Taste in the Tummy | Illusions of Significance | Stem Cell Split-up

Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ MARCH 27, 2010

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Magnetic Shield for Early Life

Copernicus Gets Seat at Periodic Table

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Attosecond science probes atomic world

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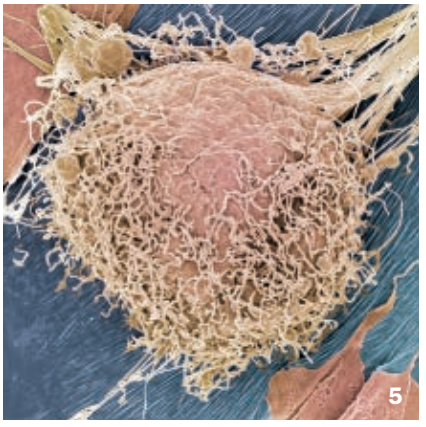

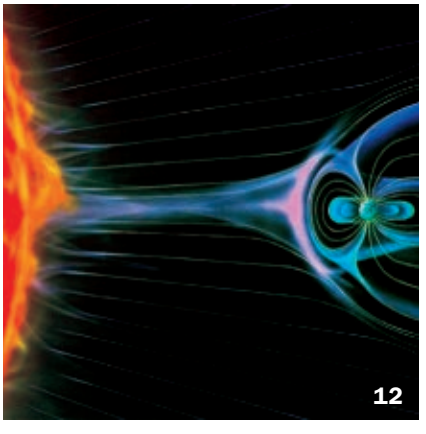

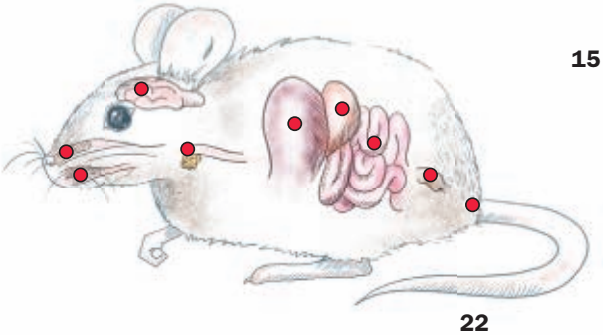

ScienceNews

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COVER In an attosecond experimental setup, an infrared laser excites neon and argon atoms, which fluoresce red and blue and emit ultrabrief light pulses. *Thorsten Naeser, www.attoworld.de*

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FROM THE EDITOR

Flaws of statistics afflict science news reporting

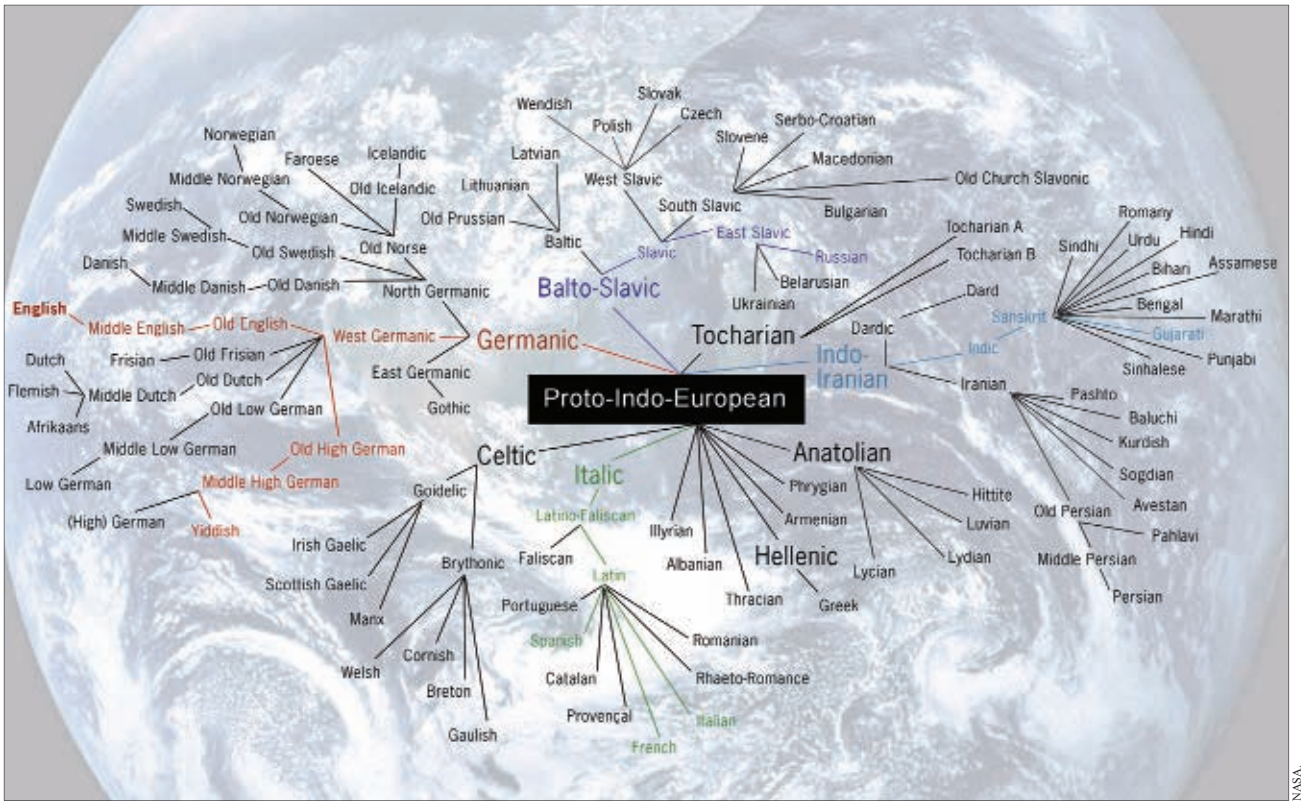
For all the jokes about damned lies, statistics still seem to get more respect than they deserve. In particular, the use of statistics to draw conclusions from experimental evidence has become entrenched in the practice of nearly all realms of science. But as I discuss in an essay on Page 26, standard statistical practice is fraught with fallacies — long recognized by many experts but routinely ignored in the conduct of many scientific studies and publication of their results.

It's not only that statistics' shortcomings often lead to erroneous conclusions about the benefits or dangers of new medicines, the risks posed by environmental pollutants and the roles of various genes in specific diseases. Widespread misuse and misinterpretation of statistics calls into question the credibility of the entire scientific enterprise.

Fortunately, science does not usually rely solely on single studies. As good scientists know, replication of a result in independent experiments confers a much higher level of confidence in a finding than any one study alone. Over time, repeated confirmations build science's repertoire of knowledge reliably enough to warrant society's trust.

But over more immediate time frames — as in reporting news from science as it happens — statistical issues can skew the public's understanding of science. And it turns out that journalistic criteria for reporting new science emphasize precisely the studies that are most likely to be wrong. A "first report" of a finding — a prime factor in defining news — is frequently false, or at least exaggerated in magnitude. Later confirming reports — much more likely to be reliable — are dismissed as "old news." Hot research fields — covered closely by journalists — are plagued by higher levels of false findings, too (with more labs working on a question, more "false positive" results will be published, while labs finding nothing do not publish as rapidly, or at all). And one of journalism's most popular opening phrases — "contrary to previous scientific belief" — is actually most often a sign of error, as previous scientific beliefs are typically founded on multiple lines of evidence.

Coping with these issues poses as considerable a challenge to journalists as to scientists. At *Science News*, we will strive to proceed with caution while continuing to report on science's flawed but forward progress toward knowledge that society can rely on. — *Tom Siegfried, Editor in Chief*



NASA

How Did One Language Evolve into 6,000?

Language not only defines us as a species, it also intrigues us with its endless mysteries. How did different languages come to be? Why isn't there just a single language? How does a language change? Professor John McWhorter, one of America's leading linguists and a frequent commentator on network television and National Public Radio, shows you the answers to these and other illuminating questions in **The Story of Human Language**.

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11. Language Families—Clues to the Past
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13. The Case For the World's First Language
14. Dialects—Subspecies of Species
15. Dialects—Where Do You Draw the Line?
16. Dialects—Two Tongues in One Mouth
17. Dialects—The Standard as Token of the Past
18. Dialects—Spoken Style, Written Style
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21. Language Mixture—Grammar
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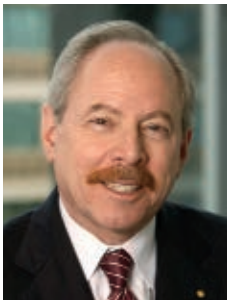
Scientific Observations

"The ability of science to deliver on its promise of practical and timely solutions to the world's problems does not depend solely on research accomplishments but also on the receptivity of society to the implications of scientific discoveries.... Widely publicized examples of scientific misconduct, or even mere accusations of misconduct, can tarnish the image and diminish the credibility of the entire scientific enterprise.... These types of revelations are highly problematic for policy makers, the public, and the scientific community. Every such case should be investigated, with a follow-up public explanation. Scientists should not tolerate threats to the integrity of science, whether they come from outside the scientific community or from within it." —**AAAS PRESIDENT PETER AGRE (TOP) AND AAAS CEO ALAN LESHNER IN THE FEBRUARY 19 *SCIENCE***



Science Past | FROM THE ISSUE OF MARCH 26, 1960

HIDDEN WATER TRACED BY BOMB FALLOUT IN RAIN — Radioactive fallout from atom bomb tests can be used to seek out and "expose" new sources of drinking water that lie hidden deep in the earth.... Raindrops have an affinity for absorbing minute particles of tritium from the fallout left in the atmosphere after nuclear bomb tests. Scientists seek ways to use these particles as "atomic dog tags" to identify underground water and find out how it percolates into the earth, where it goes and how fast it travels. This, they believe, may be done by taking samples from test wells at different places and depths from which water "tagged" with tritium can be identified with delicate instruments to learn its origin as rain or snow.

Science Future

April 23
Celebrate National DNA Day through a webchat with NIH researchers. Go to www.genome.gov/10506367

April 26–30
Scientists and engineers meet in Nottingham, England, to discuss the science of quantum dots. See www.qd2010.org

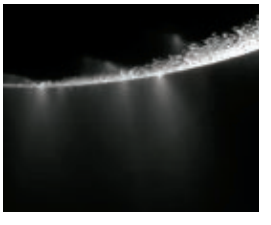
May 14
Deadline for receipt of nominations for AAAS fellows. Download forms at www.aaas.org/aboutaaas/fellows

SN Online

www.sciencenews.org

DELETED SCENES BLOG
The Martian rover Spirit has unstuck itself from the sand and moved a few centimeters. Read the blog "Spirit: 'The reports of my death have been greatly exaggerated.'"

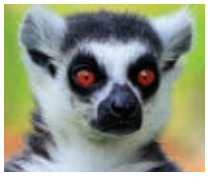
ATOM & COSMOS
New satellite photos reveal that Saturn's moon Enceladus could be warmer and wetter than was previously believed (liquid jets shown spewing from moon's surface). Read "Saturn moon could be hospitable to life, new images suggest."



BODY & BRAIN
A mouse mom's diet during pregnancy has a greater effect on gene activity in her daughters than in her sons. Read "Boys and girls differ in genetic response to what mom eats."

How Bizarre

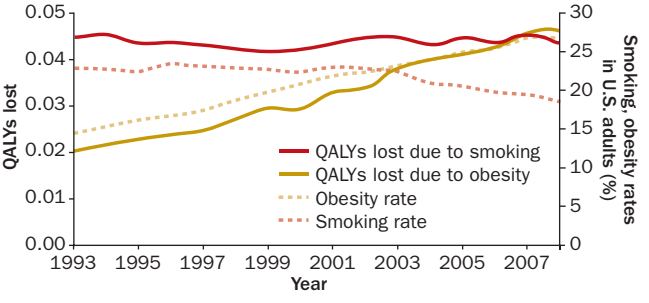
Researchers may not know why the lemur and other animals first crossed the Mozambique Channel to get to Madagascar, but scientists can now at least say how the creatures might have done it. Surface ocean currents flowed from Africa toward the island about 50 million years ago, when the lemur (shown) first populated it, researchers report in the February 4 *Nature*. The analysis by an international pair of researchers supports the decades-old hypothesis that animals floated to Madagascar on vegetation rafts rather than traipsing across a now-submerged land bridge.



Science Stats | OBESITY OUTWEIGHS SMOKING

Obesity's cost to society, based on quality-adjusted life-years (QALYs) lost per U.S. adult, has risen steadily. In 2008 it outpaced smoking.

Smoking, obesity rates and QALYs lost from each, 1993–2008



SOURCE: H. JIA AND E. LUBETKIN/*JOURNAL OF PREVENTIVE MEDICINE* 2010

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“Under extreme time pressures, it’s everybody for themselves.” — COLIN CAMERER, PAGE 11

Environment Plastics, plastics everywhere

Humans The real faces of Facebook

Earth Early life had magnetic protection

Matter & Energy Copernicium coined

Life Moms go horn-to-horn over dung

Body & Brain Stroke meeting report

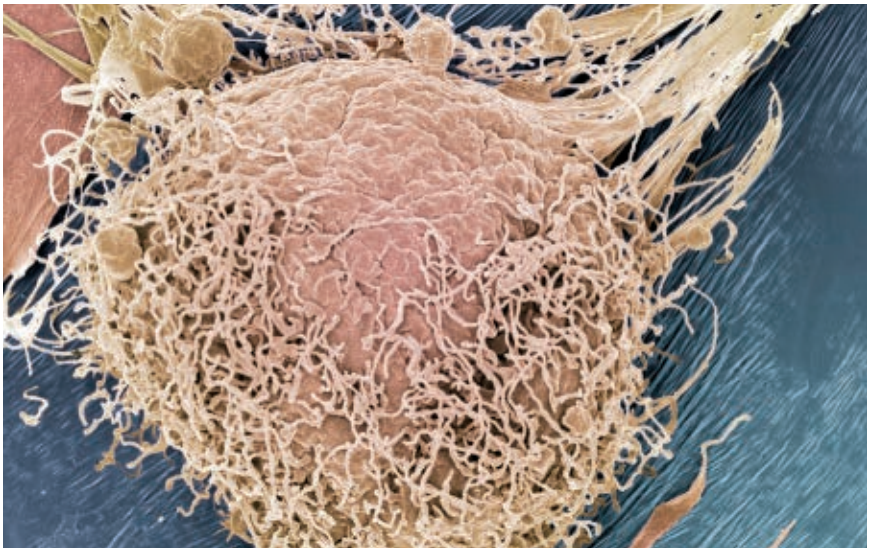
In the News

STORY ONE

Blood stem cells conceal unequal predispositions

Self-renewal comes in two different types, study finds

By Laura Sanders



PAUL GUNNING/PHOTO RESEARCHERS, INC.

Human blood stem cells residing in bone marrow (one shown) may come in more than one kind and defy simplistic characterizations, a study in mice suggests.

All blood stem cells are not created equal, a new study finds. Two distinct kinds of self-renewing blood cells have been spotted in mice, muddying a simplistic view of stem cell categories. Knowing how these different types of stem cells behave may help scientists better understand and treat blood diseases.

“The definition of a stem cell, as you look closer, gets more complicated,” comments stem cell researcher Timm Schroeder of the German Research Center for Environmental Health’s Institute of Stem Cell Research in Neuherberg. The new study, appearing March 5 in *Cell Stem Cell,* adds to a growing body of evidence that “black-and-white characterizations might not be right,” says Schroeder, who was not involved with the study.

In the blood, millions of diverse cells die every second. To keep up with this loss, stem cells continually divide to create the correct balance of cell types, which include oxygen-carrying red blood cells and a menagerie of immune cells.

“For the longest time, people always thought there was one single type of blood stem cell in the bone marrow that continually replenished the blood system throughout the life of a person,” says study coauthor Grant Challen of Baylor College of Medicine in Houston.

Recent studies have hinted that blood stem cells have distinct behaviors, but all scientists had to go on was information about how the cells acted once they were implanted in mice. Challen and colleagues identified subpopulations of stem cells before they were implanted and then watched as the cells behaved differently as they divided.

“We’re the first group to actually identify them using different markers,” says Challen.

His team used a special dye to stain stem cells removed from mouse bone marrow. Some stem cells expelled the dye at different rates, which, along with other well-known stem cell markers, allowed the researchers to sort these cells into two classes based on fluorescence. This dye difference told researchers that the stem cells looked different, but not whether the cells acted differently, too.

Researchers next transplanted several hundred cells, by type, into mice lacking blood stem cells. Over the next few months, the researchers monitored what kinds of blood cells were produced by the stem cells. While each type of stem cell was able to produce every kind of blood cell, the team found a clear difference in productivity: One type of stem cell made many more red blood cell precursors than the other type. And the second type made more of certain kinds of white blood cells, immune cells called T and B cells, than its counterpart. These strong biases for generating different kinds of cells were evident even when the researchers injected a single stem cell into a mouse and watched as the stem cell repopulated the entire blood system.

Until now, researchers didn’t know

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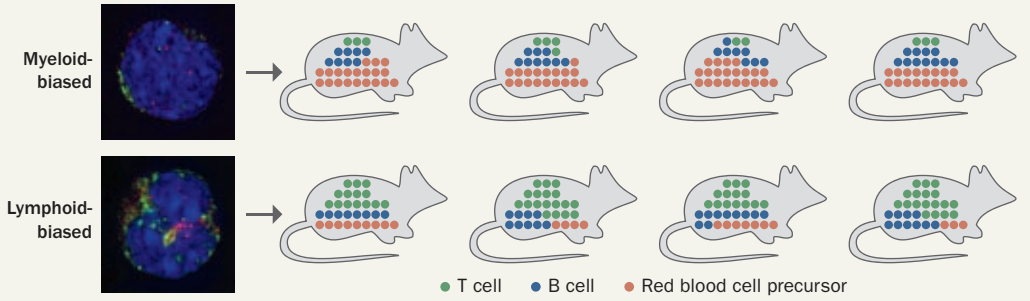


Biased cells After single cell transplantation, two types of mouse blood stem cells (color on cells indicates different protein markers) produced different proportions of red blood cell precursors and T and B cells. (Examples from four transplants are shown.)

whether cells behaved differently because individual cells were unpredictable or because there were truly different types. These new results, Schroeder says, "show they're not that unpredictable — some contribute more and some contribute less."

What's more, as the mice aged, the relative amounts of these stem cell types shifted. As mice got older the stem cells that create more red blood cell precursors, dubbed myeloid-biased stem cells, made up a larger proportion of all stem cells, beating out the T and B cell–producers, called lymphoid-biased stem cells.

This age-related change, if it holds true in humans, may be behind some of the blood diseases and cancers that increase in incidence with age.

"We believe that this phenomenon we discovered — that myeloid stem cells become increased over time — may be related to some of the myeloid proliferative diseases associated with the elderly," Challen says. The concurrent decline in immune cell–producing stem cells might be important for weakened immune systems too, he says.

In additional experiments, Challen and colleagues found that a protein called TGF-β1 spurs myeloid-biased stem cells to divide and at the same time represses division of their immune cell–producing counterparts. The discovery solves a conundrum in the field, he says.

Different reports had found conflicting roles for TGF-β1, sometimes finding it causes cell proliferation and sometimes concluding the opposite. "This effect is because people are using all of the stem cells," Challen says, instead of separating them into subtypes. The different actions of TGF-β1 may allow fine-tuning of the ratio of different stem cell subtypes, the authors propose in their new paper.

Finding fine-scale differences between blood stem cells may be a prelude of what's to come in other stem cell fields, such as gut and neuron stem cells.

"The blood stem cell is by far the most characterized stem cell in the body," Challen says. "Once those fields catch up to blood stem cells, this may pan out to be true for other organs as well."

In a separate study reported March 12 in *Science*, stem cell researchers identified a population of skin stem cells that reside in hair follicles in mice. During early development, these cells could generate three distinct cell lineages, researchers in the Netherlands and Sweden discovered. But in older mice, the cells contributed less to the hair lineage but still produced oil gland and skin cells.

Meanwhile, the case is far from closed on blood stem cells, Challen adds. More detailed experiments and better separation methods will enable scientists to make even further distinctions, he says. "I think even what we've given is a somewhat simplistic view." ■

Back Story | NOT JUST RED STUFF

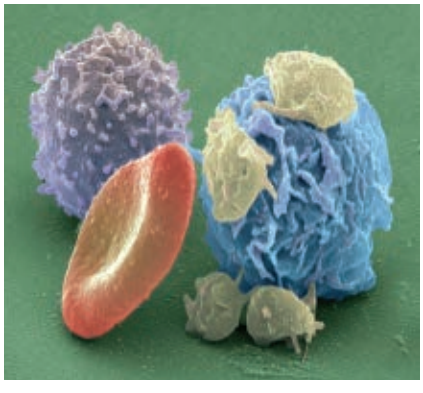
About 55 percent of the blood's volume is plasma; stem cells in the bone marrow produce the collection of cells that make up the rest.

White blood cells

Granulocytes are a type of white blood cell that gobbles up invaders, kills parasites and jump-starts the inflammatory response. The gobblers, called neutrophils (purple), are the most abundant white blood cells and give pus its yellow-white color.

Monocytes are the largest of the white blood cells. They quickly travel to infected areas where they develop into macrophages (which consume foreign material) and signal other immune cells to join.

Lymphocytes (blue) come in a variety of forms. B cells produce antibodies against invading pathogens. T cells also play important roles in the immune system. And natural killer cells destroy virus-infected or cancer-ridden cells.



Red blood cells (red) are the most abundant cells in the blood — each cubic millimeter contains around 4 million to 6 million cells. They carry oxygen and carbon dioxide in the body. These disc-shaped cells, also called erythrocytes, live for 100 to 120 days.

Platelets (yellow and gray) are fragments of larger cells and lack nuclei. Platelets play an important role in blood clotting.

FROM TOP: G. CHALLEN, MARGARET GOODELL; SPL/PHOTO RESEARCHERS, INC.

Can a bath improve your health and quality of life?

Rediscover the pleasure and pain-therapy of a luxurious bath… safely and affordably.

By June Fleming

Remember the feeling you had when you drew a hot bath, sat down in the tub, and let the warm water wash away the cares of the day? After the bath, you emerged refreshed, rejuvenated and ready to go. For many people, the luxury of taking a bath has become a thing of the past as age and mobility issues have robbed them of one of life's simple pleasures. Now, the leader in finding innovative products for Boomers and Beyond has found a product that can get you back in the water again, safely and affordably. It's called the Designed for SENIORS® SafeStep Walk-In Tub, and we'd love to tell you about it.

Come on in, the water's fine. Traditional bath tubs have a one and a half foot wall, but for many aging Americans, it might as well be six feet tall. Stepping into a slippery tub takes a degree of balance and coordination many of us no longer have. The alternative is to try to sit in the shower or take "cat-baths" at the sink, but it's just not the same. Imagine being able to simply walk in to the tub, sit down and take the bath you've been missing. It easily replaces your existing tub, so you can stay in the home you love and even help to increase its value. Because it comes standard with the best features on the market, the Designed for SENIORS® SafeStep tub is not only the most affordable … *it's the best.*

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Environment

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Oceans yield huge haul of plastic

'Garbage patches' more common and deeper than thought

By Sid Perkins

Recent studies show that the oceans may hold more fine plastic flotsam than scientists realized — and that the fragments extend well below the surface.

Most of these objects are the size of fingernail clippings or smaller. They are the wave-shattered remnants of items such as rubbish, abandoned fishing gear and floats from fishing nets and scientific instruments.

On calm days debris floats to the surface, where it can be readily collected by fine mesh nets that scientists tow behind their boats. When winds roil the seas, however, wave action mixes the tiny bits of plastic down as much as 20 meters below the surface, Giora Proskurowski of the Sea Education Association in Woods Hole, Mass., reported February 24.

These plastic bits are especially common in a region of the Pacific Ocean southwest of California that is sometimes called the Great Pacific Garbage Patch.

Proskurowski and his colleagues collected their data on six cruises through the northwestern portions of the patch between June 2004 and July 2009. The researchers estimate that part of the region — a whopping 3.5-million-square-kilometer swath about twice the size of Alaska — contains more than 20,000 bits of floating plastic per square kilometer.

The world's oceans contain a surprisingly large load of tiny plastic bits.

During sampling conducted when wind speeds were just under 28 kilometers per hour (about 17 miles per hour), a net towed along the surface caught 431 plastic bits while one towed simultaneously at a depth of five meters trapped 240. In such conditions, the researchers estimate, the waters between one and 10 meters deep hold as much plastic as the top meter of ocean.

Large swaths of the western North Atlantic also hold prodigious amounts of plastic bits, said Kara Lavender Law, an oceanographer at the Sea Education Association. On cruises between the Gulf of Maine and the Caribbean from 1986 through 2008, researchers conducted more than 6,100 surface tows that collected more than 64,000 pieces of plastic, she said.

As in the Pacific, the vast majority of plastic bits were tiny: In one sample of about 750 fragments, most were less than a centimeter across and weighed less than 0.15 grams.

Computer simulations reveal that oceanic garbage patches may be more common than even scientists generally recognize, said Nikolai Maximenko, an oceanographer at the University of Hawaii at Manoa. Patches are especially likely to occur in several large areas of the ocean where currents are slack. "Some of these areas are like a black hole," he noted. "Once things are trapped there, they never escape."

Whale hunting's carbon footprint

Effect of last century's whaling equal to 128,000 SUVs

By Sid Perkins

During the 20th century, industrial whaling activities depleted a storehouse of carbon equivalent to the forests of New England, a new study suggests.

Whales, a group of mammals that includes the largest animals ever to live, are huge repositories of carbon. Individual whales pack on carbon as they grow, typically increasing in weight between 1 and 3 percent each year. In addition to their great heft — a blue whale can weigh around 90 metric tons — whales can store carbon in their bodies for well over a century. "In marine ecosystems, whales are like forests," said Andrew J. Pershing, a biological oceanographer at the University of Maine in Orono. He presented his research February 25.

Industrial whaling — the use of large engine-driven ships to efficiently harvest whales — commenced in earnest around 1900, Pershing noted. That year, he estimates, the oceans held about 110 million metric tons of whales.

Over the course of the 20th century, whaling transferred more than 105 million tons of carbon from living whales into the atmosphere — an amount equal to about 385 million metric tons of planet-warming carbon dioxide.

Those emissions are small potatoes compared to the approximately 7 billion tons of CO_2 emitted by human activities each year. "Whaling did not cause global warming," Pershing said.

Nevertheless, he noted, the carbon footprint of last century's industrial whaling is equivalent to that produced by driving 128,000 Hummers for 100 years, or by burning 130,000 square kilometers of temperate forest — an area about the size of Alabama, containing an amount of carbon roughly equivalent to that found in all the forests in New England. ■

G. PROSKUROWSKI/SEA EDUCATION ASSOCIATION

"The data are saying if you want to save the species, stop fishing—or drastically reduce it." —DYLAN FRASER

Some exposed males mated with other males—and produced viable eggs.

T.B. HAYES/UC BERKELEY

Herbicide makes frogs Mr. Moms

Hormonal tinkering may explain a host of adverse changes

By Janet Raloff

Two studies have fingered a potential contributor to the widespread decline of amphibians: water contaminated with atrazine, a weed killer used widely on corn, cotton and turf. In the lab, atrazine fully feminized some male frogs. Outdoors, in pools designed to simulate ponds, the herbicide drastically reduced the share of wild tadpoles able to metamorphose.

Atrazine concentrations triggering these changes—up to 2.5 parts per billion—regularly occur in North American ponds and streams. The Environmental Protection Agency allows up to 3 ppb of atrazine in drinking water.

Tyrone Hayes and his colleagues at the University of California, Berkeley, exposed male frogs in the lab to 2.5 ppb of atrazine. These animals developed few sperm and had very low testosterone levels. More provocatively, 10 percent of these males transformed into functional "females" that encouraged the advances of healthy males, and in two cases were found to have produced eggs that hatched into viable young.

The Berkeley group reported its findings online March 1 in the *Proceedings of the National Academy of Sciences*.

Separately, University of Ottawa scientists teamed up with colleagues at two federal agencies in Canada to study atrazine's effects on northern leopard frogs. The team collected fertilized eggs from local ponds, incubated them until hatching, and then transplanted the tadpoles into 378-liter outdoor pools.

The brains of animals exposed to higher atrazine levels saw a 2.5-fold increase in receptors for estrogen. This change could render the animals more susceptible to the feminizing effects of their own estrogen or environmental mimics of this hormone, notes Vance Trudeau, one of the Ottawa scientists.

Higher exposure also altered activity of a liver enzyme that converts testosterone into another male sex hormone. And it perturbed production of thyroid hormones that play a pivotal role in metamorphosis, Trudeau's team reported online recently in *Environmental Health Perspectives*.

In fact, atrazine-exposed pollywogs proved only about half as likely to metamorphose as those raised in clean water. "I would consider this quite important," Trudeau says, "because if you have 50 percent less metamorphosing, you're likely to have more [young] picked off" by predators.

Older fish key to saving sturgeon

Farm-raised fry unlikely to restore caviar-producing species

By Rachel Ehrenberg

Saving grown females—not fry—is crucial to preventing extinction of the beluga sturgeon, a new conservation assessment concludes.

The study finds that current conservation efforts, which rely mostly on introducing young hatchery-bred fish into the wild, are unlikely to succeed. Instead, scientists report in an upcoming *Conservation Biology,* the species' survival depends on protecting the mature females that are most prized for their copious roe.

"It's a no-brainer," says fisheries biologist Dylan Fraser of Concordia University in Montreal, who was not involved with the study. "The data are saying if you want to save the species, stop fishing—or drastically reduce it."

Demand for caviar, which can sell for $8,000 a kilogram, has pummeled populations of beluga sturgeon. The fish once swam the Adriatic, Azov, Black and Caspian seas, but is gone from parts of its range and critically endangered in others.

Using life history and population data on sturgeon that spawn in the Ural River, researchers examined the implications of keeping different age classes of fish in the population. For fishing to have minimal effects, they concluded, sturgeon shouldn't be harvested until they are at least 31 years old in order to assure the females have had a sufficient chance to produce eggs.

Saving mature and nearly adult females was 10 times more effective than supplementing the population with hatchery fish, says study leader Phaedra Doukakis of the Institute for Ocean Conservation Science at Stony Brook University in New York.

Humans

For longer versions of these and other Humans stories, visit **www.sciencenews.org**

Facebook users are the real thing

Young adults don't deceive others on social networks

By Bruce Bower

"On the Internet," one dog tells another in a classic *New Yorker* cartoon, "nobody knows you're a dog."

The Internet is notorious for its digital dens of deception. But on Facebook, what you see tends to be what you get — at least in one study of tailless, two-legged young adults.

College-age users of Facebook in the United States and a similar social networking site in Germany typically present accurate versions of their personalities in online profiles, researchers conclude in an upcoming *Psychological Science*.

"Online social networks are so popular and so likely to reveal people's actual personalities because they allow for social interactions that feel real in many ways," says psychologist Mitja Back of Johannes Gutenberg University in Mainz, Germany.

Back's team administered personality inventories to 133 U.S. Facebook users and 103 Germans who used a comparable social networking site. The subjects — who ranged in age from 17 to 22 — took the inventory twice, first with instructions to describe their actual personalities and then to portray idealized versions of themselves. The inventories focused on the extent to which volunteers endorsed ratings of extraversion, agreeableness, conscientiousness, emotional instability and openness to new experiences.

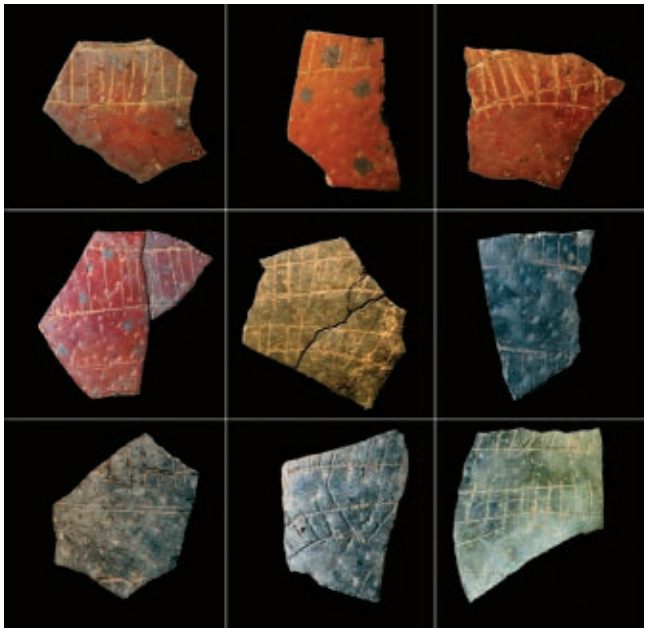
What you see tends to be what you get — at least in one study of tailless, two-legged young adults.

Then undergraduate research assistants — nine in the United States and 10 in Germany — rated volunteers' personalities after looking at their online profiles. Those ratings matched volunteers' actual personality descriptions better than their idealized ones, especially for extraversion and openness.

Past research shows that Facebook is so true to life that encountering a person there for the first time generally results in a more accurate personality appraisal than meeting face to face, Back claims.

Adriana Manago, a psychology graduate student at UCLA, calls the new findings "compelling" but incomplete. College students on Facebook and other online social networks often augment what they regard as their best qualities, Manago says. In her view, these characteristics aren't plumbed by broad personality measures like the ones used in Back's study. And students' actual personality descriptions may have enhanced their real characteristics, inflating the correlation between observers' ratings and students' real personalities, she notes.

"Online profiles showcase an enhanced reflection of who the user really is," Manago proposes. In a 2008 study she and her colleagues found that 23 college students sometimes used the online social networking site MySpace to enhance their images, say by Photoshopping acne out of a picture or posting a video of themselves driving a sports car at high speeds.



P.-J. TEXIER, DIEPKLOOF PROJECT

Groovy eggshell designs

A cache of ostrich eggshells engraved with geometric designs provides new evidence for symbolic communication among hunter-gatherers about 60,000 years ago — and traces its evolution over time. The unusually large sample of 270 engraved shell fragments, mostly excavated over the past several years at Diepkloof Rock Shelter in South Africa, displays two standard design patterns, says archaeologist Pierre-Jean Texier of the University of Bordeaux 1 in Talence, France. Each pattern enjoyed its own heyday between about 65,000 and 55,000 years ago, he and his colleagues report in a paper published online March 1 in the *Proceedings of the National Academy of Sciences*. Evidence of intentionally produced holes in several Diepkloof eggshells suggests that ancient people made canteens out of them, a practice researchers have documented among modern hunter-gatherers in southern Africa. The engraved patterns probably identified the eggshells as the property of certain groups or communities, Texier proposes. — *Bruce Bower*

18 minutes | Time it took the *RMS Lusitania* to sink

160 minutes | Time it took the *RMS Titanic* to sink

194 minutes | Running time of the 1997 movie *Titanic*

‘Women and children first’ holds only if a ship is sinking slowly

Comparison of disasters suggests chivalry takes time

By Laura Sanders

Gallantry ruled on the day the *Titanic* went down in 1912. As the vessel’s orchestra played soothing music to calm the passengers, women and children were escorted to the limited supply of lifeboats, leaving healthy young men to go down with the sinking ship.

Three years later, the sinking of the *Lusitania* by a German torpedo was an altogether different affair. As the civilian passenger ship keeled over in a matter of minutes, young healthy men scrambled to the lifeboats, leaving women and children to drown.

These dramatic differences in behavior aboard a sinking ship may all come down to time, a new study suggests. The *Titanic* took 2 hours and 40 minutes to sink beneath the waves. The *Lusitania*, in contrast, went down in 18 minutes. The new results, appearing in a paper published online March 1 in the *Proceedings of the National Academy of Sciences*, suggest that in extreme situations social norms — codified here as women and children first — require time to appear.

“The key is time. This is really a crucial finding,” says economist Benno Torgler of Queensland University of Technology in Brisbane, Australia. He and his colleagues examined the ships’ survival records to see how humans act in extreme situations.

In the melee of rapid, stressful situations, an “every man for himself” mentality may have prevailed. That would explain why young men on the *Lusitania* saved themselves without regard for fellow passengers. “People had only a couple of minutes. So very instinctive behavior — survival of the fittest — emerged,” Torgler says.

Records from the life-or-death situations on board the two ships provide a natural experiment that could never be done in a lab, comments behavioral economist Colin Camerer of Caltech. “Some of these dramatic experiments we can’t do, so we look for historical analogs,” he says. “Occasionally you stumble upon these gold mines of historical data, and that’s what they’ve got here.”

Although the ships sank under different circumstances, the vessels had key similarities that allowed Torgler and colleagues to compare who made it to the lifeboats. The *Titanic* and the *Lusitania* carried comparable numbers and types of passengers, making the two ships “similar to a field experiment,” Torgler says.

Most data on social behavior under stressful conditions are from self-reported survey answers or watered-down lab simulations, Torgler says. “The strength of analyzing people in real situations is that their true preferences are revealed,” he says.

The researchers combed through historical accounts and records from the *Titanic* and *Lusitania* and compared the survival of different groups, using passengers who were over 35, childless or traveling third class as a reference population.

Women aboard the *Titanic* were more than 50 percent more likely to survive than men, but women had no edge on the fast-sinking *Lusitania*, the team found.

On the *Titanic*, men between the ages of 16 and 35 were almost 7 percent less likely to survive than people in the reference population, but on the *Lusitania*, young men were almost 8 percent more likely to survive. On the *Titanic*, children were 31 percent more likely to make it into a lifeboat, but aboard the *Lusitania*, children fared slightly worse than the reference population, the team found.

BETTMANN/CORBIS

This illustration depicting a lifeboat full of women being lowered from the *Titanic* was created to demonstrate that “the chivalry of the sea was observed.”

What’s more, on the *Titanic*, first-class passengers were about 44 percent more likely than to survive than members of the reference population. But on the *Lusitania*, a first-class ticket didn’t confer any advantages, the team reports. Wealthy passengers apparently had more time to exert their influence as the *Titanic* sank, Torgler hypothesizes, and thus they bargained their way into lifeboats to save themselves.

Longer time frames such as the nearly three hours it took for the Titanic to sink allow social norms and order to emerge, the researchers hypothesize.

The team is now studying records from other historical episodes, such as mountaineering accidents and the September 11 attacks, to test the influence of time on social behavior.

The study’s findings are persuasive, Camerer says.

“Under extreme time pressures, it’s everybody for themselves. Coordinating and respecting norms takes time,” he says. “When people have time to deliberate, you see pro-social behavior.” ■

Earth

4.54 billion Earth's age from radiometric dating, in years

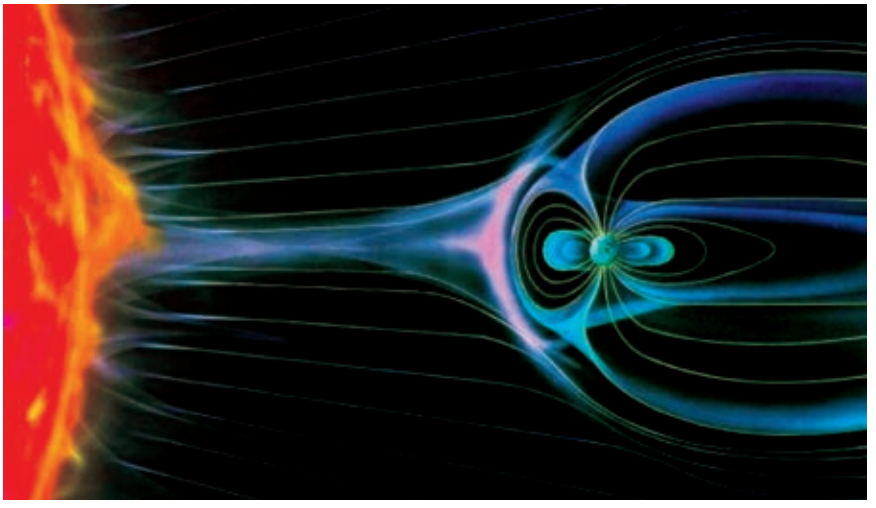
3.85 billion Oldest geochemical evidence for life, in years

3.45 billion Oldest fossil evidence for life, in years

Shields were up on early Earth

Magnetic field formed in time to protect nascent life

By Lisa Grossman



By 3.45 billion years ago, Earth's magnetic field (the bubble-like structures encasing the planet, at right) was deflecting particles streaming from the sun (left).

STEELE HILL/NASA

Evidence for the origin of Earth's magnetic field has been pushed back as much as 250 million years, new research suggests. The field may therefore be old enough to have shielded life on the planet's surface from the sun's most harmful cosmic radiation.

Earth's magnetic field existed by 3.4 billion years ago, a team including researchers from the University of Rochester in New York and the University of KwaZulu-Natal in South Africa report in the March 5 *Science*.

That formation date falls during life's earliest stages of development, between the period when the Earth was pummeled by interplanetary debris and when the atmosphere filled with oxygen. Several earlier studies had suggested that a magnetic field is a necessary shield against deadly solar radiation that can strip away a planet's atmosphere, evaporate water and snuff out life on its surface.

"I think it's a magnificent piece of work, a real landmark," says geophysicist David Dunlop of the University of Toronto, who was not involved in the research. "It pushes the boundary back about as far back as you could reasonably expect to measure on Earth."

The researchers measured the magnetic strength of rocks found in the Kaapvaal craton of South Africa, a geologic region known to date back more than 3 billion years.

Just finding old rocks wasn't enough, though; they had to be the right ones. "It's a Goldilocks theory of finding rocks," says John Tarduno of the University of Rochester, a coauthor of the new study. Iron minerals record the strength and direction of the magnetic field that was present when the rocks formed. But when they are heated in subsequent geological processes, rocks can lose or overwrite that record.

"We had to find a rock that had just enough iron to record a magnetic signature, but not so much that it would be affected by later chemical changes," Tarduno says.

The South African rocks were just right. They contained crystals of quartz less than two millimeters long, with nanometer-sized bits of iron-containing magnetite embedded in them.

"Quartz is the perfect capsule," Tarduno says. "It's not affected by later events, but it has these [iron] inclusions in it."

He and his colleagues had studied similar rocks in 2007 and found that a magnetic field half as strong as today's was present 3.2 billion years ago. Using a specially designed magnetometer and improved lab techniques, the team detected an even weaker magnetic signal indicating a field 50 to 70 percent the strength of today's in 3.45-billion-year-old rocks, Tarduno says.

"When we think about the origin of life, there are two threads to follow," he says. "One obviously is water. But you also have to have a magnetic field, because that protects the atmosphere from erosion and the complete removal of water." Mars, he adds, may be dry today because it lost its magnetic field early on.

To determine if Earth's early magnetic field was enough to hold back the rain of radiation, the team needed to know what the sun was doing. Tarduno and Eric Mamajek, an astronomer at the University of Rochester, used observations of young sunlike stars to infer how strong a solar wind the Earth was up against.

The young sun probably rotated more quickly than it does today, Tarduno says. This quick rotation powered a strong solar magnetic field that heated the sun's atmosphere and generated a strong wind of charged particles. The team calculated that the point where the Earth's magnetic field cancels out the solar wind would be only about five Earth radii above the planet's center, less than half of the 10.7 radii it is today.

The amount of radiation regularly reaching Earth from the sun 3.45 billion years ago would be comparable to what rains down on the planet during the most powerful solar storms today, Tarduno says. As a result the aurora borealis would have been visible as far south as the latitude of present-day New York City.

Matter & Energy

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Atomic heavyweight gets a name

Element 112 christened 'copernicium' after astronomer

By Rachel Ehrenberg

There's a new heavy in town. Element 112, a "superheavy" element with an atomic mass of 278, is officially named copernicium, the International Union of Pure and Applied Chemistry announced February 19. It is the heaviest named element to date.

Scientists hope that copernicium (pronounced koh-pur-NEE-see-um) is a stepping stone toward the predicted "island of stability," a region of the periodic table where researchers expect to find superheavy elements that last longer than a few seconds and might be exploited for purposes still unknown.

"One of the exciting things is, how far can we keep going?" says nuclear chemist Paul Karol of Carnegie Mellon University in Pittsburgh. "We might find something that is stable and has unusual applications."

A team led by Sigurd Hofmann of the Center for Heavy Ion Research in Darmstadt, Germany, created copernicium, symbol Cn, in 1996 by bombarding a lead target with zinc. It took a week to create one Cn atom, Hofmann notes in a commentary in the February *Nature Chemistry*, and more than a decade of follow-up research for Hofmann's team and other researchers to validate the feat.

Forcing two nuclei together is no small task, says John W. Jost, former director of IUPAC in Research Triangle Park, N.C. It requires breaking through the barrier of electrostatic repulsion at larger scales in the atom and then using the attractive forces binding the nucleus to lasso the two nuclei together. Even once fusion has occurred, the product decays almost instantly. Researchers then must analyze this "decay chain" to figure out what element they created.

Sitting below zinc, cadmium and mercury in the periodic table, copernicium may behave similarly to these metals. Copernicium might be more volatile than mercury but still be liquid at room temperature, Hofmann speculates.

Copernicium is named for the Renaissance scholar Nicolaus Copernicus, who is best known for turning the Earth-centered view of the universe inside out by presenting the first fully conceived theory of a planetary system centered on the sun rather than the Earth.

Life

For longer versions of these and other Life stories, visit **www.sciencenews.org**

Female beetles ready for dung wars

Mothers' battles over excrement favored evolution of horns

By Susan Milius

So many moms, so little fresh excrement. Though male animals are usually the ones to sport horns, such battle armor comes in handy for beetle mothers who use their oversized weapons in fights over dung.

In female dung beetles, competition for a critical resource — dung — to wrap eggs and feed young favors the evolution of exaggerated horns.

Females of the species *Onthophagus sagittarius* who have heftier horns win control of more dung and can lay more dung-encased eggs, say Nicola Watson and Leigh Simmons of the University of Western Australia in Crawley. This competition drove the evolution of feminine weaponry in the species, the researchers conclude in research published online March 3 in *Proceedings of the Royal Society B*.

"It's a rare example of this type of evolutionary event for sure," says biologist Ted Stankowich of the University of Massachusetts Amherst.

Darwin proposed that male weaponry arose from the struggle between rivals for access to females, and plenty of examples fit that scenario. But females have their own reasons to grow personal arsenals. In gemstock antelope, for example, defense against predators probably drove the evolution of female horns, Stankowich says. In other species, territorial battles probably did the same.

The female beetles sprout a large central horn with a smaller stub behind, Watson says, like a miniature version of a rhino's weaponry. Males grow a pair of stubbier horns, more like a bull's.

Because male and female horns are so different, Watson and Simmons dismiss the possibility that the female horns grow simply as some kind of genetic spillover from male horns. Another possible explanation for female horns is that males find them alluring. Probably not, Watson and Simmons report in the March–April *Behavioral Ecology*. In lab tests, male beetles showed no extra ardor for females with greater horn endowments.

To settle the debate, the team in Australia bred beetles in the lab and counted their offspring in various situations. When females of different sizes had to compete for dung, big ones flourished while smaller ones produced few dung-swaddled eggs. And when researchers paired females of similar size, those with proportionately heftier horns had more offspring.

Polar bears are a modern species

Fossil reveals close genetic ties to brown bears in Alaska

By Sid Perkins

The polar bear probably evolved about 150,000 years ago and is most closely related to brown bears that now live in southeastern Alaska, new genetic analyses of a rare fossil suggest.

Several previous studies agreed that polar bears are closely related to brown bears but provided widely divergent answers about when polar bears first evolved, with estimates ranging between 70,000 and 1 million years ago, says Charlotte Lindqvist, an evolutionary biologist at the University at Buffalo in New York. Now, genetic analyses of material from a fossil first described two years ago narrow that window, Lindqvist and her colleagues report in a paper published online March 1 in the *Proceedings of the National Academy of Sciences*.

The fossil, a jawbone found on an island in Norway's Svalbard archipelago, was unearthed from rocks that are between 110,000 and 130,000 years old. The remains represent by far the oldest polar bear fossil yet found, Lindqvist notes.

Using material from a tooth, the team reconstructed the bear's mitochondrial genome, which contains genetic material passed down with few mutations through generations of females. The researchers compared the results with mitochondrial genomes of six other specimens, including modern polar bears and brown bears from two regions in Alaska.

The genetic tests show that modern-day polar bears, which live throughout the Arctic and fall within one species, are most closely related to modern brown bears in Alaska's panhandle.

The polar bear evolved a mere 150,000 years ago, genetic analyses of a fossil found in Norway suggest.

"This is the most exciting development in polar bear research in recent years," says Ian Stirling, a biologist at the University of Alberta in Edmonton, Canada. The findings suggest that polar bears may have survived a previous warm period by retreating to higher latitudes and might be able to do so again as sea ice retreats.

FROM TOP: SEAN STANKOWSKI; TOM BRAKEFIELD/COMSTOCK IMAGES

Body & Brain

795,000 Number of U.S. people who suffer a stroke each year

137,119 Number of U.S. people killed by a stroke in 2006

‘Ministroke’ effects often missed

Common test given after attacks may not catch all damage

By Nathan Seppa

As many as four in 10 people referred to a clinic with signs of a “ministroke” may have subtle cognitive damage that standard tests miss, a new study shows.

The findings, reported by Canadian researchers February 24, suggest that after suffering ministrokes many patients lose some ability to process abstract thoughts, reason things out and make quick calculations — what doctors call “executive function.”

Full-blown strokes can cause a clear loss of cognitive function, most often due to a blood vessel blockage in the brain that shows up on an MRI or CT scan. Ministrokes are caused by smaller obstructions and can result in more subtle deficits that are less likely to be detected by brain scans or even by patients themselves. Some scientists consider the term ministroke a misnomer, preferring “transient ischemic attack,” while others use the terms interchangeably.

The symptoms of a ministroke or a full-blown one might start out the same, with numbness in the face or extremities, confusion, vision problems, dizziness or headache. But in a ministroke, these symptoms wane after minutes or hours.

In the new study, researchers tested 140 patients whose symptoms subsided within 24 hours, indicating they had ministrokes. The team gave the subjects a test of cognitive acuity routinely given to patients who show up at a clinic or hospital with signs of a stroke. Known as the Mini-Mental Status Exam, the test gauges a number of cognitive functions including short-term recall, attention span and spatial recognition.

MMSE testing showed only 5 percent to be cognitively impaired. But when researchers gave the patients four other tests specifically designed to gauge executive function, the number of impaired individuals ranged from 13 to 40 percent depending on the test, said Michael Harnadek, a neuropsychologist at the London Health Sciences Center in Canada, who presented the data.

> “We used to attribute this to aging, but now we know that this isn’t normal aging.”
> MICHAEL HARNADEK

The patients were 67 years old on average. In the general population, executive function impairment shows up in about 7 percent of people this age, he said.

The tests of executive function included tasks such as putting digits in numerical order and drawing a clock with the hands pointing to a specific time. Difficulty with these skills suggests a corresponding deterioration in everyday tasks such as taking phone messages and keeping track of car keys.

“We used to attribute this to aging, but we now know that this isn’t normal aging,” Harnadek said. “It’s these cognitive difficulties.”

Having had a ministroke also places a person at heightened risk of a full-blown stroke, said Lee Schwamm, a vascular neurologist at Harvard Medical School in Boston.

Schwamm likened the brain damage caused by unnoticed ministrokes to divots taken out of a golf course. “I’m not surprised to see impairment of executive function with this more subtle cognitive testing,” he said.

UCLA vascular neurologist Bruce Ovbiagele added that there isn’t a perfect test for suspected ministrokes. The additional tests of executive function could help physicians persuade at-risk patients to be more diligent about their health, he said. “This should be enough to at least alert clinicians to consider using this [testing] as part of their routine.”

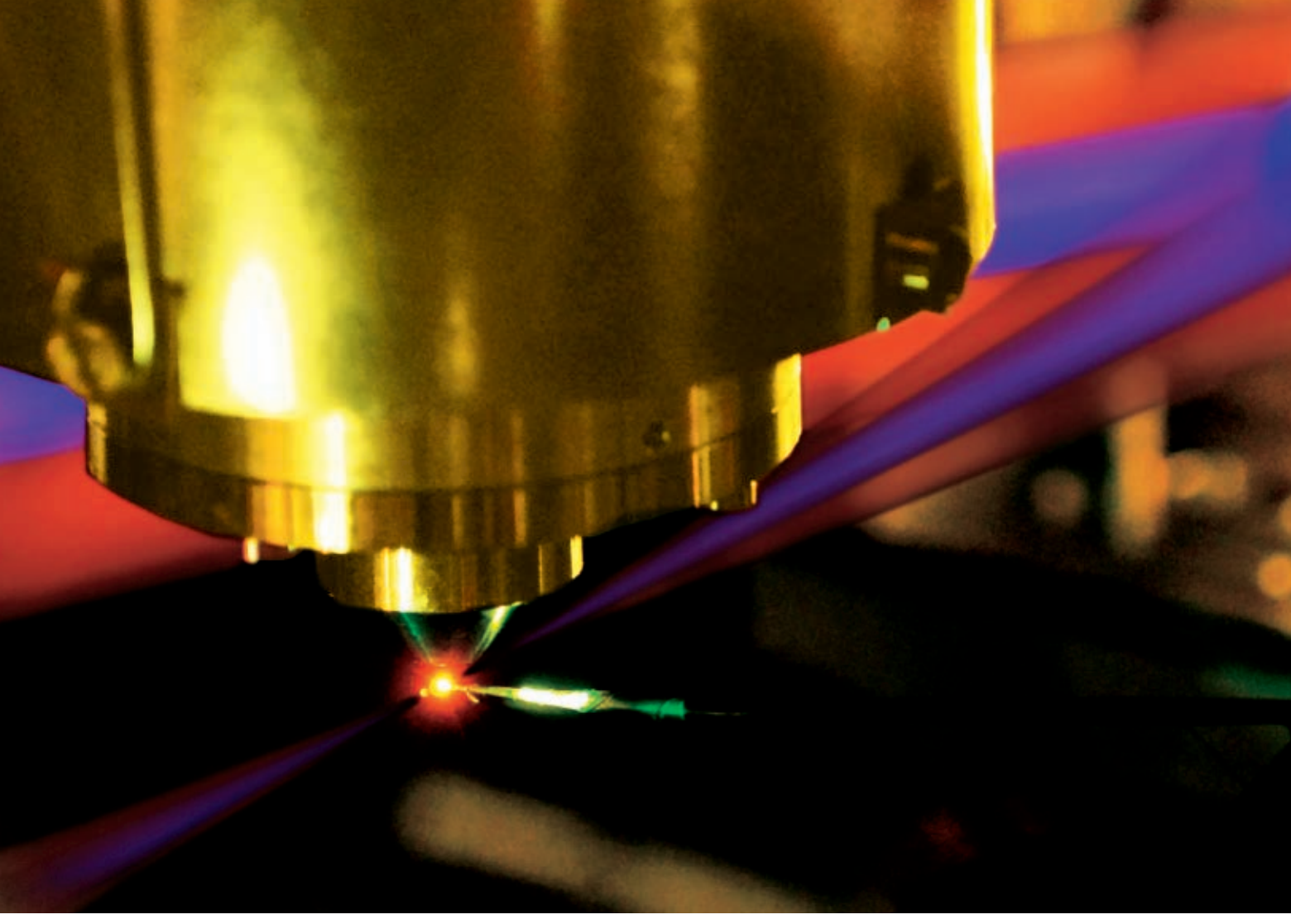
MEETING NOTES

More strokes in women

For reasons no one understands, U.S. women appear to be nearly three times more prone to strokes than men. Vascular neurologist Amytis Towfighi of the University of Southern California in Los Angeles and her colleagues analyzed data from 2,274 participants in an ongoing health study that had previously shown a doubled stroke risk for women ages 45 to 54 compared with men. “That went against thinking — women were thought to be protected against stroke until menopause,” she said. In the new analysis of people ages 35 to 64, the researchers found that 2.9 percent of women had a stroke, compared with 1.07 percent of men. The difference arose predominantly in the 45 to 54 age group, Towfighi reported February 25. The only risk factor that appeared worse in women than in men was abdominal fat, she said. “This is not direct proof, but it really suggests that abdominal obesity has something to do with the trend.” —*Nathan Seppa*

Coffee linked to lower stroke risk

People who drink coffee are nearly one-third less likely than nondrinkers to have a stroke, Yangmei Li of the University of Cambridge in England reported February 25. Li and colleagues analyzed health records of more than 20,000 European men and women ages 39 to 79. Over 12 years, people in the group had 855 strokes. After accounting for other factors, the team found that coffee drinkers were only 71 percent as likely to have had a stroke as coffee avoiders. It didn’t matter if the brew was drip, decaf or even lowly instant, nor if people drank one cup a day or four. —*Nathan Seppa*



In Pursuit of the Briefest Beat

Attosecond pulses of light could open electrons' fast-paced world

By Charles Petit

In his mind, Paul Corkum envisioned a dramatic thriller. Its actors were the pulsating electric fields of ordinary infrared laser beams and the electrons of atoms in the laser's path. As the plot unfolded, a puzzle would be resolved — opening, he realized, a new frontier in the measurement of the ultrafast and the ultrabrief.

Corkum is a laser and plasma physicist with Canada's National Research Council and the University of Ottawa. His vision, in 1993, led him to become a pioneer in a field called attosecond science; since then his work has won him a stack of Canada's top science prizes. He directs the newly opened Joint Laboratory for Attosecond Science in Ottawa. The laboratory produces X-ray flashes quick enough to "freeze" electrons orbiting an atom, and claims to make Ottawa the attosecond capital of the world.

"I tell my students we are puppet masters," Corkum says. "We have access now to forces on charged particles that are on the scale of those that hold matter together, and we can make them do what we wish, with exquisite accuracy."

Someday, attosecond science could lead to a deeper understanding of the chemistry of life, photocells of vastly greater efficiency or even electronic circuits managed by nanoscale lasers. But for now, this nearly two-decade-old science is still doing warm-up calisthenics before its first real game.

Attosecond science's current lack of major discoveries bears some resemblance to the Large Hadron Collider just going through its shakedown exercises on the French-Swiss border, or the Hubble Space Telescope back when it sat on the launchpad — loaded with delicate

THORSTEN NAESER, WWW.ATTOWORLD.DE

By probing atoms with quick light pulses (experimental chamber shown), scientists can gain a deeper understanding of chemistry.

mirrors, magnets, electronics, spectroscopes, cameras and the hopes of a corps of scientists already excited despite no achievements yet in hand. There is also a big difference. Attosecond research has no glamorous instrument to capture popular imagination. The key to its allure lies within its name.

Short and shorter

An attosecond is 10^{-18}, a billionth of a billionth, of a second. An attosecond is to a second as a second is to the age of the universe. In three attoseconds, a beam of light traveling 300,000 kilometers per second can get only from one side of a water molecule to the other. And the electron of a hydrogen atom, dissolved in a hazy cloud of quantum mechanics probability, sloshes from one side of the atom to the other every 24 attoseconds — a fundamental oscillation dubbed the atomic unit of time.

The attosecond scale stretches from one to 1,000 attoseconds, at which point the slower femtosecond domain begins. A pulse of one femtosecond, 10^{-15} (a millionth of a billionth) of a second, is still pretty fast. Ahmed Zewail, a physicist and chemist at Caltech, netted a 1999 Nobel Prize for using femtosecond pulses of laser light to study how molecules reflect and refract light, and otherwise behave at these fast time scales. A primary achievement of femtosecond science was to reveal how quickly the nuclei of atoms in molecules rearrange during a reaction.

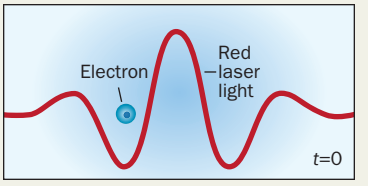
"But we knew already that before the nuclei start to move, the electrons' locations have already changed enormously," Corkum says. To see that in action would require going faster than a femtosecond, and by the early 1990s technology had not yet caught up with theory enough to do so.

It was a pause in the science of taking snapshots of nature that had begun in the 19th century when cameras first froze horses in mid-gallop, revealing to science and to art that all four feet are regularly in the air simultaneously. Over time, faster and faster strobe lights and then laser flashes permitted images of processes to be captured within a thousandth, a millionth and shorter fractions of a second. But for making signals shorter than the femtosecond range for snapshots of electron activity inside atoms and molecules, even the best laboratory lasers had wavelengths a hundred times too long. The problem was getting enough power to run lasers at ever-decreasing wavelengths; the power required goes up by a factor of 100,000 every time the wavelength goes down by a factor of 10.

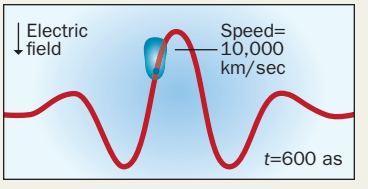
By the late 1980s, however, physicists and optical researchers — first a team led by Charles Rhodes, who was then at the University of Illinois at Chicago — had noticed hitchhikers on ordinary red laser light after it went through thin vapors of gaseous atoms. Embedded were weak but unmistakable extra signals with really short wavelengths and frequencies thousands of times higher — in the far ultraviolet, bordering on X-rays. No one could explain the mystery process and it got a generic name: high harmonic generation.

Creating the pulse

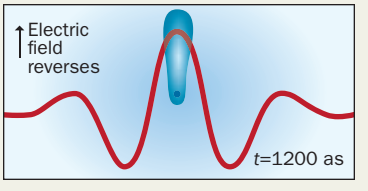
To generate attosecond pulses, researchers must steer electrons within an atom using a laser light's electromagnetic field.



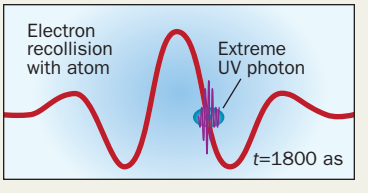
A pulse of red laser light that lasts several femtoseconds and has a specific shape and period is beamed into a wisp of atoms.



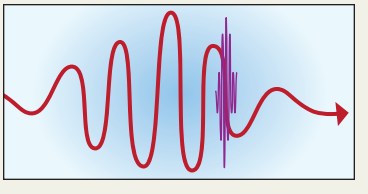
The force of the light's electromagnetic field pulls an electron (blue cloud) away from its nucleus. The field now points down, accelerating the electron up.



Despite speeds of 10,000 kilometers per second, the electron can't completely escape its nucleus because the field's direction reverses.

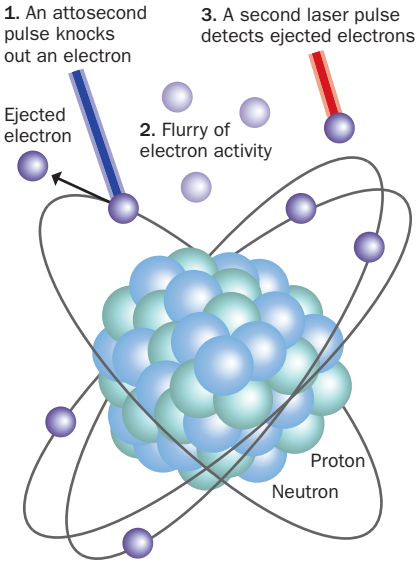


The reversal hurls the electron downward and it collides with the nucleus, releasing energy in the form of an extreme ultraviolet photon.



Each burst is weak, but the same thing happens in millions of atoms in synchrony. The emissions build up to create a more intense pulse.

ADAPTED BY T. DUBÉ



Probing an atom Once created, an attosecond pulse can be used to knock an electron away from its nucleus. This leads to a flurry of activity as another electron replaces the first and transfers its energy to yet another neighboring electron. A probing laser pulse can take a snapshot of an ejected electron; a series of such pulses can piece together a picture of what is happening in an atom.

It was a puzzle, and Corkum cut the knot. As he explains now, he imagined the laser beam's uniformly pulsating electric field as "reaching out its hand" as it encountered certain simple atoms. The hand grips an electron vulnerable to the frequency and quantum energy of the laser light's photons. The hand then pulls the electron nearly instantaneously away; it reaches a velocity of thousands of kilometers per second in a twinkling. The electron's precise locale is inherently imprecise, in accord with the particle-wave duality of the atomic world, but not so hazy that the laser's electric field can't take hold of its negatively charged locale and sweep it hundreds of times the atom's radius away.

The action is similar to the way light knocks electrons entirely out of metals in the photoelectric effect that Albert Einstein explained in 1905, later earning a Nobel Prize. But in his insight, Corkum saw a twist in that classic plot. On the brink of permanently liberating its kidnapped cargo and leaving behind an ionized atom short one electron, the laser's throbbing electric field cleanly reverses direction. It must do so — after all, a laser beam is composed of well-ordered electromagnetic radiation, its electric and magnetic components vibrating back and forth in unison. Corkum's imagined hand violently punches the electron right back into the atom whence it came, again at near light speed. The atom shudders as the process, formally called recombination, plays out.

Most important, the atom sheds the incoming electron's extra energy. It does so via a brief, intense burst of exceedingly short far-ultraviolet radiation, or even X-rays. What's more, as the laser beam washes through the gas in its path, the same thing happens — in step — to millions, even billions, of other identical atoms. Their high-frequency electromagnetic distress chirps merge into a rising chorus in perfect tune. The accumulating signal tucks itself into the longer-wave laser beam as it continues on its path. This electromagnetic melody, in its spectrum and structure, carries with it detailed information on what just happened.

By the nature of the process, it does not make a continuous signal, but one prepackaged into exceedingly short pulses of high frequency — the hitchhikers that had been seen on the red laser light. "Within days, I understood this was a route to attosecond physics," says Corkum. "This changed my career," he adds — as it changed careers for a cadre of other physicists and theoretical chemists around the world.

Fast physics

Notable among those who plunged into the field was Hungarian-Austrian experimental physicist Ferenc Krausz and his group at the Max Planck Institute of Quantum Optics in Garching, Germany. Among Krausz's key roles has been to develop special multilayer "chirped" mirrors. Their surfaces put delay times into the overlapping waves in short pulses of infrared light, piling the waves into even shorter blinks.

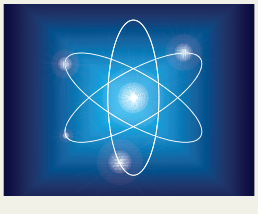
Usually, pulses of light act like luminous sausages racing through optical equipment end-first. But femtosecond pulses, and especially attosecond pulses, are more like pancakes flying face-first. Their thickness is measured in billionths of a meter, but their width is a thousand times or more their thickness.

Rapid improvement also has come in the ability to control the individual waves in the femtosecond laser pulses — leaving in each a single high peak, like a solitary rogue wave that rises at sea and threatens ships. "We have been able to realize pulses for the first time that consist of only one or two wave cycles," Krausz says. "This was the key to making an isolated attosecond pulse." In his office Krausz has a certificate given to his team in 2008 for generating "the shortest ever flash of light," a pulse

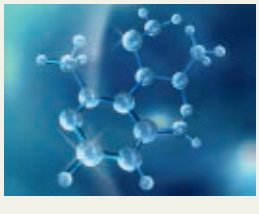
DIAGRAM: T. DUBÉ; TIMELINE, FROM LEFT: CHOOSE HERE/SHUTTERSTOCK; LENM/ISTOCKPHOTO; REDBRANCH/ISTOCKPHOTO; JACOMSTEPHENS/ISTOCKPHOTO; ANGELHELL/ISTOCKPHOTO; VIOLSCRAPER/FLICKR; NASA GODDARD SPACE FLIGHT CENTER; MATILDA/ISTOCKPHOTO; NASA, JPL-CALTECH, UCLA

Time in seconds

Short time scales are difficult to imagine, but comparing them with the approximate duration of a human heartbeat offers perspective.



10^{-18}
Motions of electrons



10^{-15}
Reactions in molecules

10^{-9}
Calculation of a typical personal computer

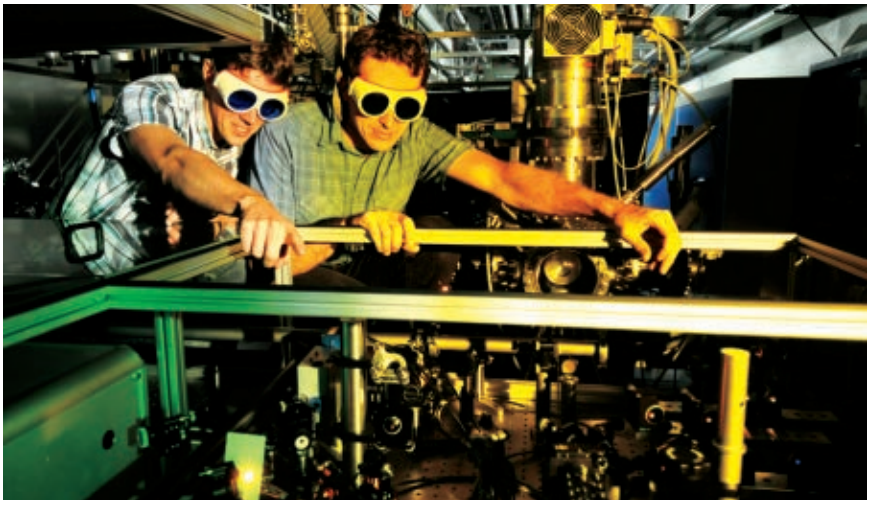
0.5×10^{-2}
Flap of a hummingbird's wing

80 attoseconds long. For now, the record stands.

Last year in *Reviews of Modern Physics*, Krausz wrote that while many expect that photons will become the most powerful tools for computing, "the advance of science and technology by research on electrons is by no means over. On the contrary, it is just beginning." He expects the field soon to be able to steer electrons inside molecules wherever a researcher might desire, sampling conditions or changing them.

"With disease, it always has its origin in some electronic motion; somewhere in the DNA or an organelle, something breaks. If we want to understand illness at the most fundamental level, we must be able to look at electronic motions," Krausz says. "Another example: You could ask yourself what are the limitations of electronics. Today electrons switch billions of times per second in a computer. So my personal belief is that the ultimate limits will be close to light frequencies." And that, he says, would mean a leap in switching speeds by a factor of a thousand.

Already some new science has emerged. A team from the University of Colorado at Boulder, led by the wife-husband team of Margaret Murnane and Henry Kapteyn, used laser light to smack molecules of two nitrogen atoms joined to four oxygen atoms, causing vibration. By probing the atoms with combinations of attosecond and femtosecond pulses, the scientists were able to deduce how the electrons sloshed among energy levels with each cycle of vibration that stretched and then squashed the molecules. Other work has led to the first snapshot of the electron orbitals of a two-atom nitrogen molecule, N_2.



Matthias Kling (left) and Sergey Zherebtsov of the Max Planck Institute of Quantum Optics discuss the setup of a beamline that will help generate attosecond pulses.

The assemblages that do such things are not, strictly speaking, as elegant to look at as, say, a giant accelerator or a telescope. An attosecond layout on a lab bench is more of a labyrinth, but one of extraordinarily precise passages. It starts simply enough, with a specialized laser in a metal box about a foot wide and two feet long. Next are rank after rank of mirrors, narrow tubes, wiggling electric field gauntlets, steel chambers and glass light-beam conduits no thicker than angel-hair pasta. Here and there are pumps working hard to keep vital stretches in near-vacuum conditions at the same time that puffs of gas are emitted. "Physics is a collection of good tricks and bad jokes," says Phil Bucksbaum, a Stanford University physicist. "And we play a lot of tricks on nature in this field."

This isn't Big Physics, but it's not cheap either. The one-room laboratory of theoretical chemist Stephen Leone in the Lawrence Berkeley National Laboratory cost perhaps $5 million, including roughly $750,000 for the laser. "Each of those chirped mirror compressors is maybe $10,000," said Phillip Nagel, a University of California, Berkeley graduate student working in Leone's lab, as he pointed at an array that would look fine in a pinball machine.

Leone and his students have been trying for several years to put a stopwatch on a molecule of sulfur hexafluoride as it falls apart after being smacked by an attosecond-class pulse.

"This will be new science, and it will be a good demonstration," Leone says. "The thing about this molecule is that if you ionize it — just knock one electron out — it totally upsets the whole bond structure."

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1
Heartbeat of a human

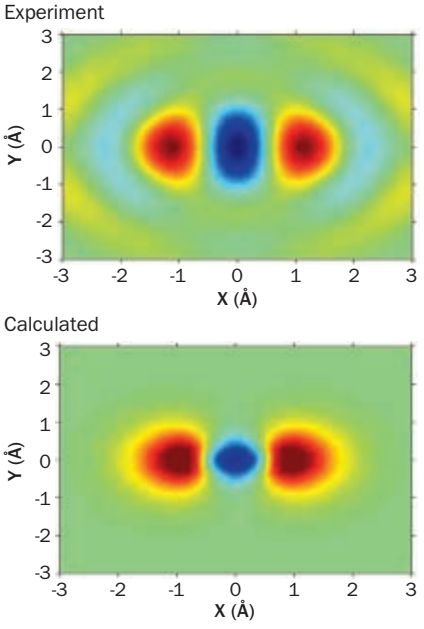
5.5×10^3
Length of the *Nutcracker* ballet

3.15×10^7
Earth year

1.59×10^{10}
Duration of the Roman Empire

4.34×10^{17}
Age of the universe

Wave function of an N_2 electron



Confirming results Researchers have been able to capitalize on a process called high harmonic generation to image the wave function of an N_2 molecule's most weakly bound electron. (The wave function describes the probability that the electron will be in any one state at a given time.) The colors in the images above show that experiment agrees with theory.

Electron snapshots

A close look at this one test provides a taste of how the whole field works. The molecule starts out as a sulfur atom nestled among six of fluorine. But how much time elapses before SF_6 becomes the ion SF_6^+ and then becomes drifting pieces of SF_4 or smaller pieces? And, more important, after the moment of ionization, when and in what order do remaining electrons begin unlashing the bonds that held the molecule together? If such things can be learned in this simple system, it would help lead to the creation of new, complex chemical systems and products that take full advantage of the capacity of atoms to rearrange and recombine.

To find out, Leone and his group tune their laser and its downstream system of chirped mirrors and other gadgets to produce infrared pulses about seven femtoseconds (7,000 attoseconds) long. The pulses first pass through a cloud of neon gas — about a billion atoms' worth — in a sturdy steel vacuum chamber. As they do so, the neon atoms each suffer the sort of fate that Corkum first imagined nearly two decades ago.

Electrons in vulnerable orbitals get yanked far from the atoms' nuclei and then smashed back in. Each rattled neon atom spits its brief package of ultraviolet rays as the electrons recombine. The result is that the onrushing laser beam's pulses continue on their way, each carrying within it a far-ultraviolet pulse about 450 attoseconds in duration.

Filters then separate and isolate the attosecond pulses. These are given the job of being pump pulses. Each is directed down another conduit to a second, near-vacuum reaction chamber a few feet away. There, each blasts through a waiting wisp of SF_6 molecules, ionizing them. The pulses are so short that Leone and his team know exactly when the ionization occurs. Thus they have a time zero for their atomic stopwatch.

As the field gradually moves from launchpad to practical, routine use, many have their eyes on the next stages.

The final step is to figure out what the electrons are doing as the molecules disintegrate. That's the job of probe pulses — additional, seven-femtosecond pulses of infrared laser light. They ionize the mortally wounded molecules and their remnants. They do it again and again, with different time gaps between the pump and probe pulses.

Analysis of the spectra and other qualities of these rounds of evicted electrons should permit the team to, in effect, make a slow-motion movie of the fast-changing electronic bond structures. "Simple, huh?" Nagel said, as he looked at the setup.

It is still a work in progress. "The electrons don't seem to be entering our detector correctly," he mumbled.

As the field gradually moves from launchpad to practical, routine use, many have their eyes on the next stages. First will be development of immense centralized facilities for certain kinds of attosecond research.

Some large research institutes expect to turn to ultrapowerful linear accelerators hundreds of meters to kilometers long to create a type of laser called a free-electron X-ray laser. Such lasers are millions of times more powerful than the current tabletop infrared lasers that are milking details from little clouds of atoms. The SLAC National Accelerator Laboratory in Menlo Park, Calif., last year demonstrated the first such system, and Europe plans to open its XFEL laser facility near Hamburg, Germany, in 2014. (But such facilities are costly and uncertain. The United Kingdom just canceled its big free-electron laser, the New Light Source.)

Not far from Leone's lab another Berkeley team is laying plans for a possible "Next Generation Light Source." Under the hills would be an underground linear accelerator more than half a mile long and with 10 or so free-electron lasers for rent to visiting researchers. Attosecond pulses, says the lab's officer in charge, physicist Roger Falcone, will be routine parts of the operation. The cost: $1 billion–plus from the federal government. At the soonest, the light source could be ready in 10 years.

In the meantime, small-scale attosecond science will plunge forward. Its researchers are thinking of the next frontier in the science of brevity: zeptosecond pulses. A thousand times shorter, they might track not just motions of electrons, but of quarks inside the nuclei of atoms. Asked how to do that with his accelerator, Falcone says, "I have no idea."

"I have an idea," Corkum responds to the same question. "We'd start with an electron in a long-wave laser, just like now. Only we'd pull it much farther from the atom, and then drive it all the way into the nucleus." He hasn't worked out the rest in detail. But someday somebody surely will try. Stay tuned.

Explore more

- Laboratory for Attosecond Physics website: www.attoworld.de

J. ITATANI *ET AL.*/*NATURE* 2004

Actual size is 40.6 mm

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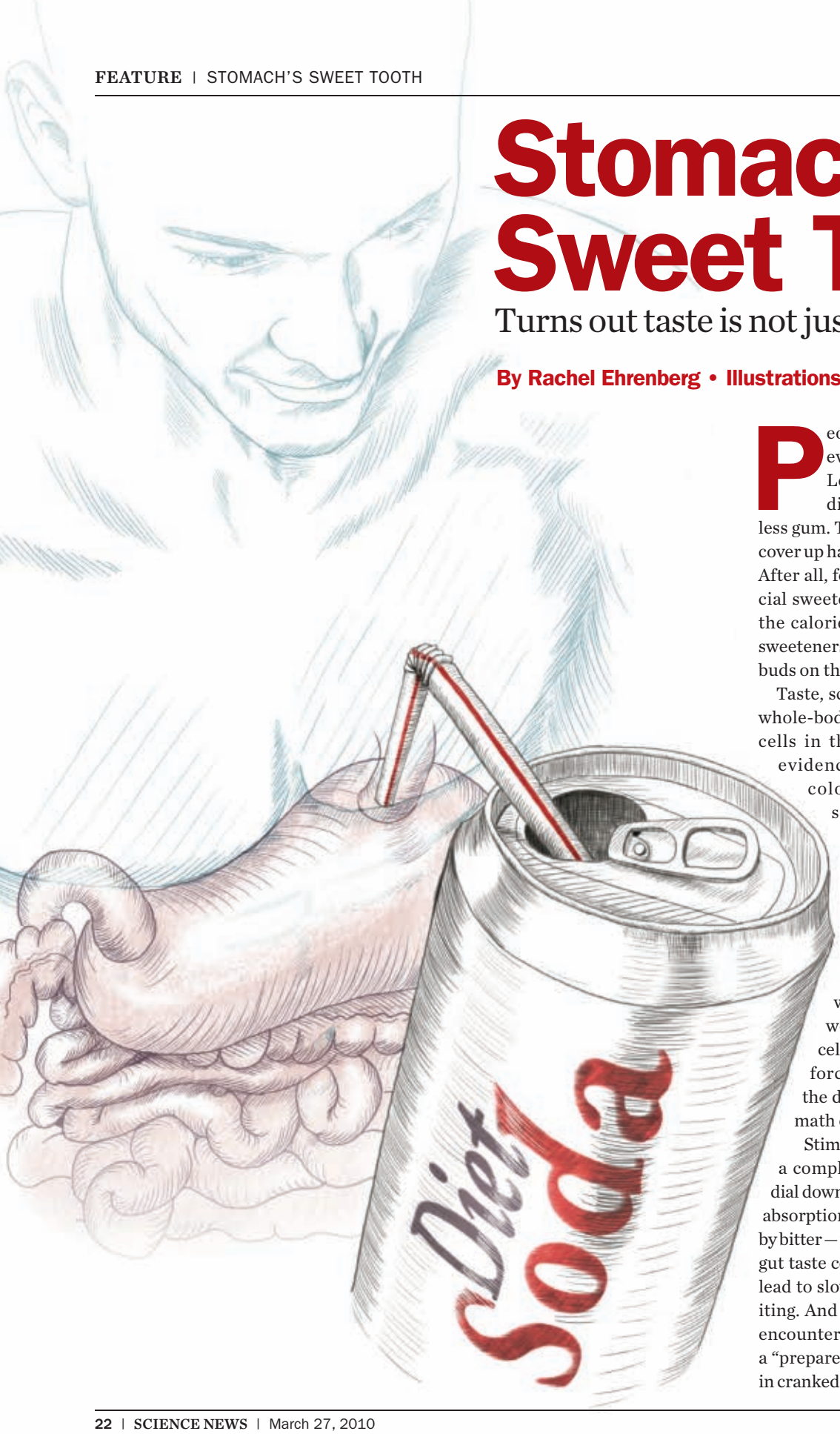
BBB ACCREDITED BUSINESS

Stomach's Sweet Tooth

Turns out taste is not just for the tongue

By Rachel Ehrenberg • Illustrations by Nicolle Rager Fuller



People deceive their taste buds every day—a dash of Sweet'N Low in the coffee, perhaps, a diet soda or a stick of sugarless gum. These little white lies seem to cover up harmless, even healthy choices. After all, fooling the mouth with artificial sweeteners provides a fix without the calories or the cavities. But these sweeteners aren't just tricking the taste buds on the tongue.

Taste, scientists are discovering, is a whole-body sensation. There are taste cells in the stomach, intestine and, evidence suggests, the pancreas, colon and esophagus. These sensory cells are part of an ancient battalion tasked with guiding food choices since long before nutrition labels, Rachael Ray or even agriculture existed. While taste cells in the mouth make snap judgments about what should be let inside, new work suggests that gut taste cells serve as specialized ground forces, charged with preparing the digestive system for the aftermath of the tongue's decisions.

Stimulating these gut cells triggers a complex series of events that can dial down, or amp up, the digestion and absorption of the body's fuel. When hit by bitter—potentially toxic—substances, gut taste cells sound an alarm that may lead to slower absorption or spur vomiting. And when the gut's taste sensors encounter something sweet, they send a "prepare for fuel" missive that results in cranked-up insulin levels in the blood.

Though scientists don't fully understand what follows, studies hint at a tantalizing, if convoluted, connection between gut taste cell activity and metabolism. Figuring out such connections may one day lead to new therapies for treating type 2 diabetes, obesity and other disorders. And the sweet-focused research could help explain recent counterintuitive findings that link such problems with drinking diet soda.

Rumblings from the gut

The gut's taste cells appear to be built from the same machinery as the taste cells of the tongue, the structures of which scientists have only recently nailed down. Taste cells interact with what are called "tastants" via receptors, specialized proteins that protrude from cell walls and bind to specific molecules drifting by. When a tastant binds to a receptor, it signals other molecules that, in the mouth, immediately send an "accept" or "reject" message to the brain.

Bitter compounds activate a family of receptors called T2Rs —there are roughly 25 kinds in humans, a variety that reflects the importance of detecting potential toxins and avoiding lethal diet mistakes. But sweet tastes and savory ones, also called umami, appear to have one receptor each. Related proteins make up both receptors, a shared structure that makes evolutionary sense since the two detect valuable, energy-rich foods. The sweet receptor is built from two proteins, dubbed T1R2 and T1R3, while T1R3 combines with a different subunit to make the umami receptor.

A signaling molecule triggered by tongue taste receptors led scientists to the gut's sensors in the late 1990s. Researchers found gustducin, a protein that gets the message going when the mouth's sweet, bitter or umami receptors are hit, in some gut and pancreas cells in rats. Nearly 10 years later, scientists established that gut cells using gustducin were "tasting" too. A team including Robert Margolskee and Bedrich Mosinger, then at Mount Sinai School of Medicine in New York City, reported that taste receptors weren't just active in the rodent gut, but also in human intestinal cells.

In the mouth, stimulating sweet receptors sends a quick go-ahead to the brain, which rapidly sends more missives, ensuring that saliva is pumped and chewing and swallowing ensues. Sweet taste receptors in the gut seem to take this response to the next level, affirming that fuel is indeed incoming and setting off reactions to cope with it.

The gut isn't just a pit stop … it is also a signaling station that keeps the body in tune with what's about to happen.

Gut taste cells appear to regulate, in part, secretion of insulin, a hormone crucial for telling body tissues whether they should tap newly arrived glucose or valuable stored fat for energy. Blocking sweet taste receptors in human intestinal cells grown in a lab dish reduced release of an important hormone, glucagon-like peptide-1, known to increase insulin secretion, Margolskee and Mosinger reported in 2007 in the *Proceedings of the National Academy of Sciences*. Mice without working gustducin also released less of the hormone. And the mice made less of a protein that helps with glucose absorption, suggesting that their bodies hadn't fully gotten the fuel-delivery message, the researchers, both now at the Monell Chemical Senses Center in Philadelphia, reported in a second paper in the same issue of the journal.

A dietary sugar and building block of carbohydrates and many dairy products, glucose is the fundamental fuel: The body metabolizes glucose to make ATP, the energy currency of cells. Fuel's a hot commodity, so it's fitting that taste cells in the gut prepare the body to take advantage of it when it's available, says Pankaj Jay Pasricha of Stanford University School of Medicine. If the body doesn't know glucose is there, cells can't exploit the molecule to move muscles, fire nerves or do any other basic body function.

The gut isn't just a pit stop where foods are made usable, he says; it is also a signaling station that keeps the body in tune with what's about to happen.

"It's not surprising," says Pasricha. "It's surprising that it took us so long to find out."

Answers from within

The discovery that gut taste cells play a role in that signaling system may help explain several persistent mysteries of metabolic science.

Scientists have long been puzzled by the fact that the pancreas releases far more insulin when a person ingests glucose than when it is injected directly into the blood. Known as the incretin effect (incretins are gut hormones that trigger insulin release), the response is thought to be due in part to glucagon-like peptide-1 activity. The link between taste cells in the gut and the release of GLP-1 may explain the effect, Pasricha and Stanford colleague Kelley Yan wrote

Ready, sweet, fire

A suite of compounds stimulates the mammalian sweet taste receptors on the tongue. Evidence now suggests that many of these same molecules activate taste receptors in the gut as well.

Sugars	Artificial sweeteners	D-amino acids	Sweet proteins
Examples:	**Examples:**	**Examples:**	**Examples:**
■ sucrose	■ saccharin	■ D-alanine	■ monellin
■ fructose	■ aspartame	■ D-phenylalanine	■ curculin
■ glucose	■ neotame	■ D-serine	■ thaumatin
■ maltose	■ sucralose		
Found in:	**Found in:**	**Found in:**	**Found in:**
■ fruits	■ candy	■ aged cheese	■ serendipity berry
■ milk	■ breakfast bars	■ aged meat	■ *Curculigo latifolia* berries
■ pasta	■ canned fruits		■ *Thaumatococcus daniellii* berries
■ honey	■ soft drinks		

SOURCE: J. CHANDRASHEKAR *ET AL./NATURE* 2006

in a commentary in the July 2009 *Gut*. If the gut never tastes glucose because the sugar enters via an IV, the body might not prepare for the fuel delivery.

Taste-receptor cells in the gut may also be responsible for two odd side effects of existing medical treatments, some scientists have suggested.

Many people with type 2 diabetes are insulin resistant — meaning their tissues ignore the hormone's signal to absorb glucose from the blood, which may lead to dangerously high blood sugar levels. Some overweight patients who undergo gastric bypass surgery experience an almost instant decrease in insulin resistance, Pasricha notes. The surgery shortens the nutrient-absorbing portion of the small intestine. Some scientists think this could give taste cells at the tail end of the intestine — cells that may still function properly — a chance to ramp up local secretion of GLP-1 and restore normal metabolism.

The second case involves people with type 2 diabetes who take fibrates, drugs often used along with statins to treat high cholesterol. Side effects can include lower blood sugar levels, suggesting less insulin resistance.

Mosinger and colleagues noticed that fibrates are structurally similar to lactisole, a known blocker of sweet receptors. The researchers exposed mouse and human cells decked with sweet receptors to various concentrations of the compounds. Fibrates blocked sweet receptors in human cells but not in mouse cells, the team reported online in October in the *Journal of Medicinal Chemistry*. This blocking may somehow affect insulin resistance, Mosinger proposes.

"We are still in the stage of intense research," he cautions. Eventually such research may yield targets for new therapies: "Many people are hopeful that in the future there could be treatments."

Bitter taste receptors in the gut may also be good future drug targets, says Catia Sternini of the University of California, Los Angeles. In the mouth, these receptors send red-alert rejection signals, but gut bitter receptors seem to play a role in slowing or preventing the absorption of toxic compounds that make it past the tongue. "These bitter receptors could be seen as a second line of defense," Sternini says. "They help the gut distinguish the good from the bad. If there is a toxin, the response is to try to reduce damage."

The mechanisms still aren't clear, she says, but work suggests that activating gut bitter receptors can trigger reactions that convince a body that it's satiated.

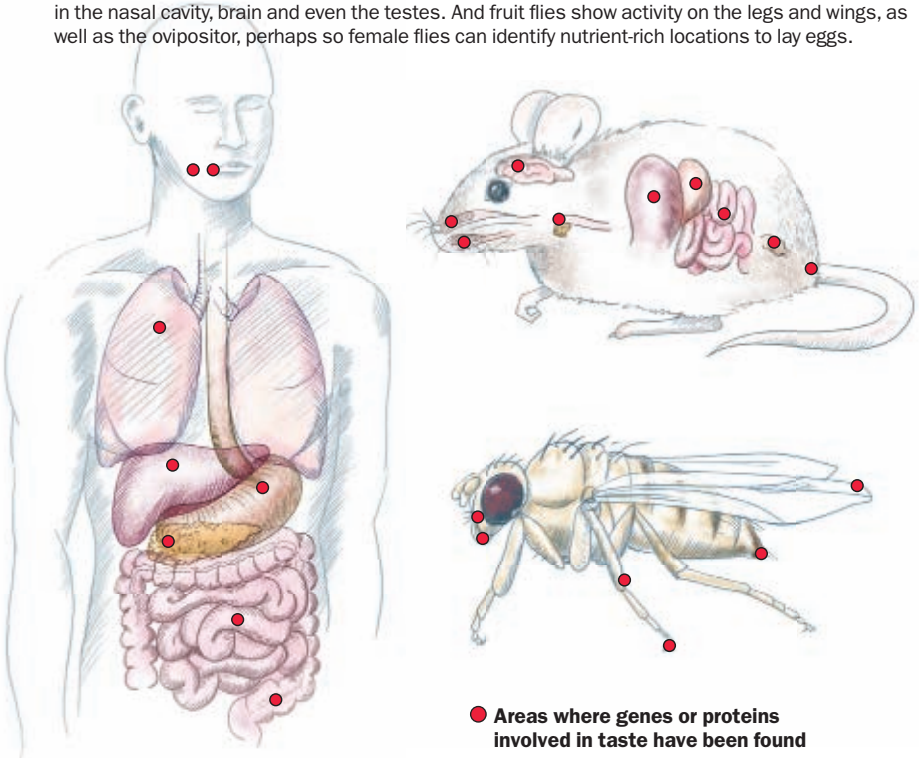
Scientists have only just begun to explore the sweet, umami and bitter receptors in the gut. Work on sour and salty receptors — assumed to also be present — has just begun. And taste cells represent a fraction of the gut's signaling system. Gut signaling cells make up less than 1 percent of the cells of the intestinal wall, yet together these signaling cells constitute the largest hormone-releasing organ of the body, Sternini pointed out in 2007 in *Current Opinion in Pharmacology*. "The gut," she says, "is an amazing organ."

Twists and turns

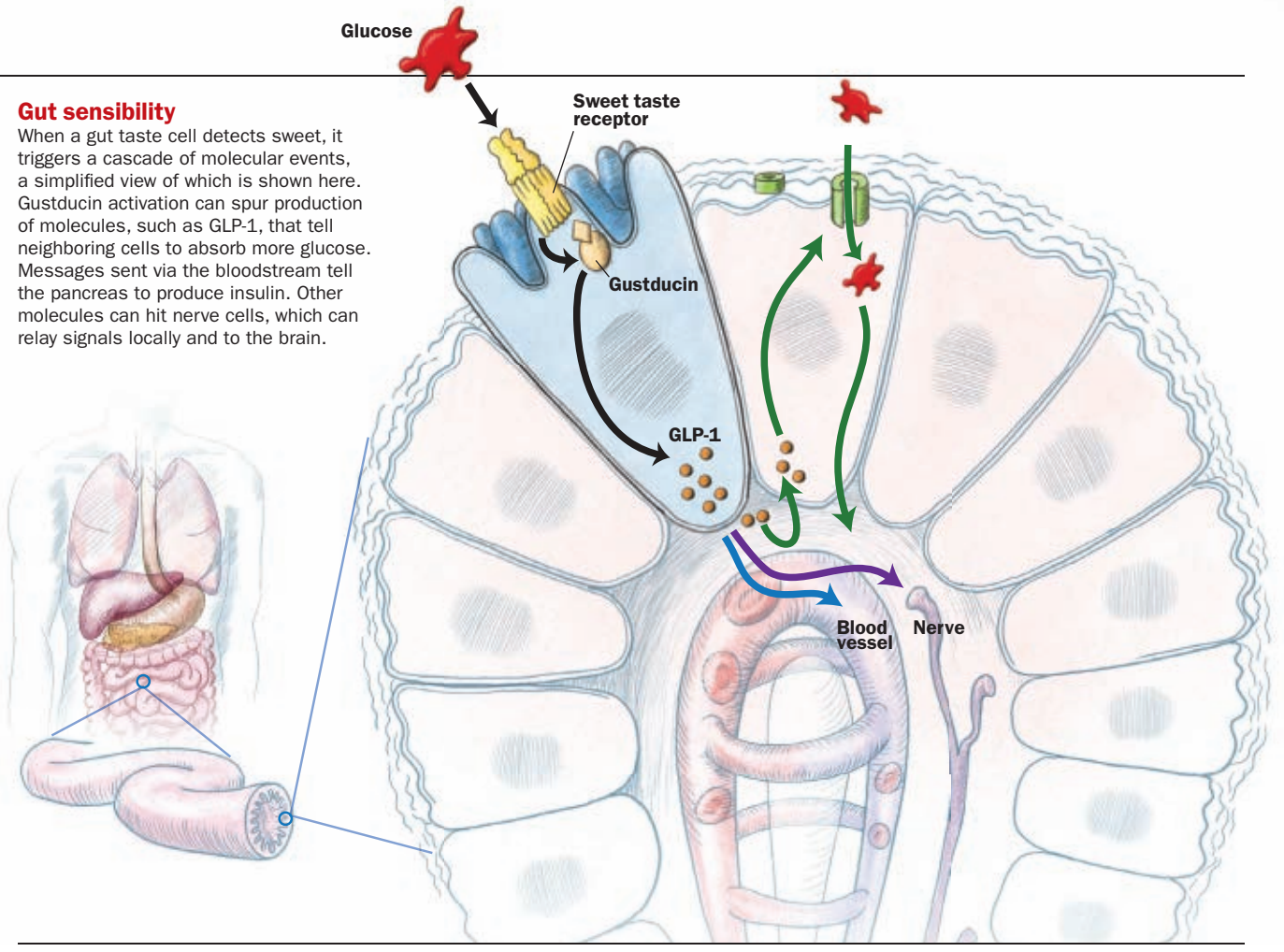
This vast hormonal landscape is a complex one involving multiple signals that might be received locally or far away. Stimulating gut taste receptors leads down roads much more long and winding than those that bring taste from the tongue to the brain, says Jayaram Chandrashekar of the Howard Hughes Medical Institute's Janelia Farm Research Campus in Ashburn, Va. (Chandrashekar is lead author of a recent paper in *Nature* that confirmed the identity of the tongue's salt taste receptor.) When a taste receptor is hit in the mouth, the brain gets the message almost instantaneously. But the effects of triggering gut taste cells may take minutes. "The link between activation and nutrient absorption has to take into account this delay," Chandrashekar says. "It is probably more complicated than the tongue and involves multiple pathways."

This complexity makes gut tasting hard to study, as does the fact that what tastes sweet or bitter to a person doesn't necessarily taste that way to mice and rats, which are often used in lab experi-

Inner taste Activity in taste-related genes and proteins has been found throughout the body, not just in the mouth. For humans, the tongue and cheeks are the usual suspects, but activity has also been identified in the liver, lungs and gut. Mouse taste-related genes and proteins are active in the nasal cavity, brain and even the testes. And fruit flies show activity on the legs and wings, as well as the ovipositor, perhaps so female flies can identify nutrient-rich locations to lay eggs.



● Areas where genes or proteins involved in taste have been found



Gut sensibility
When a gut taste cell detects sweet, it triggers a cascade of molecular events, a simplified view of which is shown here. Gustducin activation can spur production of molecules, such as GLP-1, that tell neighboring cells to absorb more glucose. Messages sent via the bloodstream tell the pancreas to produce insulin. Other molecules can hit nerve cells, which can relay signals locally and to the brain.

ments. For example, sweet taste cells on the human tongue appear broadly tuned to recognize a number of compounds, including the sugars fructose, glucose and sucrose; several artificial sweeteners, such as saccharin (Sweet'N Low) and aspartame; and some amino acids and sweet proteins. But mice, for example, don't seem to respond to aspartame, the sweet of Equal and NutraSweet.

Taste preferences also differ in animals that are more closely related than mice and men, so results may depend on the model organism. Research suggests chimpanzees and gorillas taste aspartame as sweet, while New World primates, such as marmosets and capuchins, don't. (Fruit flies do, scientists reported in 2008.) A recent survey of the sweet tastes of animals in the order Carnivora, which includes lions, house cats, ferrets and dogs, found all of the animals were indifferent to six artificial sugars, except the red (a.k.a. "lesser") panda. The red panda gulped down solutions with aspartame, neotame and sucralose, researchers reported in April 2009 in the *Journal of Heredity*.

Red pandas aren't the only ones that fancy artificial sweeteners. Humans, like their chimp relatives, taste these compounds as sweet. Data from the National Health and Nutrition Examination Survey, conducted by the U.S. Centers for Disease Control and Prevention, suggest that regular consumers of diet drinks slurp more than three 8-ounce servings per day. But if the artificial sweeteners in these drinks are stimulating gut taste receptors, there may be consequences. Three recent studies assessing large data sets found an association between drinking diet soda and the risk of developing metabolic syndrome and type 2 diabetes.

"The diet soda association was not hypothesized and deserves further study," notes one report, published in *Circulation* in 2008. These studies can't establish causation. Indeed, heavier people more at risk of developing metabolic problems may drink more diet soda to begin with. But the results are interesting, notes a commentary published in December in the *Journal of the American Medical Association*. Diet drinks are often enjoyed without food, which means the gut may be preparing for fuel that never arrives.

So beware those little white lies. Thousands of years of evolution have yielded a finely tuned digestive machine, one that recognizes incoming energy and knows how to make the most of it. These intricate chains of events evolved during a time when that sweet zing reliably indicated food rich in valuable calories. And for thousands of years, the gut reacted appropriately.

Perhaps that adage "trust your gut" should be accompanied with another edict: "Tell it no lies." ■

Explore more:

- For more on taste (and smell) research, visit www.monell.org

Odds Are, It's Wrong

Science fails to face the shortcomings of statistics

By Tom Siegfried

For better or for worse, science has long been married to mathematics. Generally it has been for the better. Especially since the days of Galileo and Newton, math has nurtured science. Rigorous mathematical methods have secured science's fidelity to fact and conferred a timeless reliability to its findings.

During the past century, though, a mutant form of math has deflected science's heart from the modes of calculation that had long served so faithfully. Science was seduced by statistics, the math rooted in the same principles that guarantee profits for Las Vegas casinos. Supposedly, the proper use of statistics makes relying on scientific results a safe bet. But in practice, widespread misuse of statistical methods makes science more like a crapshoot.

It's science's dirtiest secret: The "scientific method" of testing hypotheses by statistical analysis stands on a flimsy foundation. Statistical tests are supposed to guide scientists in judging whether an experimental result reflects some real effect or is merely a random fluke, but the standard methods mix mutually inconsistent philosophies and offer no meaningful basis for making such decisions. Even when performed correctly, statistical tests are widely misunderstood and frequently misinterpreted. As a result, countless conclusions in the scientific literature are erroneous, and tests of medical dangers or treatments are often contradictory and confusing.

Replicating a result helps establish its validity more securely, but the common tactic of combining numerous studies into one analysis, while sound in principle, is seldom conducted properly in practice.

Experts in the math of probability and statistics are well aware of these problems and have for decades expressed concern about them in major journals. Over the years, hundreds of published papers have warned that science's love affair with statistics has spawned countless illegitimate findings. In fact, if you believe what you read in the scientific literature, you shouldn't believe what you read in the scientific literature.

"There is increasing concern," declared epidemiologist John Ioannidis in a highly cited 2005 paper in *PLoS Medicine*, "that in modern research, false findings may be the majority or even the vast majority of published research claims."

Ioannidis claimed to prove that more than half of published findings are false, but his analysis came under fire for statistical shortcomings of its own. "It may be true, but he didn't prove it," says biostatistician Steven Goodman of the Johns Hopkins University School of Public Health. On the other hand, says Goodman, the basic message stands. "There are more false claims made in the medical literature than anybody appreciates," he says. "There's no question about that."

Nobody contends that all of science is wrong, or that it hasn't compiled an impressive array of truths about the natural world. Still, any single scientific study alone is quite likely to be incorrect, thanks largely to the fact that the standard statistical system for drawing conclusions is, in essence, illogical. "A lot of scientists don't understand statistics," says Goodman. "And they don't understand statistics because the statistics don't make sense."

Statistical insignificance

Nowhere are the problems with statistics more blatant than in studies of genetic influences on disease. In 2007, for instance, researchers combing the medical literature found numerous studies linking a total of 85 genetic variants in 70 different genes to acute coronary syndrome, a cluster of heart problems. When the researchers compared genetic tests of 811 patients that had the syndrome with a group of 650 (matched for sex and age) that didn't, only one of the suspect gene variants turned up substantially more often in those with the syndrome — a number to be expected by chance.

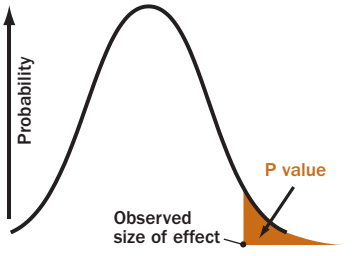
"Our null results provide no support for the hypothesis that any of the 85 genetic variants tested is a susceptibility factor" for the syndrome, the researchers reported in the *Journal of the American Medical Association*.

How could so many studies be wrong? Because their conclusions relied on "statistical significance," a concept at the heart of the mathematical analysis of modern scientific experiments.

Statistical significance is a phrase that every science graduate student learns, but few comprehend. While its origins stretch back at least to the 19th century, the modern notion was pioneered by the mathematician Ronald A. Fisher in the 1920s. His original interest was agriculture. He sought a test of whether variation in crop yields was due to some specific intervention (say, fertilizer) or merely reflected random factors beyond experimental control.

Fisher first assumed that fertilizer caused no difference — the "no effect" or "null" hypothesis. He then calculated a number called the P value, the probability that an observed yield in a fertilized field would occur if fertilizer had no real effect. If P is less than .05 — meaning the chance of a fluke is less than 5 percent — the result should be declared "statistically significant," Fisher arbitrarily declared, and the no effect hypothesis should be rejected, supposedly confirming that fertilizer works.

Fisher's P value eventually became the ultimate arbiter of credibility for science results of all sorts — whether testing the health effects of pollutants, the curative powers of new drugs or the effect of genes on behavior. In various forms, testing for statistical significance pervades most of scientific and medical research to this day.



A P value is the probability of an observed (or more extreme) result arising only from chance.

But in fact, there's no logical basis for using a P value from a single study to draw any conclusion. If the chance of a fluke is less than 5 percent, two possible conclusions remain: There is a real effect, or the result is an improbable fluke. Fisher's method offers no way to know which is which. On the other hand, if a study finds no statistically significant effect, that doesn't prove anything, either. Perhaps the effect doesn't exist, or maybe the statistical test wasn't powerful enough to detect a small but real effect.

"That test itself is neither necessary nor sufficient for proving a scientific result," asserts Stephen Ziliak, an economic historian at Roosevelt University in Chicago.

Soon after Fisher established his system of statistical significance, it was attacked by other mathematicians, notably Egon Pearson and Jerzy Neyman. Rather than testing a null hypothesis, they argued, it made more sense to test competing hypotheses against one another. That approach also produces a P value, which is used to gauge the likelihood of a "false positive" — concluding an effect is real when it actually isn't. What eventually emerged was a hybrid mix of the mutually inconsistent Fisher and Neyman-Pearson approaches, which has rendered interpretations of standard statistics muddled at best and simply erroneous at worst. As a result, most scientists are confused about the meaning of a P value or how to interpret it. "It's almost never, ever, ever stated correctly, what it means," says Goodman.

Correctly phrased, experimental data yielding a P value of .05 means that there is only a 5 percent chance of obtaining the observed (or more extreme) result if no real effect exists (that is, if the no-difference hypothesis is correct). But many explanations mangle the subtleties in that definition. A recent popular book on issues involving science, for example, states a commonly held misperception about the meaning of statistical significance at the .05 level: *"This means that it is 95 percent certain that the observed difference between groups, or sets of samples, is real and could not have arisen by chance."*

That interpretation commits an egregious logical error (technical term: "transposed conditional"): confusing the odds of getting a result (if a hypothesis is true) with the odds favoring the hypothesis if you observe that result. A well-fed dog may seldom bark, but observing the rare bark does not imply that the dog is hungry. A dog may bark 5 percent of the time even if it is well-fed all of the time.

Another common error equates statistical significance to "significance" in the ordinary use of the word. Because of the way statistical formulas work, a study with a very large sample can detect "statistical significance" for a small effect that is meaningless in practical terms. A new drug may be statistically better than an old drug, but for every thousand people you treat you might get just one or two additional cures — not clinically significant. Similarly, when studies claim that a chemical causes a "significantly increased risk of cancer," they often mean that it is just *statistically* significant, possibly posing only a tiny absolute increase in risk.

Statisticians perpetually caution against mistaking statistical significance for practical importance, but scientific papers commit that error often. Ziliak studied journals from various fields — psychology, medicine and economics among others — and reported frequent disregard for the distinction.

"I found that eight or nine of every 10 articles published in the leading journals make the fatal substitution" of equating statistical significance to importance, he said in an interview. Ziliak's data are documented in the 2008 book *The Cult of Statistical Significance*, coauthored with Deirdre McCloskey of the University of Illinois at Chicago.

Multiplicity of mistakes

Even when "significance" is properly defined and P values are carefully calculated, statistical inference is plagued by many other problems. Chief among them is the "multiplicity" issue — the testing of many hypotheses simultaneously. When several drugs are tested at once, or a single drug is tested on several groups, chances of getting a statistically significant but false result rise rapidly. Experiments on altered gene activity in diseases may test 20,000 genes at once, for instance. Using a

S. GOODMAN, ADAPTED BY A. NANDY

P value of .05, such studies could find 1,000 genes that appear to differ even if none are actually involved in the disease. Setting a higher threshold of statistical significance will eliminate some of those flukes, but only at the cost of eliminating truly changed genes from the list. In metabolic diseases such as diabetes, for example, many genes truly differ in activity, but the changes are so small that statistical tests will dismiss most as mere fluctuations. Of hundreds of genes that misbehave, standard stats might identify only one or two. Altering the threshold to nab 80 percent of the true culprits might produce a list of 13,000 genes — of which over 12,000 are actually innocent.

Recognizing these problems, some researchers now calculate a "false discovery rate" to warn of flukes disguised as real effects. And genetics researchers have begun using "genome-wide association studies" that attempt to ameliorate the multiplicity issue (*SN: 6/21/08, p. 20*).

Many researchers now also commonly report results with confidence intervals, similar to the margins of error reported in opinion polls. Such intervals, usually given as a range that should include the actual value with 95 percent confidence, do convey a better sense of how precise a finding is. But the 95 percent confidence calculation is based on the same math as the .05 P value and so still shares some of its problems.

Clinical trials and errors

Statistical problems also afflict the "gold standard" for medical research, the randomized, controlled clinical trials that test drugs for their ability to cure or their power to harm. Such trials assign patients at random to receive either the substance being tested or a placebo, typically a sugar pill; random selection supposedly guarantees that patients' personal characteristics won't bias the choice of who gets the actual treatment. But in practice, selection biases may still occur, Vance Berger and Sherri Weinstein noted in 2004 in *Controlled Clinical Trials*. "Some of the benefits ascribed to randomization, for example that it eliminates all selection bias, can better be described as fantasy than reality," they wrote.

Randomization also should ensure that unknown differences among individuals are mixed in roughly the same proportions in the groups being tested. But statistics do not guarantee an equal distribution any more than they prohibit 10 heads in a row when flipping a penny. With thousands of clinical trials in progress, some will not be well randomized. And DNA differs at more than a million spots in the human genetic catalog, so even in a single trial differences may not be evenly mixed. In a sufficiently large trial, unrandomized factors may balance out, if some have positive effects and some are negative. Still, trial results are reported as averages that may obscure individual differences, masking beneficial or harmful effects and possibly leading to approval of drugs that are deadly for some and denial of effective treatment to others.

"Determining the best treatment for a particular patient is fundamentally different from determining which treatment is best on average," physicians David Kent and Rodney Hayward wrote in *American Scientist* in 2007. "Reporting a single number gives the misleading impression that the treatment-effect is a property of the drug rather than of the interaction between the drug and the complex risk-benefit profile of a particular group of patients."

Another concern is the common strategy of combining results from many trials into a single "meta-analysis," a study of studies. In a single trial with relatively few participants, statistical tests may not detect small but real and possibly important effects. In principle, combining smaller studies to create a larger sample would allow the tests to detect such small effects. But statistical techniques for doing so are valid only if certain criteria are met. For one thing, all the studies conducted on the drug must be included — published and unpublished. And all the studies should have been performed in a similar way, using the same protocols, definitions, types of patients and doses. When combining studies with differences, it is necessary first to show that those differences would not affect the analysis, Goodman notes, but that seldom happens. "That's not a formal part of most meta-analyses," he says.

Statistical criticisms

For decades, experts have noted serious flaws in the standard statistical approach. Some typical comments:

"Despite the awesome pre-eminence this method has attained ... it is based upon a fundamental misunderstanding of the nature of rational inference, and is seldom if ever appropriate to the aims of scientific research." —*William Rozeboom, 1960*

"What used to be called judgment is now called prejudice, and what used to be called prejudice is now called a null hypothesis.... It is dangerous nonsense." —*A. W. F. Edwards, 1972*

"Huge sums of money are spent annually on research that is seriously flawed through the use of inappropriate designs, unrepresentative samples, small samples, incorrect methods of analysis, and faulty interpretation." —*D.G. Altman, 1994*

"The methods of statistical inference in current use ... have contributed to a widespread misperception ... that statistical methods can provide a number that by itself reflects a probability of reaching erroneous conclusions. This belief has damaged the quality of scientific reasoning and discourse." —*Steven Goodman, 1999*

"Many investigators do not know what our most cherished, and ubiquitous, research desideratum — 'statistical significance' — really means. This ... signals an educational failure of the first order." —*Raymond Hubbard and J. Scott Armstrong, 2006*

"These classical methods [of significance testing] are in fact intellectually quite indefensible and do not deserve their social success." —*Colin Howson and Peter Urbach, 2006*

"A finding of 'statistical' significance ... is on its own almost valueless, a meaningless parlor game." —*Stephen Ziliak and Deirdre McCloskey, 2008*

Meta-analyses have produced many controversial conclusions. Common claims that antidepressants work no better than placebos, for example, are based on meta-analyses that do not conform to the criteria that would confer validity. Similar problems afflicted a 2007 meta-analysis, published in the *New England Journal of Medicine,* that attributed increased heart attack risk to the diabetes drug Avandia. Raw data from the combined trials showed that only 55 people in 10,000 had heart attacks when using Avandia, compared with 59 people per 10,000 in comparison groups. But after a series of statistical manipulations, Avandia appeared to confer an increased risk.

In principle, a proper statistical analysis can suggest an actual risk even though the raw numbers show a benefit. But in this case the criteria justifying such statistical manipulations were not met. In some of the trials, Avandia was given along with other drugs. Sometimes the non-Avandia group got placebo pills, while in other trials that group received another drug. And there were no common definitions.

"Across the trials, there was no standard method for identifying or validating outcomes; events ... may have been missed or misclassified," Bruce Psaty and Curt Furberg wrote in an editorial accompanying the *New England Journal* report. "A few events either way might have changed the findings."

More recently, epidemiologist Charles Hennekens and biostatistician David DeMets have pointed out that combining small studies in a meta-analysis is not a good substitute for a single trial sufficiently large to test a given question. "Meta-analyses can reduce the role of chance in the interpretation but may introduce bias and confounding," Hennekens and DeMets write in the Dec. 2 *Journal of the American Medical Association*. "Such results should be considered more as hypothesis formulating than as hypothesis testing."

These concerns do not make clinical trials worthless, nor do they render science impotent. Some studies show dramatic effects that don't require sophisticated statistics to interpret. If the P value is 0.0001 — a hundredth of a percent chance of a fluke — that is strong evidence, Goodman points out. Besides, most well-accepted science is based not on any single study, but on studies that have been confirmed by repetition. Any one result may be likely to be wrong, but confidence rises quickly if that result is independently replicated.

"Replication is vital," says statistician Juliet Shaffer, a lecturer emeritus at the University of California, Berkeley. And in medicine, she says, the need for replication is widely recognized. "But in the social sciences and behavioral sciences, replication is not common," she noted in San Diego in February at the annual meeting of the American Association for the Advancement of Science. "This is a sad situation."

Bayes watch

Such sad statistical situations suggest that the marriage of science and math may be desperately in need of counseling. Perhaps it could be provided by the Rev. Thomas Bayes.

Most critics of standard statistics advocate the Bayesian approach to statistical reasoning, a methodology that derives from a theorem credited to Bayes, an 18th century English clergyman. His approach uses similar math, but requires the added twist of a "prior probability" — in essence, an informed guess about the expected probability of something in advance of the study. Often this prior probability is more than a mere guess — it could be based, for instance, on previous studies.

Bayesian math seems baffling at first, even to many scientists, but it basically just reflects the need to include previous knowledge when drawing conclusions from new observations. To infer the odds that a barking dog is hungry, for instance, it is not enough to know how often the dog barks when well-fed. You also need to know how often it eats — in order to calculate the prior probability of being hungry. Bayesian math combines a prior probability with observed data to produce an estimate of the likelihood of the hunger hypothesis. "A scientific hypothesis cannot be properly assessed solely by reference to the observational data," but only by viewing the data in light of prior belief in the hypothesis, wrote George Diamond and Sanjay Kaul of UCLA's School of Medicine in 2004 in the *Journal of the American College of Cardiology*. "Bayes' theorem is ... a logically consistent, mathematically valid, and intuitive way to draw inferences about the hypothesis."

With the increasing availability of computer power to perform its complex calculations, the Bayesian approach has become more widely applied in medicine and other fields in recent years. In many real-life contexts, Bayesian methods do produce the best answers to important questions. In medical diagnoses, for instance, the likelihood that a test for a disease is correct depends on the prevalence of the disease in the population, a factor that Bayesian math would take into account.

But Bayesian methods introduce a confusion into the actual meaning of the mathematical concept of "probability" in the real world. Standard or "frequentist" statistics treat probabilities as objective realities; Bayesians treat probabilities as "degrees of belief" based in part on a personal assessment or subjective decision about what to include in the calculation. That's a tough placebo to swallow for scientists wedded to the "objective" ideal of standard statistics. "Subjective prior beliefs are anathema to the frequentist, who relies instead on a series of ad hoc algorithms that maintain the facade of scientific objectivity," Diamond and Kaul wrote.

Conflict between frequentists and Bayesians has been ongoing for two centuries. So science's marriage to mathematics seems to entail some irreconcilable differences. Whether the future holds a fruitful reconciliation or an ugly separation may depend on forging a shared understanding of probability.

"What does probability mean in real life?" the statistician David Salsburg asked in his 2001 book *The Lady Tasting Tea*. "This problem is still unsolved, and ... if it remains unsolved, the whole of the statistical approach to science may come crashing down from the weight of its own inconsistencies." ■

For references and more information, see http://bit.ly/aq1x28

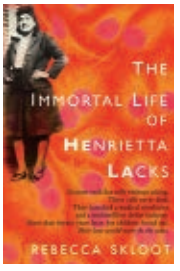
The Immortal Life of Henrietta Lacks

Rebecca Skloot

Combining careful reporting with vivid narration, science writer Rebecca Skloot describes how cancerous cells growing in the cervix of a poor black tobacco farmer named Henrietta Lacks changed the face of modern medical science.

In the book, Skloot expertly explains the science behind the cells and their significance, but more importantly, she makes it clear that the story is not just about the cells' utility to scientists. It's the story of the unknown woman behind the famous cells.

A dime-sized sample of Lacks' cells, sliced away in 1951 without permission, quickly became an invaluable research tool. Unlike normal cells that stop dividing soon after they leave the body, these cancer cells have a special genetic structure that allows them to live on forever. Even now, almost 60 years after Lacks' death, tubes, flasks and beakers of her cells flourish in laboratories around the world. They are grown under the name HeLa cells, short for Henrietta Lacks, though many students still learn the cells came from Helen Lane — a name doctors originally made up to hide Lacks' identity. Studies using HeLa cells have led to new cancer drugs, flu treatments, the first polio vaccine and countless other medical advances.

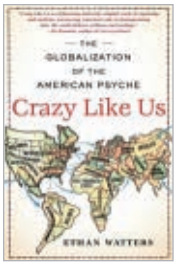


Lacks' family was left in the dark about the research, confused and angry about what they perceived as scientists making big money from stolen cells while the family couldn't afford health care. Whether they should have shared in the profits, Skloot refrains from judging. Instead, she paints a nuanced portrait of a complicated, emotion-laden sequence of events, raising many more questions than she answers. — *Laura Sanders*
Crown Publishers, 2010, 369 p., $26.

Crazy Like Us: The Globalization of the American Psyche

Ethan Watters

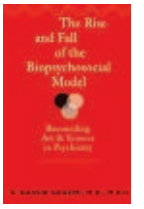
Watch out world — here comes American culture waving a manual of psychiatric diagnoses. Soon, everyone from Hong Kong schoolgirls to Sri Lankan villagers will think about mental health and illness in the same homogenized way. In *Crazy Like Us*, journalist Ethan Watters makes a case that this monolithic scenario could happen, a disturbing specter for psychiatrists who study how people in different parts of the world define and treat problems classified as mental disorders in the West.



Watters explores several disturbing instances of Western mental health ideas gone awry in non-Western nations. He describes teenagers in Hong Kong who began refusing to eat after hearing from Western celebrities and researchers that anorexia is the modern way for young people to express distress. In another case, an influx of Western trauma counselors labeled Sri Lankan tsunami survivors with post-traumatic stress disorder. This individual-centered diagnosis conflicted with that culture's emphasis on meeting social responsibilities to feel better.

It's not clear from these instances, though, that people around the world are passively abandoning local beliefs in favor of a one-size-fits-all biomedical disease model of mental illness. Even in the United States, psychiatrists heatedly debate this approach. Watters notes that he doesn't want to portray traditional cultures as "right" and Westerners as "wrong" in treating mental illness, but at times he comes awfully close.

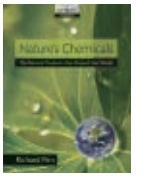
The export of Western notions of mental illness to other societies deserves close scrutiny, as Watters argues. So does the argument that this phenomenon will erase cultural contrasts. — *Bruce Bower*
Free Press, 2010, 306 p., $26.



The Rise and Fall of the Biopsychosocial Model

S. Nassir Ghaemi

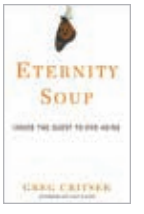
A psychiatrist criticizes the idea of psychiatric disease as a product of biological and social factors. *Johns Hopkins Univ. Press, 2010, 253 p., $50.*



Nature's Chemicals: The Natural Products that Shaped Our World

Richard Firn

A biologist explores useful compounds made by plants and microbes. *Oxford Univ. Press, 2010, 250 p., $65.*



Eternity Soup: Inside the Quest to End Aging

Greg Critser

An aging society has spurred academics and entrepreneurs to study getting old and what could or should be done to stop it. *Harmony Books, 2010, 234 p., $26.*

The Warcraft Civilization: Social Science in a Virtual World

William Sims Bainbridge

Studying players in the computer game *World of Warcraft* can explain real-world group behavior, a sociologist argues. *MIT Press, 2010, 244 p., $27.95.*

Flatland: An Edition with Notes and Commentary

Edwin A. Abbott, notes by William F. Lindgren and Thomas F. Banchoff

Two mathematicians add new analyses and context to Abbott's classic story about a two-dimensional universe. *Cambridge Univ. Press, 2010, 294 p., $14.99.*

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Ancient graffiti

Regarding "Graffiti on the walls in Pompeii" (*SN: 01/30/10, p. 14*), I remember reading some years ago about graffiti being discovered in Pompeii. There was even a symbol that researchers interpreted as a sort of "Kilroy was here." Is this an ongoing study? New sites? I wonder if there were other markings, such as height marks recording children's growth? The article says "written" — were all of the marks scratched into the rock?
Bob Wilson, Oakridge, Ore.

Graffiti were first observed at Pompeii in the late 19th century. More than 11,000 instances of graffiti have been found in the ancient city, about two-thirds of which has been excavated. Most consist of written messages scratched or incised on walls, with some drawings as well. These graffiti have attracted little scientific interest until recently. Graffiti research will continue, but rapid deterioration of previously excavated parts of Pompeii probably means that new excavations won't occur anytime soon. — Bruce Bower

Missing antidepressant data

In the article "Depression drug shifts personality" (*SN: 01/02/10, p. 14*), the anecdotal correlation between "personality change" and depression relapse rate is encouraging, but where are the data, either for the SSRI phase or for the year following that?
Sam Pilato, Arlington, Mass.

There wasn't space to show all the study's results in print. Go online (http://bit.ly/bE4a4d) for more detail and a reference to the original paper. — Bruce Bower

Dividing worms

In the interesting article "Starting anew" (*SN: 02/13/10, p. 22*), Susan Gaidos states that the annelid family includes naidids, roundworms, leeches and earthworms. My knowledge of invertebrate zoology is a little rusty, but I believe that roundworms are in the nematode phylum.
Pete Clason, Northville, Mich.

The reader is correct. Roundworms are part of the nematode phylum, not the annelid phylum. — Editors

Correction: *In "Seeing in red" (*Back Story, SN: 01/30/10, p. 6*), the image labeled as galaxy HUDF-JD2 does not in fact show that galaxy, but a different, much closer galaxy. HUDF-JD2 lies above the galaxy shown but can't be seen in visible light. An infrared image of this patch of sky would have revealed HUDF-JD2.*

Send communications to: Editor, Science News, 1719 N Street, NW, Washington, D.C. 20036 or **editors@sciencenews.org**. Letters subject to editing.

Barry Barish

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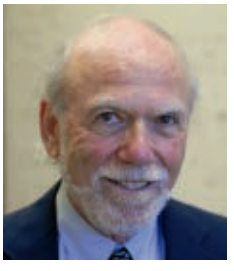
Contemplating future plans for particle colliders

Caltech physicist Barry Barish is the director of the global design effort for the International Linear Collider, which is currently in the planning stages. If built, the ILC would smash together electrons and their antimatter counterparts, positrons, at nearly the speed of light. The ILC would complement the Large Hadron Collider, a European proton collider that is the world's most powerful but has had technical problems that will prevent it from operating at full power until 2013. That gives the world's second most powerful collider, the Tevatron at the Fermi National Accelerator Laboratory in Batavia, Ill., a slim chance to be first to find evidence for the long-sought Higgs boson, which has been proposed as the particle responsible for providing other particles with mass. Following a presentation on February 22 in San Diego at the American Association for the Advancement of Science's annual meeting, Barish answered questions from the audience and news media about the future of particle physics. Science News *Deputy Managing Editor Elizabeth Quill compiled some of his comments.*



I think in some areas we are going to be completely surprised because the theories aren't really very deep.

Do physicists think that the Large Hadron Collider's findings will be the end of particle physics?

There is a tendency we have among ourselves to use colorful language — quarks, neutrinos and all these things — but also maybe to speak in hyperbole.... [The end] is nowhere near because we barely can formulate the right questions to ask yet about the early universe.... We have a popular theory called string theory, and string theory doesn't predict very much at this stage ... yet people go around calling it the theory of everything.

There is kind of some narrow line between being humble enough to say you don't understand everything about nature and you are starting to ask the questions, and radiating your enthusiasm for the fantastic things you are doing. Somehow we don't have exactly the right balance.

Will results from the LHC provide confirmation for any existing theories?

I think in some areas we are going to be completely surprised because the theories aren't really very deep. So the fact that we have some theory — which I would call a model, not a theory — means we are able to make predictions. And that is very good for experimentalists, because it allows us to design detectors that we can test against somebody's ideas....

One of the biggest surprises may come, in my mind, in what's publicized as the Higgs boson.... We have a theory of elementary particles, which works pretty well, but [its particles are] massless and we put this [the Higgs boson] in by hand. It's one guy's idea, and life is probably different than that.

Once the LHC is running at top energy, will the world need the International Linear Collider?

If you look at how particle physics has been done over the last decades, it's been a combination of two complementary techniques — colliding hadrons and colliding electrons.... If we project into the future what we think the science is going to be like at the Large Hadron Collider, it is going to again be true that you are going to want an electron machine to complement and to fully realize that.

The caveat, of course, is that ... you don't lose that much by being patient — that one should see that the science that comes out of the LHC has some semblance of the hype that we have given it.

What's a realistic timescale for construction of the ILC?

Well, it is going to take three to five years to learn enough from the LHC to warrant making the kind of investment [that ILC requires]. And then it will take 10 years to build it. That is where I came out with 2025 as the timescale.... To make sure that we can do it even on that timescale, we are investing significantly in the technology to be able to make a large linear collider.

Given that the LHC is gearing up so slowly, might Fermilab find the Higgs boson first?

Yes, they are going to run for another year or so.... Fermilab is our best bet, for the time being, to see the Higgs.

Will there be even more powerful accelerators in the future, or are physicists reaching a limit on how fast they can make particles go?

The limitation in accelerators themselves comes from a couple things, but one of the main limitations is materials.... It has been demonstrated that if you can get rid of the materials, you can make much higher gradients to accelerate particles to higher energy. And this can be done with plasmas or lasers.... The problem is we don't know how to make a laser or a plasma accelerator that has all the elements that you need to focus particles to efficiently do all that kind of stuff. ■

CALTECH

New lamp lets you read indoors as if the sun was shining over your shoulder.

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Can a floor lamp improve your life? This one can. The Market Street Lamp brings the many benefits of natural daylight indoors to help you read better, see better and feel better.

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