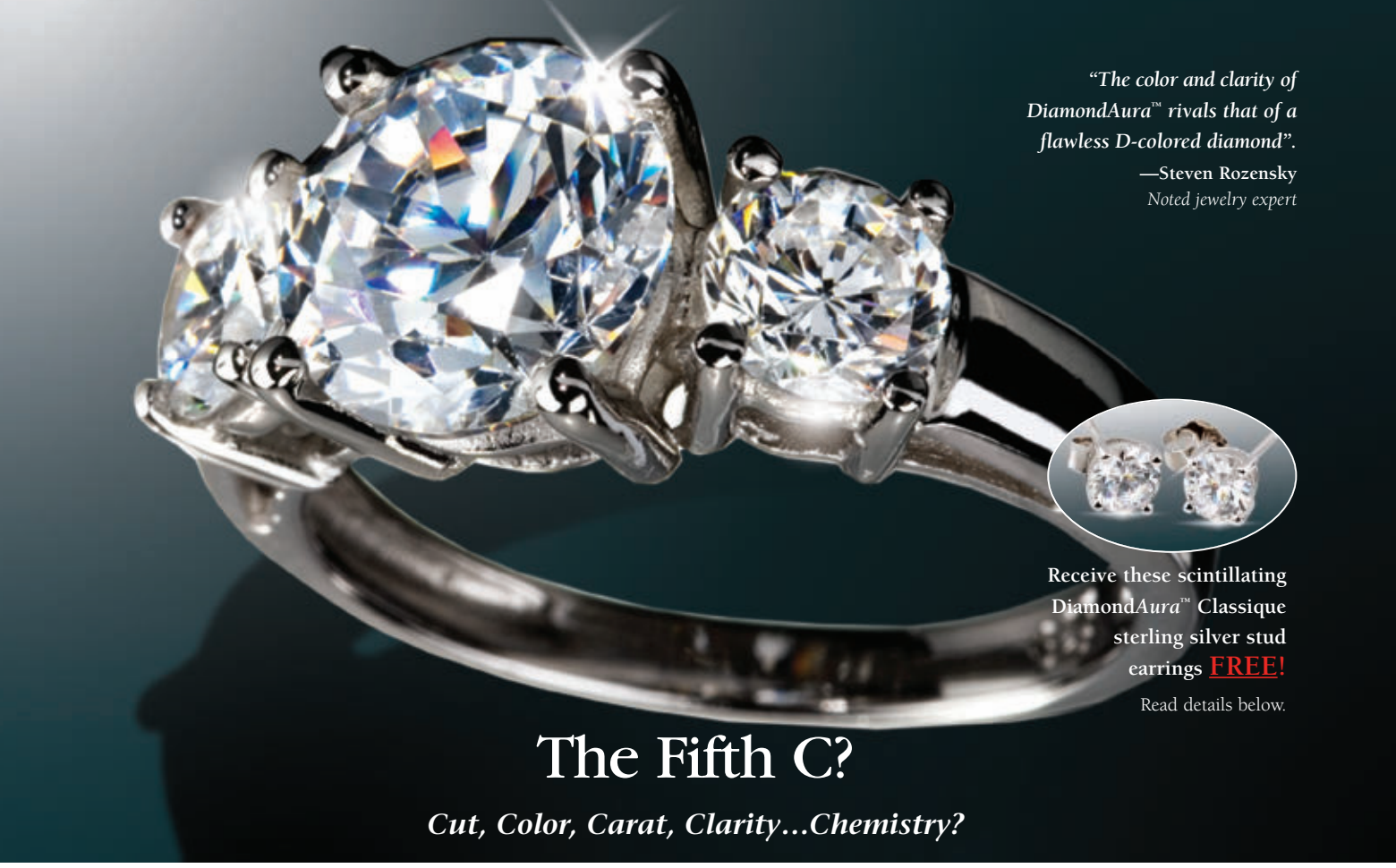
Of course, scientists should invite humanists to reciprocate with parables or other kinds of seeds. Better still, students should be invited, whether in science or humanities courses, to undertake such culture-melding projects of their own designs. Exhibiting these in or outside class would amplify interest and learning via social interactions, emulating science-and-art festivals in an academic context.

That context is important to help students move beyond a "gee-whiz" impression of science. Genuine science literacy requires understanding how scientific knowledge is attained, its nature and limitations. Ironically, such large epistemological questions are seldom addressed in science courses. Those issues require the kind of probing discussions found in humanities courses.

A liberal arts education aims, above all, to instill the habit of self-generated questioning and thinking, of actively scrutinizing evidence. In pursuit of that aim, as urged by Rabi, the sciences and humanities should be complementary.

Human societies are linked by shared stories. Well-chosen parables ought to be among the provoking catalysts for a more inclusive academic culture. ■

Dudley Herschbach, winner of the 1986 Nobel Prize in chemistry, is Frank B. Baird, Jr. Professor of Science at Harvard University and is chairman of the Board of Trustees of the Society for Science & the Public.



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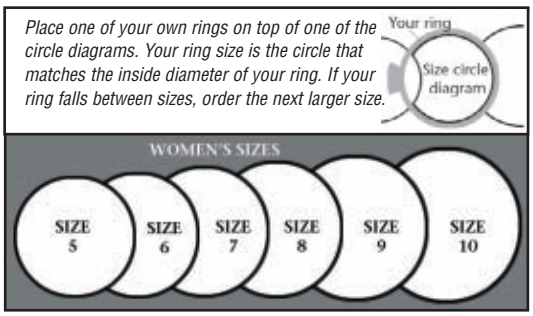

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