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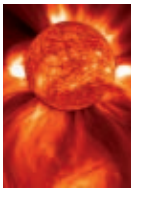

COVER Astronomers have been revising their views on the internal composition of the sun, shown expelling matter into space in this 2002 image.
SOHO (ESA & NASA)

ScienceNews
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FROM THE EDITOR

Science isn't in the books, it's in the stars and atoms

A lot of what scientists know about stars comes from studying the sun. In space terms, it's right next door, a mere eight minutes of light's travel time away. So astronomers have had an easy opportunity to spy on their stellar neighbor to learn everything about it, including its inner chemistry.

Armed with this close-up intelligence on how the sun works, astronomers can draw more reliable inferences than would otherwise be possible about more distant stars — and use that knowledge to help piece together the history of the entire cosmos.

But after decades of solar studies, it seems that scientists actually don't know as much as they thought they did about the sun's ingredients. New research has been challenging textbook estimates of how much oxygen, carbon and other elements the sun possesses, as Alexandra Witze reports in this issue (Page 18). Astronomers may now have to revise some of their conclusions about several other astronomical issues, such as how stars and galaxies throughout the universe form and evolve.

All that is fun enough. But the real message of this development is the reminder that science is not the sum of past research as recorded in textbooks, but the active process of continuing to question nature even if those books say the answers are already in.

Take the size of the proton, for example. You could look that up in a physics book, or you could shoot a laser beam at a muon orbiting a proton and measure how much energy it takes to boost the muon from one energy level to another. This energy depends quite precisely on how big the proton is. When scientists did this experiment, they found that the calculated size didn't match the textbook answer, as Rachel Ehrenberg reports on Page 7.

Puzzled scientists will have to do even more experiments now to find out whether the old or new measurements are right. It may even turn out to be the case that one of the most well-established theories in all of physics, quantum electrodynamics, will need to be revamped to reconcile the conflicting data.

So it is with many areas of scientific endeavor. No matter how thorough scientific knowledge might seem to be, there's always something new inside the sun.

—Tom Siegfried, Editor in Chief

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Scientific Observations

"What is clear from earlier spills … is that adding microbes is highly unlikely to be of any help. While pure cultures of microbes do a wonderful job of degrading some hydrocarbons in laboratory culture vessels and bioreactors, they have never been shown to be able to compete with the diverse community of oil degraders that develops naturally in oceans.… But that does not stop companies from trying to sell an immediate solution that will instantly clean up the spilled oil.… There were the orange and lemon rinds that would bring about the instant disappearance of the oil—indeed if you use the olfactory test for the presence of oil and you add enough oranges and lemons you will no longer be able to smell the oil and could erroneously conclude that the oil was gone.… Let's hope that BP insists on scientifically proven methods and resists the urge to buy instant snake oil cures." —**BIOLOGIST RONALD ATLAS OF THE UNIVERSITY OF LOUISVILLE IN KENTUCKY IN A JUNE 7 POST ON AN AMERICAN SOCIETY FOR MICROBIOLOGY BLOG**

Science Past | FROM THE ISSUE OF JULY 30, 1960

LIP-SMACKING GRASSHOPPER—A grasshopper with a talent for lip-smacking has turned out to be quite an unusual insect. *Paratylotropidia brunneri* Scudder is the first insect known to communicate over fairly long distances by producing an audible sound from the mouth—literally smacking its lips.... Produced at the rate of six or seven per second, usually in groups of four, the grasshopper ticks resemble a shorter, softer version of the ticking song of a katydid. The call can be heard several yards away.... It may be ... that the grasshopper's lip-smacking signal evolved through a stage in which feeding noises were significant. At present it may be effective as a long-range signal only in areas where there are few other sound-producing insects.

Science Future

August 14–17
The American Sociological Association meets in Atlanta. See www.asanet.org/meetings

August 30–September 3
Researchers and policy makers meet in Boston to discuss environmental factors affecting penguin population health. See www.penguinconference.org

September 1
A psychologist lectures in New York City on the connection between beauty and happiness. See www.nyas.org/events

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ON THE SCENE BLOG
New estimates of CO_2 input and output by land-based life may improve climate change models. Read "New carbon data should produce better climate forecasts."

LIFE
Coral reef fish larvae lose their senses—at least in discerning smells—when water's pH falls. See "Ocean acidification may make fish foolhardy."

ATOM & COSMOS
Dry river deltas and valleys support the idea of an ancient Martian ocean, a new study finds. Read "Wet past for Red Planet."

BODY & BRAIN
A new chemical seems to help baby brain cells reach maturity. Read "Fertilizing future brain cells."

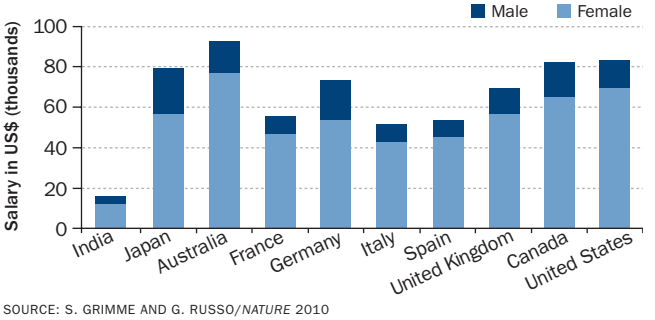
Firsts

Scientists have for the first time pinned down an extrasolar planet's mass by observing the planet directly. Till now, astronomers have calculated exoplanet mass by how much "wobble" its gravity produced in its host star's orbit. But by studying how the starlight shifted as it passed through the atmosphere of exoplanet HD 209458b (illustrated), Dutch researchers found the planet's orbital velocity. Plugging the data into Newton's law of gravity gave a value for the planet's mass—about 64 percent of Jupiter's, the team reports in the June 24 *Nature*. The study also assessed the abundance of molecules in the planet's atmosphere.

Science Stats | GLOBAL GENDER PAY GAP

Male scientists outearn female scientists in each country surveyed in a recent poll, with a lead of about 30 percent in some cases.

Average scientist salary by gender and country



SOURCE: S. GRIMME AND G. RUSSO/*NATURE* 2010

CLOCKWISE FROM TOP LEFT: TOM FOUGEROUSSE/UNIV. OF LOUISVILLE; COURTESY OF DR. SIMON FOALE, ARC CENTRE OF EXCELLENCE FOR CORAL REEF STUDIES; ESO

“Presumably somebody made a mistake.... But everybody’s convinced that nobody made a mistake, so it’s really intriguing.”
—RANDOLF POHL, PAGE 7

In the News

STORY ONE

Go north, young hominid, and brave the chilly winter weather

Stone tools in England hint at early arrival of human relatives

By Bruce Bower

Palm-sized stone tools uncovered at a site (shown) in Happisburgh, England, suggest that hominids may have lived in northern Europe at least 800,000 years ago.

FROM TOP: PHIL CRABB, NATURAL HISTORY MUSEUM, LONDON; ENJOYNZ/ISTOCKPHOTO, ADAPTED BY T. DUBÉ. SOURCE: PARFITT *ET AL*/*NATURE* 2010

Excavations at a site in southeastern England indicate that hominids chilled out there a surprisingly long time ago.

Discoveries at Happisburgh, situated on an eroding stretch of coastline near the city of Norwich, show that members of an as-yet-unidentified *Homo* species settled on the fringes of northern Europe’s boreal forests at least 800,000 years ago, well before many scientists had assumed, say archaeologist Simon Parfitt of University College London and his colleagues.

Hominids repeatedly trekked to this northern locale, Parfitt’s team reports in the July 8 *Nature*. In excavations from 2005 to 2008, the researchers found 78 palm-sized stones with intentionally sharpened edges in several sediment layers.

“We suspect these tools were made by the last dregs of a larger hominid population that had come when the area was warmer, but hung on and survived under challenging conditions as the climate cooled,” says anthropologist and study coauthor Chris Stringer of the Natural History Museum in London.

A land bridge linked today’s England to the rest of Europe during the early Pleistocene.

Until half a dozen years ago, researchers thought that hominids reached northern Europe no earlier than 500,000 years ago, says Robin Dennell of the University of Sheffield in England. “Now it’s anyone’s guess when our earliest ancestors came this far north,” he says.

Fossil finds show that hominids migrating out of Africa reached western Asia by 1.8 million years ago (*SN: 5/13/00, p. 308*) and Spain’s Atapuerca Mountains as early as 1.2 million years ago (*SN: 3/29/08, p. 196*). Recent stone-tool finds at Pakefield, another site in southeastern England, indicate that hominids lived there 700,000 years ago (*SN: 1/14/06, p. 29*). Because the climate warmed briefly at that time, researchers proposed that hominids spread northward when temperatures rose and retreated south when the going got cold.

The Happisburgh finds hammer that hypothesis, Parfitt’s team contends. An array of environmental clues—including remains of cold-adapted animals, insects and plants—excavated along with the stone tools indicate that hominids weathered chilly northern European winters.

Summer temperatures in Happisburgh were similar to or slightly warmer than those of today, the team estimates, but winters were probably at least 3 degrees Celsius cooler: “still miserable for those used to Mediterranean climes,” write geochronologists Andrew Roberts and

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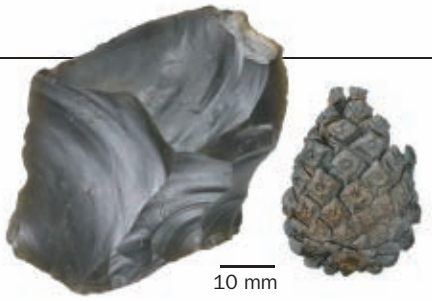
Rainer Grün of the Australian National University in Canberra in a comment published with the new report.

Happisburgh toolmakers lived just outside what is today a densely forested, frigid swath of northern Europe. Forest plants and animals dwindled during ancient winters, the scientists say. Crucially, though, geological analyses indicate that Happisburgh lay on an ancient course of the River Thames, near the North Sea and what was then a land bridge connecting southeastern England to continental Europe.

Ocean tides would have formed freshwater pools in the river and brought in marine life, such as the mollusks and barnacles whose shells have been unearthed at Happisburgh. Marshes on the river's floodplain would have attracted mammoths, rhinos and horses. Bones of such creatures have also been recovered in the area, which has been worked by fossil hunters for more than a century.

Soil at the site contains evidence of a previously dated reversal of Earth's magnetic field that provides a minimum age estimate of 780,000 years for the hominid finds. Excavated remains of extinct fossil plants and animals, combined with data on marine oxygen isotopes used in dating ancient climate shifts, narrow the timing of hominid visits to relatively warm periods either around 840,000 or 950,000 years ago.



Stone artifacts and plant material suggest that hominids living in northern Europe survived its cold winters.

No hominid fossils have turned up at Happisburgh. Toolmakers at the site may have been related to hominids that resided in Atapuerca 800,000 to 1.2 million years old ago, Stringer says. Discoverers of those remains assigned them to a species called *Homo antecessor*, which the team considered a precursor of European Neandertals and modern humans.

Homo erectus and small-bodied *Homo floresiensis* (*SN: 5/8/10, p. 14*) also existed at that time, but lived in Asia and Indonesia, too far to have reached Happisburgh, Stringer contends.

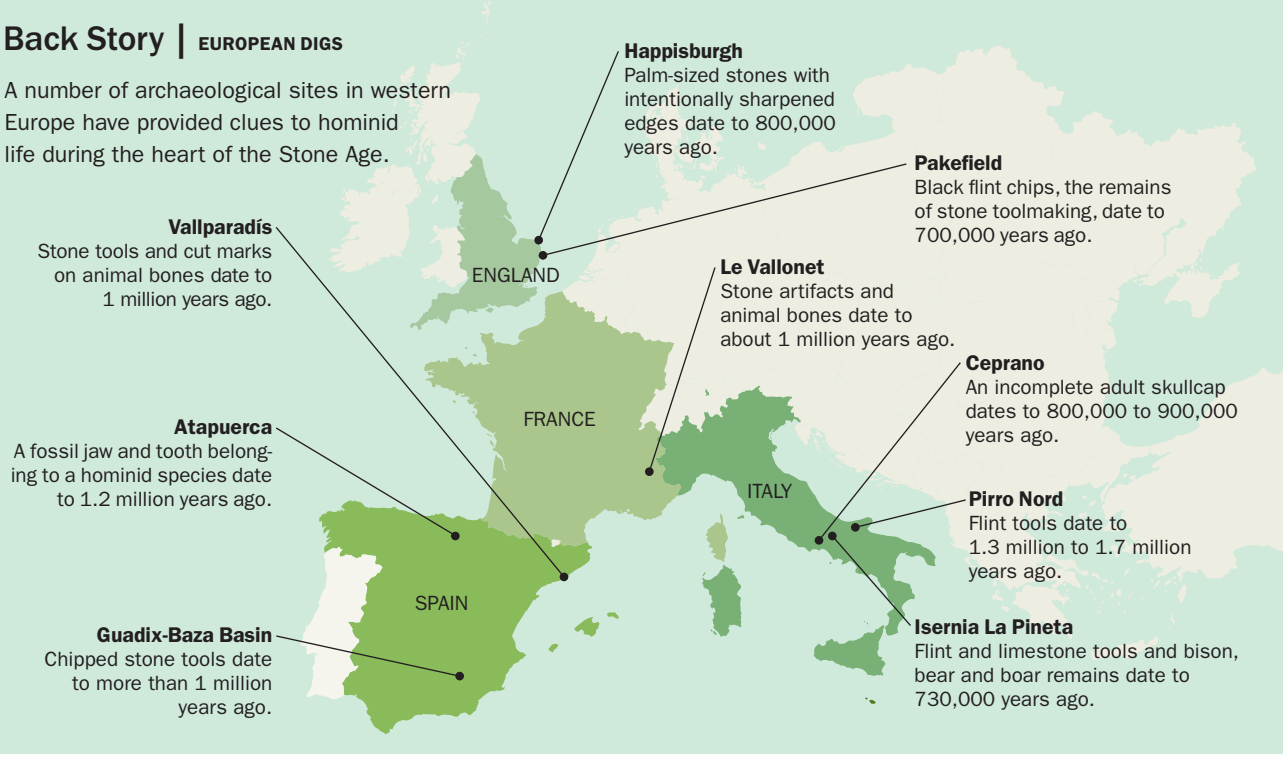
Although *H. antecessor* seems a good bet to have made the Happisburgh tools, the site has yet to yield evidence of controlled fire use, hunting or regular campsites — which would give clues to hominid behavior, Dennell says. "Were they tourists, migrants or colonists?" he asks. "We don't know."

Other potential hominid sites along a stretch of coastline that includes Happisburgh may help answer that question. "This area has the potential to be a British version of Olduvai Gorge," Stringer says.

Work at Tanzania's Olduvai Gorge since the 1930s has produced key hominid finds dating to as early as 1.8 million years ago. ■

Back Story | EUROPEAN DIGS

A number of archaeological sites in western Europe have provided clues to hominid life during the heart of the Stone Age.



FROM TOP: PARFITT *ET AL./NATURE* 2010; ENJOYNZ/ISTOCKPHOTO, ADAPTED BY E. FELICIANO

Matter & Energy

0.8768 femtometers | Established estimate of proton's radius

0.84184 femtometers | New measure of proton's radius

Smaller proton could be a big deal

Subatomic particle may not be as large as theory dictates

By Rachel Ehrenberg

Nothing is immune to downsizing in tough economic times — not even subatomic particles. New experiments suggest that the proton's radius is about 4 percent smaller than had been thought.

It could just be a mistake. But if confirmed, the finding could have enormous implications, scientists say.

"If this result holds up, there's something drastically wrong," says physicist Jeff Flowers of the National Physical Laboratory in England. "That opens the door for a major advancement in theory."

It could be that there's a problem with quantum electrodynamics, or QED, a theory that incorporates Einstein's special relativity into quantum mechanics to describe how light and matter interact.

In the new work, reported in the July 8 *Nature,* a team led by Randolf Pohl of the Max Planck Institute of Quantum Optics in Garching, Germany, created an exotic form of hydrogen in which a muon replaces the atom's lone electron. Muons have the same charge as electrons but are about 200 times heavier, so they orbit much closer to the proton at the atom's center. This coziness enhances the muon's interaction with the proton, so researchers can probe it in more detail than is possible with ordinary hydrogen.

In their experiments, the scientists fired laser beams at muonic hydrogen in a gas, hoping to bump the muon to a higher energy level. Measuring the gap between the muon's lower and higher energy levels would allow the team to calculate the proton's radius.

New laser measurements suggest the proton is smaller than previously thought.

Yet after years of trying, the team still wasn't having any luck. The laser had been tuned so that it could measure the proton's radius if it fell within 0.87 to 0.91 femtometers, in line with QED. But by tuning the laser to work with a smaller proton, the team finally saw results. The new measure of the proton's radius: just over 0.84184 femtometers (10^{-15} meters).

"There was no signal till the last three weeks before the experiment would have been stopped," says study coauthor Aldo Antognini of the Paul Scherrer Institute in Villigen, Switzerland. "It was like in a Hollywood movie where everything goes bad till five minutes before the end."

The new proton radius puzzles physicists because it is more precise than previous measurements but well outside their range. "Presumably somebody made a mistake," says Pohl. "But everybody's convinced that nobody made a mistake, so it's really intriguing."

Getting control over turbulence

New model helps predict fluid flow near boundaries

By Laura Sanders

With just a single measurement, a new model may deftly describe turbulent fluid flows near an airplane wing, ship hull or cloud. If it proves successful, the model may lead to more efficient airplanes and more accurate weather forecasts.

Fluid dynamicist Alexander Smits of Princeton University calls the new model "a very significant advance" that opens up a new way of thinking about chaotic, energy-sapping turbulence.

Turbulence is a problem that extends far beyond a bumpy plane ride. Fluid flowing past a body — whether air blowing by a fuselage or water streaming across Michael Phelps' swimming suit — contorts and twists as it bounces off an edge and interferes with incoming flows, creating chaotic patterns. Airliners squander up to half of their fuel just overcoming the turbulence within a foot or so of the aircraft, and turbulent patterns in the lower 100 meters of the atmosphere confound weather predictions.

Physicists and engineers have had a good grip on the basic behaviors of fluids since the mid-1800s, but have been baffled by the complexity of flows near a boundary.

"We don't really have a handle on the physics," says study coauthor Ivan Marusic of the University of Melbourne in Australia. "So even though the problem is over a hundred years old, we still really haven't had a major breakthrough."

In the new study, published July 9 in *Science,* the researchers measured forces in a giant wind tunnel and found a tight link between small-scale turbulence near a wall and large, smoother patterns of airflow farther away. In particular, newly identified flow patterns called superstructures had a big effect on turbulence near the wall. These smooth flow patterns away from the wall change the turbulence right next to the wall in predictable ways, an association that allowed Marusic and colleagues to write a mathematical formula relating the two.

"We were sort of amazed because it's such a simple formulation," Marusic says. "With this model, all we need to do is measure the outer flow and we can predict what's happening near the wall."

F. REISER AND A. ANTOGNINI/PAUL SCHERRER INSTITUTE

Humans

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

Effects of Botox go beyond the face

Freezing the frown muscle may hamper emotional sensitivity

By Bruce Bower

Botox treatment to erase unsightly frown lines may cause unforeseen emotional wrinkles. First-time Botox patients become slower at evaluating descriptions of negative emotions, possibly putting the patients at a social disadvantage, a new study indicates.

For more than a century, scientists have posited that facial expressions trigger and intensify relevant feelings, rather than simply advertise what an individual already feels. Because parts of their faces are paralyzed for three to four months after the procedure, Botox patients provide a novel line of support for this idea, as well as for the notion that facial expressions activate links between brain regions responsible for emotions and language, says psychology graduate student David Havas of the University of Wisconsin–Madison.

Two weeks after their first Botox injections, 40 women took an average of about one-quarter of a second longer to read a sentence describing an angry or sad situation than they had before the procedure, Havas and his colleagues found. The women showed no decline in the speed with which they read sentences about happy situations, the researchers report in an upcoming *Psychological Science*.

Botox shots may blunt patients' ability to recognize, not just express, emotions.

Havas hypothesizes that Botox-induced paralysis of the frown muscle, which runs across the forehead and pulls the eyebrows inward and down, may gradually weaken brain circuits that coordinate negative emotions.

Banishing frown lines with Botox can indeed have social repercussions, says Nicolas Vermeulen, a psychologist at the Catholic University of Louvain in Belgium. Previous studies indicate that mimicry of facial expressions crucially aids in understanding others' emotions, intentions and behaviors, he points out.

"Botox patients who are interacting with others behind a locked face might be at risk to react in the wrong way to, say, an angry driver or an angry customer in a pub," Vermeulen says.

Though the volunteers in the Wisconsin study displayed no loss of sentence comprehension, real-life conversations involve exquisitely timed banter, and seemingly small disturbances in evaluating emotional statements may foster misunderstandings, Havas suggests.

In the study, volunteers read 20 happy, 20 sad and 20 angry sentences just before undergoing the Botox procedure, pressing a computer key to indicate having finished each sentence. Comprehension questions were administered at random after one-third of the sentences.

Two weeks later, participants performed the same task with a different set of emotionally evocative sentences.

Voting with their big foam fingers

Incumbents poll better if the home team wins, study finds

By Laura Sanders

Whether politicians win or lose may come down to how local athletes play the game.

When local football or basketball teams are victorious, incumbents get a bump at the polls, a study published online July 6 in the *Proceedings of the National Academy of Sciences* concludes.

Study coauthor Neil Malhotra of the Stanford Graduate School of Business and his colleagues tallied up the wins and losses of 62 Division I college football teams from 1964 through 2008 and found how voters in the teams' home counties behaved. A local football team's win in the 10 days before an election garnered the incumbent senator, governor or president (or his or her political party) an extra 1.61 percentage points of the vote on average, the researchers found.

In a second analysis, the researchers surveyed over 3,000 people three times during the 2009 NCAA college basketball tournament. Respondents were asked to name their favorite team and then rate the performance of President Obama. On average, people whose favorite team had just won a March Madness game rated the president's performance 2.3 percentage points higher compared with those whose team had recently lost.

But when respondents were explicitly told about the results of the basketball game before they were asked to judge the president's job performance, the effect disappeared completely, Malhotra and his colleagues found. "Making people more aware of these biases is how to counteract them," Malhotra says.

The principle that emotions from unrelated events spill over into other areas of life may help explain other phenomena, says political scientist Herb Weisberg of Ohio State University in Columbus. For instance, the results might partially explain why a good economy leads people to vote for the incumbent.

MARSBARS/ISTOCKPHOTO

Numbers

"It was like solving an ancient puzzle." —CYNTHIA RUDIN

Program picks manholes most likely to explode

Computer scientists take on a classic Manhattan hazard

By Rachel Ehrenberg

Every so often in New York City, a disk of cast iron weighing up to 300 pounds bursts out of the street and flies as high as several stories before clattering back to the blacktop. Flames, smoke or both may issue from the breach, as if somebody had pulled hell's own pop-top.

Manhole explosions aren't just spectacular; they're dangerous. As one firefighter observed after a manhole exploded near Times Square in May: "It's not Disneyland, people. Get the hell out of the way."

Since Thomas Edison fired up the city's commercial electric grid in 1882, New Yorkers have had to contend with the random hazards of smoking, flaming and exploding manholes. Many of the blasts result from decrepit wiring, which can lead to sparks. Throw in a bit of gas and a confined space and, like a combustion engine, the blast can move metal. Until recently, there was no way of knowing where or when the next outburst would occur; repairs commenced only after a manhole had growled.

But in 2004, electricity provider Consolidated Edison began a proactive inspection program to find the places in New York's network of electrical cable where trouble is most likely to strike.

The company also called on a team of Columbia University researchers for help in predicting which of New York City's manholes might be the next to blow. Led by Cynthia Rudin, now at MIT, the scientists developed a computer algorithm to identify subterranean trouble spots. A report in the July issue of *Machine Learning* suggests that the researchers are winning the battle of machine versus manhole.

"To us it was like solving an ancient puzzle, but one that we weren't sure we were going to crack, and one that nobody had solved before," Rudin says.

Rudin and her team tackled Manhattan first. Beneath the borough's streets and avenues lies over 21,000 miles of cable, enough to girdle more than three-quarters of the Earth.

The researchers set out to rank Manhattan's manholes by vulnerability to serious events. The team had piles of historical data: Con Ed has records on miles of cable dating back to the 1880s. The team also had 10 years' worth of "trouble tickets," more than 61,000 reports typed by dispatchers as they directed crews.

Relevant past events such as fires, explosions, smoking manholes or flickering lights were buried in piles of irrelevant information, says Rudin: "Parking information for the Con Ed vehicle, or the fact that there is a customer that has a language problem."

Another challenge was that serious manhole events are rare: Only a few hundred occur each year among the 51,000-odd manhole and service boxes in Manhattan.

"Finding a pattern when something is very rare is very hard," says computer scientist Gary Weiss of Fordham University in New York City. "If you only have a few examples, there are so many patterns that can fit those few examples ... you can't really tell the difference between a pattern that is meaningful and one that is coincidental."

The algorithm's job was to "learn" from the past records and find meaningful patterns. Then it could predict the likelihood that a particular manhole would have a future flare-up.

The team developed a "hotspot" theory: Manholes with a larger number of cables — and so a larger amount of insulation subject to decay and thus to sparking — were more vulnerable to serious events in the long run.

Con Ed blind-tested the team's model by withholding information on a recent set of fires and explosions. The top 2 percent of manholes ranked as vulnerable by the algorithm included 11 percent of the manholes that had recently had a fire or explosion, Rudin notes.

Tweaking and adding more data has improved the model further, says Rudin, and Con Edison is now using it to help prioritize inspection and repairs. The team has completed rankings for manholes in Brooklyn and the Bronx, and Rudin plans to return to Manhattan's grid armed with the most recent inspection and repair data. ■

CHAD RACHMAN/AP

Computer scientists working with Con Ed are developing the ability to predict and prevent scenes like this one on Manhattan's West 37th Street in September 2004.

Genes & Cells

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

Centenarians can thank DNA, or not

Chip flaw raises questions about genetic paths to longevity

By Tina Hesman Saey

Just like the fountain of youth, a study that purported to find genetic secrets to longevity may be a myth, critics say.

Researchers led by Thomas Perls and Paola Sebastiani of Boston University reported online July 1 in *Science* that they had identified 150 genetic markers that distinguish centenarians from people with average life spans with 77 percent accuracy. Because of a technical flaw, though, the study came under fire almost immediately.

Most of the controversy stems from some of the devices used to take genetic fingerprints of people in the study. Known as DNA or SNP chips, these devices probe genetic markers called single nucleotide polymorphisms, or SNPs. These markers are places in the genome where most people have one letter of the four-letter DNA alphabet — such as an A — and others have a different letter — a G, C or T.

All of the chips used in the study were manufactured by Illumina, a San Diego–based biotech company. But one type of chip, the Illumina 610 array, used for a small number of people in the study, has flaws that could prevent researchers from correctly identifying some SNPs, possibly skewing the results.

> "If it turns out that the whole thing was an artifact, that would be surprising."
> NICHOLAS SCHORK

Ironically, the team's statistical analysis of the data — commonly a trouble spot for SNP studies — was very careful, says Nicholas Schork, a statistical geneticist at the Scripps Research Institute in La Jolla, Calif.

"There are many things in the paper that they did to protect themselves against error, but this is one that slipped through the cracks and may not even have been on their radar," he says. "The jury is still out on the degree to which this problem might affect their results. If it turns out that the whole thing was an artifact, that would be surprising."

Some critics also question whether the study found too many genetic markers associated with exceptional longevity.

"We went into this research expecting there would be few longevity genes," says Nir Barzilai, who conducts similar research as director of the Institute for Aging Research at Albert Einstein College of Medicine in New York City.

But the definition of "few" ranges from one researcher's estimate of four to another's of 2,000, Barzilai says. His preliminary data, generated using a different population of people and different SNP chips, also indicate that about 150 SNPs separate the exceptionally long-lived from people who live an average life span.

Barzilai and the Boston University team also agree on another important point. People who live to 100 and beyond have just as many genetic variants associated with disease as anyone else. But what centenarians have, and the vast majority of others lack, are longevity genes.

The Boston researchers checked their results by performing the statistical analysis on a separate group of centenarians and younger people, and came up with the same answer. That indicates that either the model is correct or that both the original set of data and the data used to replicate the experiment are tainted with questionable SNPs. "It might be a garbage in, garbage out thing," Schork says.

Blood offers new stem cell source

Advance may be easier and faster than existing methods

By Laura Sanders

Blood drawn with a simple needle stick can be coaxed into producing stem cells that may have the ability to form any type of tissue in the body, three independent groups report in the July 2 *Cell Stem Cell*.

Taking blood is safer, faster and more efficient than current stem cell harvesting methods, some of which require biopsies and pretreatment with drugs.

The findings "represent a huge and important progression in the field," Shinya Yamanaka of Kyoto University in Japan writes in a commentary in the same issue of the journal.

Researchers prodded human immune cells from blood to become induced pluripotent stem, or iPS, cells. iPS cells share many but not all of the same regenerative abilities as embryonic stem cells. iPS cells also avoid the ethical questions posed by embryo-derived cells.

All three teams used viruses to deliver a four-gene cocktail that reverts cells to a naïve state in which, theoretically at least, any developmental path is open. Scientists were able to coax some iPS cells into a few types of mature blood cells, including infection-fighting T cells.

It remains unclear whether these cells can be further coaxed to form fully functional tissue, says Rudolf Jaenisch of MIT and the Whitehead Institute for Biomedical Research in Cambridge, Mass., who led one of the studies.

Past studies have induced other kinds of mature cells to form stem cells. The most common source has been adult skin cells called fibroblasts, which have been manipulated into stem cells as well as directly into neurons. Harvesting fibroblasts is harder than drawing blood, requiring surgery and sutures.

"Once you get out of whack, this is something that might help bring you back." —MARINA PICCIOTTO

RNA snippet may curtail addiction

Elevating levels in rodents' brains blunted cocaine use

By Tina Hesman Saey

Little things can make a big difference in the brain. Case in point: A tiny snippet of RNA may help guard cocaine-using rats against addiction, a new study shows.

The tiny molecular guard is a hairpin-shaped piece of RNA known as a microRNA. Raising levels of the microRNA *miR-212* in the brains of cocaine-using rats led them to take less of the drug than rats with normal microRNA levels, researchers report in the July 8 *Nature*. Blocking the microRNA's action increased the rats' cocaine use.

If the results hold true in people, researchers may be able to develop new therapies for treating addiction to cocaine and other drugs of abuse, perhaps by developing drugs that mimic *miR-212*'s action.

"Once you get out of whack, this is something that might help bring you back," says Yale University neuroscientist Marina Picciotto, who was not involved in the study.

At 21 to 23 RNA units long, microRNAs are regulatory molecules (*SN: 3/1/08, p. 136*) that govern part of the process by which instructions contained in DNA are transformed into proteins. The molecules generally block protein production.

So it was a surprise to find that levels of a protein called CREB increase with rising levels of *miR-212*, says Paul Kenny, a neuroscientist at the Scripps Research Institute in Jupiter, Fla.

CREB has been found to help fight addiction (*SN: 5/24/08, p. 14*) by decreasing the reward from taking cocaine, sometimes to the point that rats actually develop an aversion to the drug.

Protecting against cocaine addiction may be a side benefit of *miR-212*'s normal job of regulating CREB production and other biochemical processes in the brain, Kenny says. The microRNA helps set the correct level of CREB production. In rodents, low levels of the protein have been linked to addiction and anxiety and high levels to depression. So any therapy targeting CREB would have to strike a delicate balance. "Obviously there could be some very profound side effects," Kenny says.

The researchers are investigating how *miR-212* is regulated and whether it is protective against addiction to other drugs, such as nicotine and alcohol.

Body & Brain

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

Marburg virus vaccine passes test in monkeys

Ebola-related disease might be stoppable after exposure

By Nathan Seppa

A devastating tropical virus that has no cure can be ambushed by vaccination a day or two after exposure, tests in monkeys show. The findings, appearing in the July *Emerging Infectious Diseases*, suggest that African villagers, health officials and laboratory workers who come into contact with the often-deadly Marburg virus will someday have a way to fend it off.

Marburg virus is related to Ebola virus. Both cause hemorrhagic fevers — in severe cases leading to shock, delirium and organ failure — and both have high mortality rates in people. In recent decades, cases of Marburg virus have shown up in Uganda, Zimbabwe, the Democratic Republic of the Congo, Kenya and Angola, sometimes spreading to other countries via infected travelers and animals.

Earlier research showed that monkeys exposed to Marburg virus and vaccinated within 30 minutes survived (*SN: 5/6/06, p. 277*). In the new study, six rhesus macaques were exposed to the virus and not vaccinated until 24 hours had passed. The strategy was designed to mimic situations in which people are exposed, says study coauthor Heinz Feldmann, a virologist at the National Institute of Allergy and Infectious Diseases' Rocky Mountain Laboratories in Hamilton, Mont.

Five of the infected animals fended off the disease; one died. Of six other monkeys similarly exposed but not vaccinated until 48 hours had passed, two survived and four died.

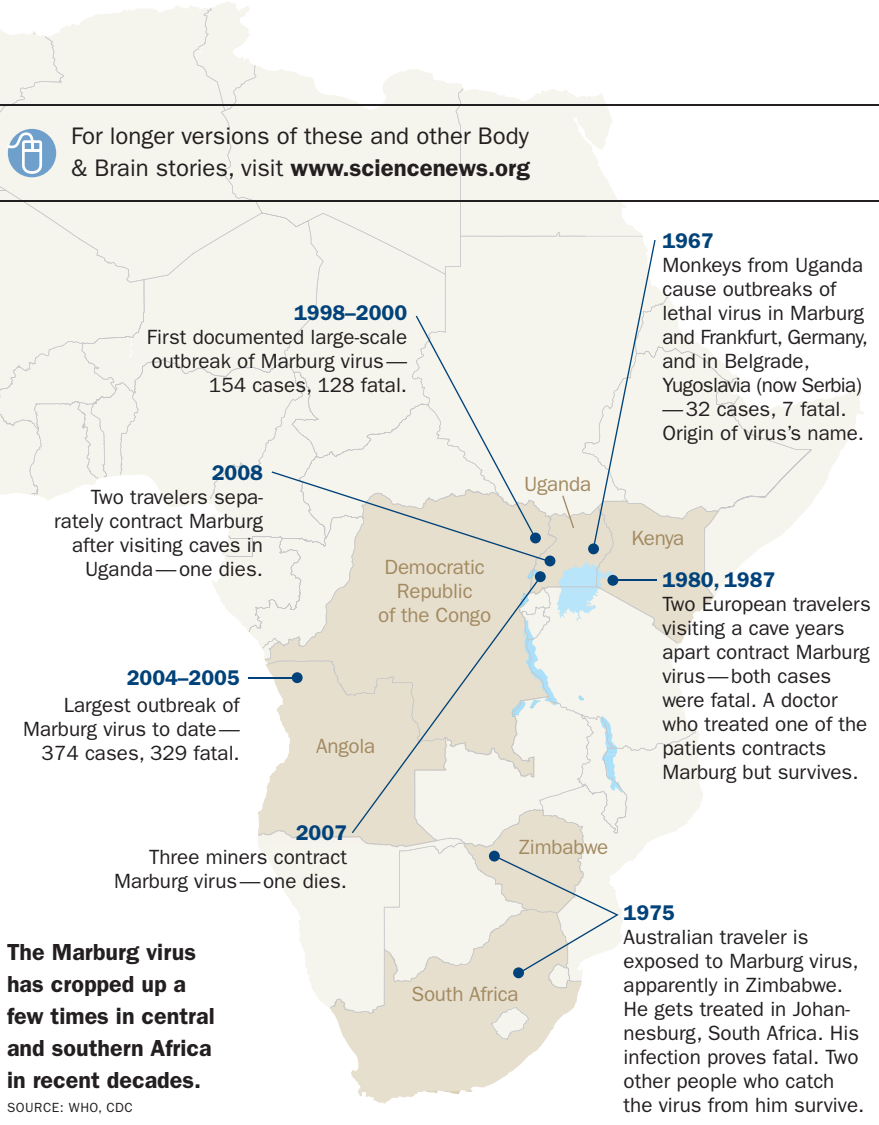
Clinical reports of past Marburg virus outbreaks suggest that people can be exposed longer to the virus than monkeys before showing symptoms. Feldmann says that the window of opportunity for vaccination after exposure might therefore be greater. Also the animals in these tests were given a high dose of the virus, possibly higher than the levels people might be exposed to during an outbreak.

"This would have tremendous value in public health workers and families affected by Marburg virus outbreaks," says Daniel Bausch, an infectious disease physician at the Tulane University School of Public Health and Tropical Medicine in New Orleans. The key will be to reach people in time, as most don't know when they have been exposed.

Delivered in a single injection, the vaccine contains a livestock virus with a single surface glycoprotein from the Marburg virus. The resulting live, attenuated combination virus doesn't cause disease in primates, but it does awaken the immune system, which gins up an army of cells and proteins to fight infection.

Feldmann says the vaccine also seems to compete with the virus for access to important target cells, including dendritic cells — immune cells that help engineer retaliation against a foreign pathogen. This competition may prevent the virus from infecting dendritic cells, Feldmann says, thereby preserving the cells' function and buying time for the immune system to produce T cells and antibodies to wipe out the virus.

Though there will never be a true clinical trial of a Marburg virus vaccine in people (because of the ethics of exposing someone to a live virus), Feldmann hopes that funding can be provided to induce the vaccine industry to manufacture batches to have ready for the next outbreak and for lab personnel.



The Marburg virus has cropped up a few times in central and southern Africa in recent decades.

SOURCE: WHO, CDC

CARTESIA, ADAPTED BY E. FELICIANO

91 percent Portion of HIV strains targeted by VRC01 & VRC02 antibodies

79 percent Portion of strains targeted by PG9 antibody

73 percent Portion of strains targeted by PG16 antibody

Fish oil may fend off breast cancer

Other supplements studied show no signs of protection

By Nathan Seppa

A large survey of postmenopausal women has found that fish oil may guard against breast cancer. Though the study wasn't designed to show a cause-and-effect relationship, an upcoming trial of fish oil consumption may clarify the issue.

Meanwhile, 14 other over-the-counter dietary supplements showed no apparent benefit against breast cancer, researchers report in the July *Cancer Epidemiology, Biomarkers & Prevention*.

While other studies have found that fish oil supplements or a diet high in fish shows promise against cardiovascular ailments (*SN: 2/15/97, p. 101*), the new study is the first to suggest a link between fish oil and a lower risk of breast cancer, says study coauthor Emily White, an epidemiologist at the University of Washington and the Fred Hutchinson Cancer Research Center in Seattle.

White and her colleagues used data from a massive survey of women in western Washington who filled out questionnaires between 2000 and 2002 regarding diet, supplement intake, exercise habits and overall health and lifestyle. The analysis included more than 35,000 postmenopausal women who didn't have breast cancer at the study outset. By the end of 2007, 880 of the women had developed breast cancer.

Women who reported taking fish oil at the start of the study were roughly half as likely as nonusers to develop ductal carcinoma of the breast, the most common form of breast cancer. Fish oil didn't affect the risk of lobular breast cancer.

"It seems to me that this is not a fluke or a false-positive finding," says epidemiologist Timothy Rebbeck of the University of Pennsylvania in Philadelphia.

Three antibodies shown to block HIV

Find may suggest new, if challenging, path to AIDS vaccine

By Nathan Seppa

Scientists have discovered three previously unknown human antibodies that neutralize HIV, including two that target a broad range of HIV strains. Reported online July 8 in two papers in *Science*, the findings come less than a year after another team discovered two other antibodies that bind to and neutralize HIV.

AIDS vaccine research may get a jumpstart thanks to the new discoveries. "The path forward isn't as clear as we'd like it to be, but we are turning a corner," says viral immunologist David Montefiori of Duke University Medical Center in Durham, N.C., who wasn't involved in the research.

Nearly everyone infected with HIV makes some antibodies to it. But while HIV antibodies have been detected since the 1990s, none have had the properties to serve as a cornerstone around which to build a vaccine.

The newer antibodies might be made of tougher stuff. One in particular, called VRC01, displays potency and broad coverage across HIV strains, says Peter Kwong, a structural biologist at the National Institute of Allergy and Infectious Diseases in Bethesda, Md., who coauthored both new reports.

In the studies, Kwong and his colleagues collected antibodies from the blood of HIV-infected people. The team then tested these antibodies against nearly 200 strains of HIV in the lab to determine how many strains were susceptible to each antibody and how much antibody was needed to neutralize the virus.

VRC01 and VRC02 each neutralized 91 percent of HIV strains, the team reports. A third antibody, VRC03, neutralized 57 percent. By comparison, an antibody discovered in the 1990s neutralizes only about 40 percent of known HIV strains, and the PG9 and PG16 antibodies unveiled last year neutralize 79 percent and 73 percent of strains.

Such recent findings "establish a proof of the principle that it's possible for the body to generate these kinds of antibodies," Montefiori says. "We haven't seen anything like what these antibodies can do — not even close."

> "We haven't seen anything like what these antibodies can do — not even close."
> DAVID MONTEFIORI

Scientists will do well to design an HIV vaccine that elicits the immune system to produce a combination of antibodies, to get an additive effect, Montefiori says.

HIV poses challenges for vaccine design because it mutates frequently and is camouflaged from the immune system by sugar molecules, says vaccine immunologist Ralph Pantophlet of Simon Fraser University in Burnaby, Canada.

In one of the new reports, the researchers took apart the VRC01 antibody and found that it binds to HIV on a site that the virus needs to latch onto and gain entry into unsuspecting cells.

VRC01 showed up in only one individual and didn't appear until a few years after infection. Before they can begin development work on a vaccine, scientists must find out if the antibody exists in others. The delay in antibody production might be manageable, Kwong says. Many vaccinations are given over many months.

As for constructing the vaccine itself, Kwong says: "The answer is going to be there, and it's going to be doable."

Environment

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Africa exports bumper crop of dust

Emissions skyrocketed with 19th century agriculture boom

By Sid Perkins

Northwestern Africa has always been a prodigious source of airborne dust. But dust supplies really took off when commercial agriculture came to the region in the 19th century, a new analysis suggests.

Climate exerts a strong influence on African dust emissions: When precipitation is lower than normal, atmospheric concentrations of dust increase. But new data gleaned from sediments deposited on the North Atlantic seafloor suggest that since the 19th century, human activity — especially agriculture along the southern fringe of the Sahara, a region known as the Sahel — has played a big role too, says Stefan Mulitza, a paleoclimatologist at the University of Bremen in Germany. He and his colleagues report their findings in the July 8 *Nature*.

Airborne dust has increased since agriculture for export took off in Africa's Sahel in the early 1800s.

The researchers analyzed two sediment cores taken from the seafloor about 30 kilometers from the mouth of the Senegal River. That material contains both fine-grained, iron-rich sediment carried there by the river and silicon-rich dust blown to the site by prevailing winds, Mulitza says. One core, which measures more than 5 meters long, covers the last 3,200 years, the team's radiocarbon dating suggests. The other core, only 43 centimeters long, provides a high-resolution look at sediment that has accumulated more recently.

The researchers found that for most of the last 3,200 years, changes in precipitation were strongly correlated with dust emissions. But since the early 1800s — when commercial agriculture greatly expanded in the western Sahel — dust emissions have increased substantially. As early as the 1700s, Portuguese settlers in Africa began extensive farming of maize, which was soon replaced by millet and sorghum. But dust emissions really skyrocketed when farmers began growing groundnuts such as peanuts during the region's "cash crop revolution," which dates to the 1840s.

The uppermost layers of seafloor sediment also chronicle an increase in windblown dust reaching the site after 1968, the first year of an extended drought in the Sahel, Mulitza says.

"This is potentially a very important study," says Natalie Mahowald, an atmospheric scientist at Cornell University. The new findings back up her team's recent models, which show a doubling of dust emissions from northern Africa during the 20th century. Those analyses suggest that increased dust flux has substantially affected global climate, she notes. Determining the modern-day balance of dust emission sources could help scientists better understand past climate as well.

Of methane and microorganisms

Hydrates in northern ocean basins an ecological concern

By Sid Perkins

Methane released from arctic seafloors by global warming could cause a cascade of ecological ills, scientists propose in the June 28 *Geophysical Research Letters*.

Worldwide, particularly in deeply buried permafrost and high-latitude ocean sediments where pressures are high and temperatures are below freezing, icy deposits called gas hydrates hold immense amounts of methane (*SN: 6/25/05, p. 410*). Studies indicate that sediments beneath parts of the Arctic Ocean and North Pacific have large reservoirs of the planet-warming greenhouse gas, says Scott M. Elliott, a marine biogeochemist at Los Alamos National Laboratory in New Mexico. The climate warming expected in coming decades will likely melt or destabilize some of those hydrates, releasing their trapped methane, he explains.

Elliot and his colleagues' new model shows that the freed methane would be an unexpected bounty for microbes that eat the compound, consuming dissolved oxygen and producing carbon dioxide in the process. And the waters down-current of a large methane plume could lose as much as 95 percent of their oxygen. Ocean acidification resulting from the increased carbon dioxide could stifle the growth of phytoplankton and other marine organisms. The added microbial activity would also deplete key nutrients including nitrate, copper and iron.

Such a cascade of ecological effects mirrors processes seen in the "dead zones" of many lakes and oceans today, says David Valentine of the University of California, Santa Barbara. Nevertheless, he says, the largest rates of methane release considered in the model "are considerably larger than scientists have seen in the Arctic recently."

J. LEYRER/NIOZ

Atom & Cosmos

7 degrees Angular resolution of COBE, launched 1989

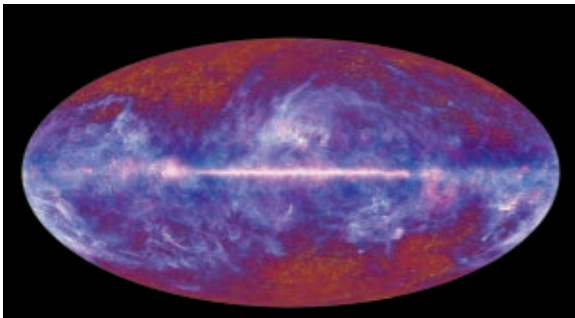
0.5 degree Angular resolution of WMAP, launched 2001

0.08 degree Angular resolution of Planck, launched 2009

Sharper image of universe's early glow is released

Planck mission produces its first picture of the whole sky

By Tom Siegfried



A new image from the European Space Agency's Planck spacecraft shows the bright Milky Way and other galaxies (white and blue) against the faint microwave glow (red and yellow) left over from the Big Bang.

A sharper view of the early universe than any previous image has been captured by the European Space Agency's Planck spacecraft. Launched in May 2009, Planck has been sweeping the sky to record microwave radiation, the remnant glow from the Big Bang, which created the universe about 13.7 billion years ago *(SN: 4/11/09, p. 16)*.

Planck's new image, recorded at nine frequencies, depicts subtle variations in the universe's temperature at different points in the sky, reflecting the distribution of matter when the universe was 380,000 years old. At that time the initial cosmic fireball receded, allowing radiation to flow freely through space.

Patterns within the cosmic microwave radiation provide clues to the history of the universe, including the formation of galaxies and their growth into huge structures. Planck data will also help pin down even more precisely various properties of the cosmos, such as how old it is and what mix of various forms of matter and energy it is made of.

In Planck's sky map, white and blue areas represent foreground interference from the Milky Way and other galaxies; that data must be subtracted before the primordial microwaves (represented by yellow and reddish portions of the image) can be fully analyzed.

Do not attempt to analyze the visible portion of the primordial microwaves on your own, though. This image has been intentionally degraded to prevent scientists not on the Planck team from drawing any premature conclusions, Nazzareno Mandolesi, the principal investigator for one of Planck's instruments, said July 5 during a news conference in Turin at the ESOF 2010 meeting.

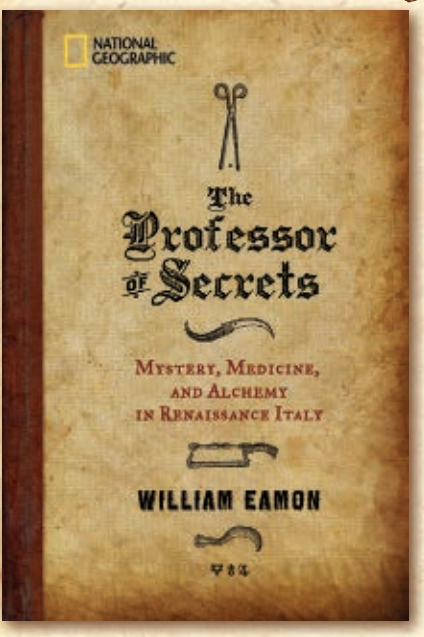
"We were able to produce a map of the full sky with a number of features that have never been seen," Mandolesi said.

Positioned at a gravitationally stable point 1.5 million kilometers from Earth, the Planck satellite should ultimately improve measurements of basic cosmological data by a factor of five compared with NASA's WMAP satellite, Mandolesi said. WMAP, launched in 2001, has provided the most precise microwave background information available so far.

Planck's new map was based on six months of sky sweeps. ESA plans to release findings on some matters of astrophysical interest by early next year, Mandolesi said, but results on major cosmic questions are not planned for public release until 2012. By mission's end, if all goes well, the spacecraft will have made four all-sky scans. ■

ESA, HFI & LFI CONSORTIA

MYSTERY, MEDICINE & ALCHEMY



Step into the scientific underworld of Renaissance Italy—a time of sorcerers, plagues, alchemy, and war—with Leonardo Fiovaranti, Italy's first "celebrity doctor," whose unconventional way of thinking and healing drew both adoration and scorn.

This historical thriller by Pulitzer-prize nominated author William Eamon chronicles the scientific and medical practices of the day and is a fascinating window into Italian life and culture in the late 16th century.

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Life

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Sabertooths strong-armed victims

Extinct cat's thick forelimbs ideal for pouncing on prey

By Gwyneth Dickey

A saber-toothed cat's pounce may have been as bad as its bite. These extinct animals had exceptionally strong forelimbs that probably held a victim still while razorlike teeth ripped out its throat, a new study shows.

Saber-toothed cats (skull and skeleton shown) may have pinned their prey with strong forelimbs.

Most carnivorous cats suffocate their victims with a crushing bite to the throat or nose. This wouldn't have worked for sabertooths because their formidable twin canines were surprisingly fragile. The teeth were oval-shaped when cross-sectioned, not round like other cats', making the canines good for slicing flesh but easily snapped by writhing prey.

A new fossil analysis shows how one saber-toothed cat, *Smilodon fatalis*, avoided breaking those pearly whites. Its humerus, the forelimb bone between the shoulder and elbow, was stronger than that in any other cat, living or extinct.

"This is the first study to look at the internal bone to see how strong limbs are and how they resist forces," says Julie Meachen-Samuels, who did the work at UCLA and is now at the National Evolutionary Synthesis Center in Durham, N.C.

She compared leg bones of 29 carnivorous cat species with those of *S. fatalis*. Digital X-rays revealed details of the bones' structure including the cortex, the hard outer bone surrounding the inner marrow. The sabertooth's humerus cortex was thicker relative to bone length than the other cats', making the bone more resistant to bending and twisting, Meachen-Samuels and UCLA's Blaire Van Valkenburgh report July 2 in *PLoS ONE*.

"It's very strong evidence that the limbs were used in certain ways to grapple with prey so it could make a quick bite," says Christopher Shaw of the George C. Page Museum in Los Angeles.

The strong forelimb–sharp tooth combo was ideal for pouncing on prey, pinning it down and quickly gouging its throat. Sabertooths "had such a specific mode of prey killing that they were probably limited in the range of prey they could take," Meachen-Samuels says, adding that this specificity might have contributed to the cats' eventual extinction.

J. MEACHEN-SAMUELS

MEETING NOTES

Evolution 2010, Portland, Ore., June 25 – 29

Fishy odor just like dad's

A tendency for daughters to fall for a guy like dad helps keep neighboring species of fish from interbreeding. Two distinct species of the three-spined stickleback dart about in each of several lakes in British Columbia. The open-water, slimmer ones mate with their own kind, and the larger, bottom-feeding ones mate with theirs. Experiments in which researchers switched egg clutches between the species now show that, early in life, females of both kinds pick up some cue from their fathers, which do the child care in the sticklebacks. Switched daughters grew up to prefer their foster father's species, while daughters raised with no father around showed no species preference in mating. Further tests suggest that one cue was dad's odor, Genevieve Kozak of the University of Wisconsin–Madison reported June 26. A process known as imprinting may help the stickleback species stay separate despite the close quarters. The work may shed light on other cases in which species form and stay separate while sharing space, such as in African cichlid fish. —*Susan Milius*

Adaptation breeds confusion

The recent evolution of camouflage among lizards in the dunes of White Sands National Monument in New Mexico can lead to misunderstanding when males choose to make love, not war. Since the dunes developed, a light-colored form of the normally dark-shaded eastern fence lizard has arisen; the new form blends in with the landscape.

The change in hue produced confusion over sex-recognition signals in arranged encounters between pale lizards and their darker neighbors, Jeanne Robertson and Erica Bree Rosenblum, both of the University of Idaho in Moscow, reported June 27. When the two males meet, the dark lizard gets ready to fight, showing off his bulk and doing some menacing push-ups. But the pale lizard starts wooing. Blue belly splotches may be the miscue. The darker lizards' smaller blotches resemble those of dune-dwelling females. The pale lizards probably perceive their darker brethren as courtship-worthy females.

This confusion looks as if it has developed as an indirect effect of dodging predators through camouflage. —*Susan Milius*

36 centimeters | Longest tooth of *L. melvillei*, including root

30 centimeters | Longest tooth of *T. rex* "Sue," including root

18 centimeters | Longest tooth of extinct shark *C. megalodon*

Evidence for earlier multicellular life

Soft-bodied creatures presumed to have breathed oxygen

By Gwyneth Dickey

Researchers have found what may be the oldest evidence of multicellular life on Earth. Centimeter-sized fossils uncovered in 2.1-billion-year-old rock from Gabon, in west-central Africa, appear to be examples of macroscopic life in what was then a sea of single-celled microbes.

Scientists believe that multicellular life really took hold much later, in the great expansion of animal body plans known as the Cambrian explosion, which began about 540 million years ago.

"The discovery is fantastic because it shows the existence of multicellular fauna 1.5 billion years earlier than what we know," says team leader Abderrazak El Albani, a sedimentologist and paleobiologist at the University of Poitiers in France. "This is important to understand the evolution of life on Earth."

Some evidence suggests a few species of multicellular organisms may have arisen as early as 1.6 billion years ago, but that evidence is controversial. El Albani and his colleagues were thus surprised to find large fossils in the newly excavated ancient Gabonese rocks. So far, the researchers report in the July 1 *Nature*, they have collected more than 250 specimens ranging in size from 0.7 to 12 centimeters.

Using detailed X-ray imaging, the team created 3-D images of the fossils inside and out. The organisms had flat, oblong, soft bodies, with slits around the edges and complex, patterned folds inside.

Fossils uncovered in Gabon appear to be examples of early multicellular life.

FROM TOP: C. LETENNEUR/MNHN; A. EL ALBANI, A. MAZURIER

Other researchers agree that the large size, thickness and three-dimensionality of the organisms suggest that they were indeed multicellular. "There does seem to be something more than just a clonal colony of bacteria," says paleobiologist Philip Donoghue of the University of Bristol in England.

El Albani and his team believe the complex patterns and folding mean that the creatures must have coordinated their growth through cell-to-cell signaling, as multicellular organisms do today. The fossils could even be the earliest known examples of eukaryotes, cells with membrane-bound nuclei, according to the team.

In their paper, the researchers offered several lines of evidence to demonstrate that the fossils are not simply mineral formations that look like animals, or the remains of more recent creatures that burrowed down into older sediments.

Pyrite, a sulfur-containing mineral also known as fool's gold, filled the fossils, providing evidence that sulfur-using bacteria had eaten away at living tissue.

Further analysis showed that the fossils couldn't have been made from more recent organisms that burrowed deep into sediments, because the surrounding rock was the same inside and outside the organisms' folds.

Rock chemistry indicates the organisms lived about 30 to 40 meters deep in seawater. They probably breathed oxygen, which by that time had been building up in the oceans and atmosphere for about 300 million years. Donoghue says it's exciting that scientists are "edging back" the fossil record toward the Great Oxidation Event 2.5 billion years ago, when oxygen began accumulating in the atmosphere.

It's Moby Dick meets Jaws

What would you get if you crossed a whale with a shark? Maybe something like *Leviathan melvillei*, an extinct hypercarnivorous sperm whale with teeth longer than any that *T. rex* ever had. The whale (depicted above) lived between 12 million and 13 million years ago, says Olivier Lambert, a vertebrate paleontologist at the National Museum of Natural History in Paris. A jawbone and partial skull of the whale were found in southern Peru in November 2008, Lambert and his colleagues report in the July 1 *Nature*.

Leviathan's longest tooth measures about 36 centimeters including the root, more than 40 percent longer than those of today's sperm whales. The researchers estimate that *Leviathan* measured between 13.5 and 17.5 meters long—slightly smaller than the largest adult male sperm whales of today—and fed on medium-sized baleen whales, whose blubber would have been a rich source of calories. —*Sid Perkins*

Beneath that blazing facade

TRACE PROJECT/NASA

Researchers revamp ideas about what's in the sun | By Alexandra Witze

In the pantheon of cosmic celebrities, the sun is one true superstar. It's not only the Earth's prime source of light and heat—it also fuels the greenery that makes breathing possible, keeps time by setting the body's daily rhythms and spits out charged particles that create the beauty of the aurora borealis.

But for all its roles on life's stage, the sun remains something of an inscrutable star. You might say it's the Tiger Woods of the cosmos.

Behind its blazing facade, the sun turns out to be reluctant to give up its secrets. Most frustratingly, astronomers haven't figured out one of the most basic facts about Earth's nearest star: exactly what it's made of.

"We really don't know what the sun's composition is," says Carlos Allende Prieto, an astronomer at the Instituto de Astrofisica de Canarias in the Canary Islands. "It's a big problem."

Physicists do know a lot about the sun and how it works: Hydrogen atoms fuse in its core, forging helium and heavier elements and spewing out energy in the process. But over the past several years, scientists have dramatically overhauled estimates of the sun's chemical makeup. In particular, they say there may be far less of key elements such as oxygen, carbon and nitrogen than previously thought. These changes are major enough to throw into question other basic assumptions about the sun, such as ideas about how sound waves travel through its interior, ringing it like a gong.

And because the sun is the yardstick by which many other astronomical phenomena are measured, if scientists change their ideas about solar chemistry, they must also modify their thoughts about the chemical composition of sun-like stars. Those changes, in turn, affect ideas about how galaxies evolve, such as the rate at which stars form over time, synthesizing and ejecting heavier

Scientists are still trying to pin down the abundances of elements that swirl and churn beneath the sun's busy surface.

elements out into the universe.

"People always compare stars of the same type to the sun, and now the sun has changed," says astronomer Nicolas Grevesse of the University of Liège in Belgium. "Now we're rechecking everything, restarting all the analyses from A to Z."

Slowly, however, researchers are edging toward an answer. New, more sophisticated computer models have improved understanding of the sun's atmosphere, permitting better estimates of chemical abundances. Deeper discussions of which data to include, and which to leave out, are helping smooth battle lines between research teams arguing over what the final numbers should be. Soon, stories about what Earth's superstar is made of could read more like trusted newspaper copy than celebrity gossip.

Reading between the lines

Researchers' preferred way to study the sun's chemical makeup, from nearly 150 million kilometers away, is to analyze the light flowing from it. Spread sunlight out into its spectrum of wavelengths, as a prism creates a rainbow, and the light appears riddled with dark lines. Since the late 1850s scientists have known that these dark lines correspond to chemical elements in the sun's outer layers; the elements absorb radiation coursing outward from the core and blot out the light. The more light is absorbed, the more of that element is assumed to be present.

Though spectral lines alone offer basic clues to the sun's innards, researchers need models to interpret those lines.

In 1929, astronomer Henry Norris Russell used this spectroscopic technique to publish solar abundances for 56 elements. Since then, astronomers have refined the numbers further, and generally believe that hydrogen, the lightest element, makes up around 70 percent of the sun by mass. Over millions of years, nuclear fusion in the solar core slowly converts the hydrogen to helium and subsequently to heavier elements, collectively known to astronomers as "metals" (though they include gases such as oxygen). The question has been exactly how much of the sun was made of metals.

An influential 1989 review paper, coauthored by Grevesse, reported that metals make up 2 percent of the solar photosphere, the lower level of the sun's atmosphere where spectral lines are formed. But during the 1990s, new and more sophisticated analyses began to throw that estimate into doubt.

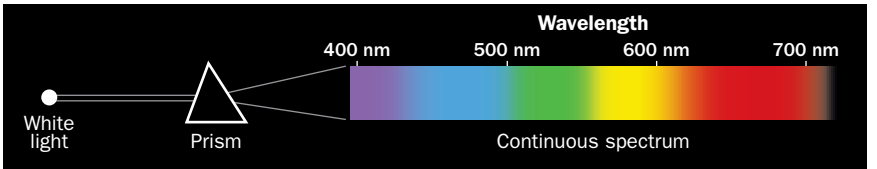
Though spectral lines alone offer basic clues to the sun's innards, researchers need models to interpret those lines. Such models try to reproduce the churning and flowing of gases in the sun's photosphere. Previous modeling had used one-dimensional computer simulations that divided the solar atmosphere into simple stratified layers. In contrast, the new models look at a small chunk of the atmosphere but simulate it in three dimensions and in much more detail — including, for instance, how mass and energy churn out from the convection zone, the outermost layer of the sun's interior, into lower layers of the atmosphere.

The 3-D simulations had a profound implication: Astronomers' earlier interpretations of spectral lines had to be changed. In some cases, the strength of an absorption line could signal an abundance that was different from what scientists had thought.

These recalculations seemed to improve things, by tightening estimates for the abundances of elements like iron and silicon. "It was only when we started applying it to more important elements like oxygen and carbon, the most abundant metals in the sun, that we quite quickly realized our results were going to be very different," says Martin Asplund, an astronomer at the Max Planck Institute for Astrophysics in Garching, Germany.

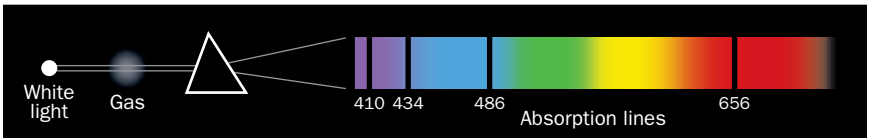
Asplund's team published estimates of solar photospheric oxygen abundance that were 30 to 40 percent lower than commonly accepted values, with similar changes for carbon, nitrogen and neon. The researchers also analyzed the other elements in the sun, most of which required only minor revisions. In all, the

Peering within Scientists take advantage of the fact that all elements absorb and emit light at particular wavelengths to study the composition of the sun and other celestial bodies.



When a narrow beam of hot white light is viewed through an instrument that acts as a prism, the light is separated into its component parts, creating a continuous spectrum.

Similarly, gases emit light of different wavelengths depending on the elements present. When viewed through the instrument, a gas appears as a set of bright lines (hydrogen shown).



When white light travels through gas before separating, as in the sun, the gas absorbs some of the light — leaving dark lines indicative of the elements present (hydrogen shown).

B. RAKOUSKAS

team found a solar metal content not of 2 percent, but of 1.4 percent. The researchers summarized their latest work last year in the *Annual Review of Astronomy and Astrophysics*.

Radiating puzzles

Lower metallicity doesn't bode well for other aspects of solar study — particularly models of the solar interior based on helioseismology, the study of how waves, such as sound waves, travel through the sun.

Turbulence within the sun generates sound waves that oscillate back and forth within the star. Studies of this reverberation have yielded important insights into the solar interior, such as how its layers rotate at different speeds. The technique can even be used to study sunspots on the far side of the sun, since sunspots absorb the sound waves and dampen the reverberation.

Helioseismology studies have built up a certain picture of the solar interior, including such details as the depth of the convection zone. These models of the solar interior were reasonably successful, and physicists thought they understood the sun's insides.

The work of Asplund's team throws a wrench in that picture. If models of the solar interior are adjusted to fit the 30 to 40 percent lower oxygen abundance in the photosphere, then they no longer match up with helioseismologists' observations. For instance, the models now calculate incorrect values for the speed of sound and the density within the sun, as compared with those actually measured.

Assuming Asplund's abundance measurements are correct, "what this tells us is our models are not good enough," says Sarbani Basu, a helioseismologist at Yale University.

In other respects, though, the lower abundances solve a different astronomical dilemma. "It was a problem for a long time that the sun appeared to be unusually abundant in heavy elements compared to the solar neighborhood," Asplund says. Now, the new work "makes the sun completely normal" relative to nearby stars, he says.

Some astronomers are already incorporating the new, lower metal abundances into studies of the evolution of stars in galaxies other than the Milky Way. Because stars become more metal-rich over time, measuring the metallicity of galaxies provides a look at how far those stars have evolved and a clue to when they formed.

But Lisa Kewley, an astronomer at the University of Hawaii at Manoa, says that some researchers — herself included — haven't started using the new abundances yet, because it is not clear whether Asplund's numbers or others offered up by a competing team are correct. It's possible to study metal content in other galaxies without having a solar reference to pin it to, she notes. For instance, astronomers can compare the abundance of oxygen with the abundance of hydrogen in a particular galaxy. Using this same measure over many galaxies allows researchers to build a comparative picture of galaxy metallicity without ever having to worry about what the sun's true oxygen abundance is.

Still, arguments over the true solar numbers are making a lot of researchers uncomfortable. Several years ago at the Paris Observatory in France, scientists led by Hans-Günter Ludwig decided to use their own 3-D simulations of the solar atmosphere to see if they could confirm Asplund's work. And they found that they couldn't, at least not exactly. Ludwig's team, including then graduate student Elisabetta Caffau, has reported its own abundances of certain elements — most of which were higher than Asplund's but not as high as the earlier, 1980s-era estimates.

This spring, the two teams converged in Garching for a weeklong discussion to try to hammer out their differences. Both groups agree that their 3-D models confirm lower metallicity. That finding is also broadly supported by another line of evidence: primordial meteorites. The space rocks known as "CI carbonaceous chondrites" are thought to be the most chemically primitive rocks known, providing clues about what the chemistry of the early solar system, including the newborn sun, was like. Analyses of such

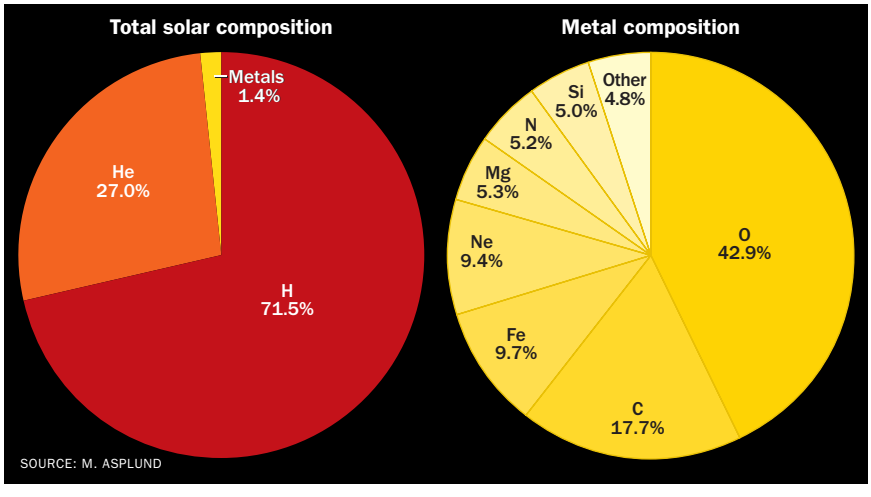
Disputes over selected solar abundances

	Anders & Grevesse 1989	M. Asplund *et al.* 2009	E. Caffau *et al.* 2010
Carbon	8.56	8.43	8.50
Nitrogen	8.05	7.83	7.86
Oxygen	8.93	8.69	8.76
Neon	8.09	7.93	n/a

SOURCES: *GEOCHIMICA ET COSMOCHIMICA ACTA* 1989; *ANNUAL REVIEW OF ASTRONOMY AND ASTROPHYSICS* 2009; *SOLAR PHYSICS* 2010

Debated values Two teams have published revised estimates for photospheric metal abundances (selected ones above) that differ from 1989 values. (The values are expressed on a log scale that sets hydrogen at 12.)

What lies within Although scientists are still debating the sun's precise composition, one new study suggests that hydrogen makes up just over 71 percent, helium 27 percent and metals 1.43 percent. Of the metals, oxygen is by far the most abundant, followed by carbon, iron and neon.



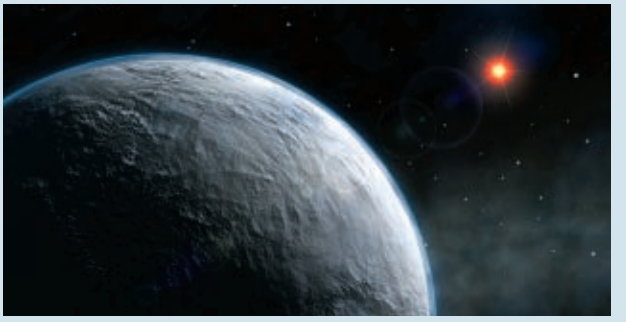
Hunting for exoplanets

Some astronomers are hoping that pinning down the sun's chemical composition will tell them not only about Earth's parent star, but also about other planetary systems.

By looking at the chemical makeup of nearby stars, some researchers say, they may one day pinpoint which neighbors are likely to have Earthlike planets. If so, scientists would be able to identify the best candidate systems for hosting extraterrestrial life—without the time and expense of building satellites to hunt for such planets.

Stars that resemble the sun in temperature, gravity and metal content are known as "solar twins." The key in planet-hunting would be to look for solar twins that have reduced levels of elements such as iron and aluminum that easily condense into dust particles, says astronomer Martin Asplund of the Max Planck Institute for Astrophysics in Garching, Germany. In theory, those elements may have been caught up and incorporated into Earthlike planets that coalesced from the swirling disk of gas and dust around the newborn star. The stuff that ends up in the planets doesn't end up in the star.

Astronomers have discovered more than 460 planets around stars other than the sun, but most of those planets are far more like the gas giants Jupiter and Saturn than like small, rocky Earth. Scientists look for planets through either a slow method (laboriously watching the movement of a star over many years for the tiny gravitational perturbation caused by a nearby small planet) or an expensive method (sending spacecraft into orbit to look for the dimming of light caused by a planet passing in front of its star). The French-led mission COROT and the NASA mission Kepler are currently looking for terrestrial planets in this way. None have yet been confirmed.



By targeting stars with sunlike metallicities, scientists may streamline the search for Earthlike planets (one depicted).

The chemical analysis method could streamline such hunts, Asplund argues. "We propose that you can identify stars likely to have terrestrial planets just by looking at their chemical composition," he says.

Limited surveys suggest that about 10 to 20 percent of solar twins seem to be depleted in elements like iron and thus, like the sun, may also host Earthlike planets, Asplund says. —*Alexandra Witze*

meteorites suggest that oxygen and other elements may be less common than the 1980s solar estimates reported.

The problem, though, comes in a number of smaller choices made by each team in determining the abundance estimates. For instance, Ludwig, now at the University of Heidelberg in Germany, and his colleagues use a larger number of spectral lines to derive abundances, but Asplund's team rejects a number of those lines.

Grevesse, who works with Asplund, says that Ludwig's group is using spectral lines that are blended, or contaminated, by lines from other elements in the solar atmosphere. "We discarded a lot of lines that had been used in the past," Grevesse says. Ludwig counters that educated guesses have to be made: "One starts to have to make subjective decisions, like which kind of lines one should include."

Other subtle effects also contribute to differences between the two groups, such as whether to include only signatures from atoms—such as oxygen atoms—or also lines from molecules—such as carbon and oxygen bound together as CO. (Asplund includes molecular data, whereas Ludwig does not.) The two teams also use different assumptions to calculate details of how the spectral lines form in the first place. "It's a fairly tricky business," Asplund says.

Over the past few months, the two teams have edged closer together on the abundances for some elements. Oxygen, however, remains the major battleground. Ludwig's team comes in with an abundance some 15 percent higher than Asplund's.

Reconciling the two groups will either require one to accept the other's line-selection and calibration calculations or will require entirely new types of relevant data. Grevesse says he'd like to see better data from atomic spectroscopists (scientists who study the spectral lines created by different elements) in order to better calibrate observations of the sun. But such studies are expensive and time-consuming.

Ludwig, too, would like better observations—a better catalog of spectral lines as they appear coming from across the entire face of the sun. And Asplund would prefer new and more sophisticated calculations of solar opacity, to see if that might resolve the discrepancies with helioseismology.

None of these approaches are being actively pursued, so a resolution is not likely any time soon. "I think it's going to take a while to get a definitive answer," says helioseismologist Basu. The sun may hold onto its secrets as long as it can. ■

Explore more

- M. Asplund *et al*. "The chemical composition of the sun." *Annual Review of Astronomy and Astrophysics*. 2009.

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Nature's recourse

How plants and animals fight back when deals go sour

By Susan Milius

Nature has a shifty side. Bees cheat flowers. Flowers cheat bees. Fish cheat other fish, and so on. The more biologists look, the more skulduggery turns up.

In this sense, cheating means pretty much what it does among people, says evolutionary biologist Toby Kiers of VU University Amsterdam: One party exploits another, taking more than its fair share or happily reaping benefits without paying the costs. "There is always that one person that orders the most expensive meal on the menu and then insists on splitting the bill evenly," Kiers says.

Diners in nature don't always mind their manners, either. A bee that bites through a flower wall for a long, sweet drink of nectar but doesn't reciprocate by moving pollen, for instance, has cheated the plant. Such nectar snatches violate an evolutionarily ancient arrangement of trading food for pollination.

No outraged tablemates crack down

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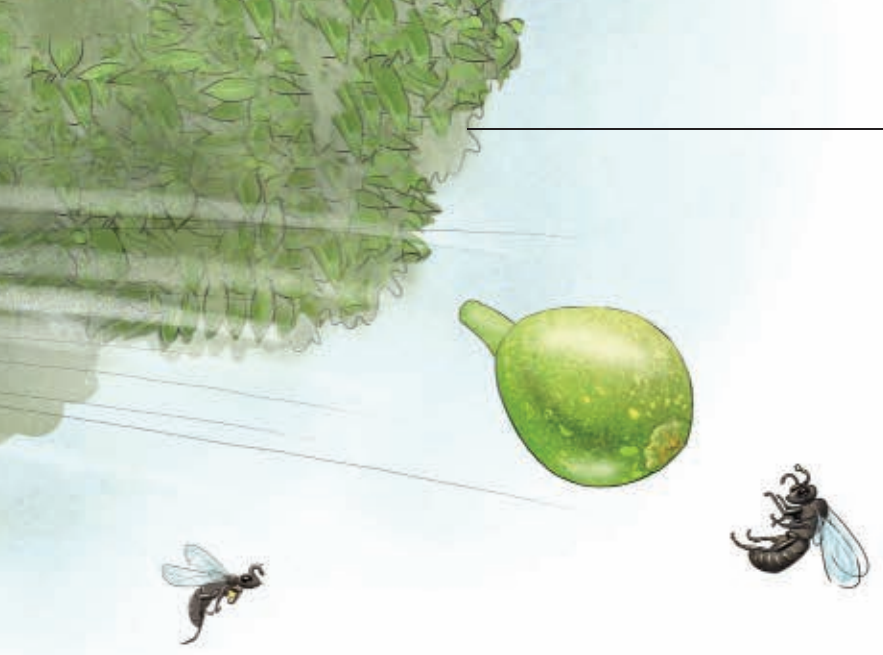


on freeloaders in the wild. Yet, Kiers says, "Nature has its own tools." These safeguards help keep pollinators pollinating and many other vital, two-partner biological processes humming along.

Theorists have long predicted that such anti-exploitation measures would have evolved. Now a burst of studies are revealing how real organisms cope with cheating. Most dramatic are the lethal punishments enacted by otherwise harmless-looking partners. "Plants can be brutal," Kiers notes. Other creatures deliver sanctions that aren't so harsh, or instead switch partners when things don't work out. And in some cases of natural larceny, the cheating amounts to an annoyance that is easier to live with than to fight.

Odd couples

Species trade benefits all the time. Biologists have estimated that virtually every species on the planet participates in some win-win exchange, dubbed a mutualism, says Judith Bronstein of the University of Arizona in Tucson. And these mutualisms make life work.

Most organisms on Earth can't get the nitrogen they need from the atmosphere. Instead many rely on the partnership between legume plants and bacteria that live in root nodules and create user-friendly nitrogen. And more than 80 percent of land plant species get extra phosphorus from the soil via fungi that also mingle their way into root tissues, getting sugar in the process.

Animals, including magazine readers, get nutrition assistance from gut-dwelling microbes with enhanced digestive powers. And many flowering plants, including three-fourths of leading food crops, need mobile members of the animal kingdom to act as go-betweens for sexual encounters. This flower-pollinator bond alone enhances human endeavors from the florist and landscaping industries to romance, poetry and the bold frontiers of hat design.

There's a dark side, though. "Point out a mutualism to me, and I can point out a cheater," Bronstein says.

Cheating looks, at least in some sense, like a winning strategy. Not paying the full cost gives an exploiter more resources to put into making cheater babies. Over generations these freeloaders might expand and take over, destroying the partnership. Yet a lot of mutualisms seem to be doing just fine, thank you. So what effect the cheaters have is an open question.

"The big thing in the last few years has been a wave of support for how sanctions and other enforcement mechanisms can stabilize cooperation," says Stu West of the University of Oxford in England. Some of the restraints found so far are Wild West straightforward: The cheater gets taken out.

Greedy pollinators

For an Asian tree, a no-nonsense strategy for dealing with cheaters means aborting some flowers, Kiers and colleagues report in the March *Ecology Letters*.

Goblet-shaped, green female flowers and more flattened male ones burst out in masses on the *Glochidion acuminatum* tree. The blooms are tiny, though, each flower barely as large as a rice grain, and Kiers says a casual observer can walk by a tree in full bloom without noticing. The pollinator is easy to miss too: a gray moth visiting only at night.

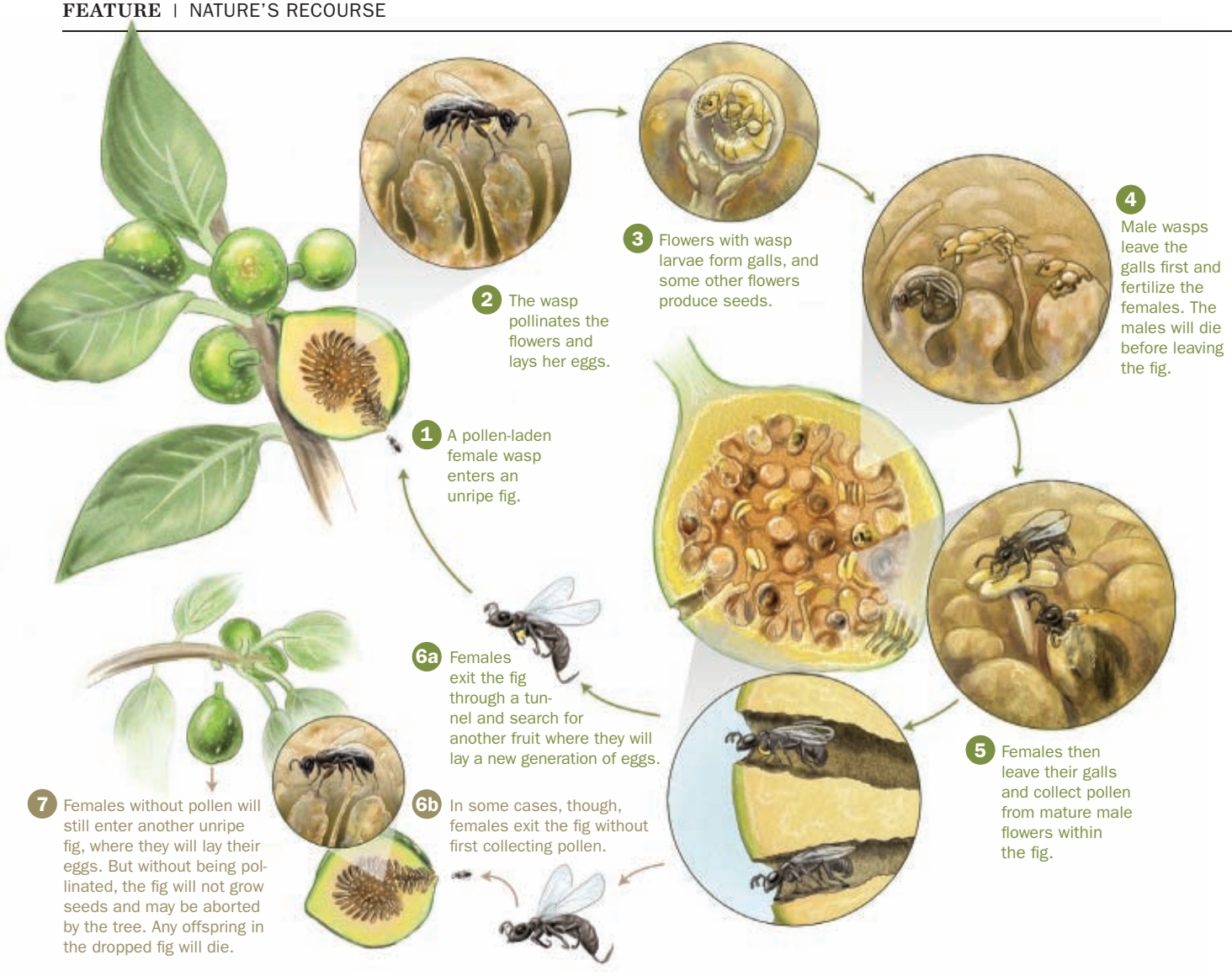
Science as a whole had missed this mutualism until a 2003 study by Makoto Kato of Kyoto University, who was a coauthor on the *Ecology Letters* paper. With extreme patience, Kato's team discovered that female *Epicephala* moths transfer pollen from the male flowers to the female ones. Moths benefit by injecting eggs into the safe, nurturing innards of the female flower. Having an egg injected into a maturing flower reduces the number of seeds the flower can produce, but the attention from moths must be worth it, at least up to a point.

To explore the dynamics of the newfound mutualism, Kiers joined Japanese colleagues camping among World War II bunkers on Japan's Amami-Ohshima Island. Sitting in the dark waiting for a gray moth might not thrill everyone, Kiers says, "but for a scientist studying mutualisms, spotting the moth is like seeing a Siberian tiger in the wild."

The *Glochidion* trees shed a lot of their flowers before they mature into fruits, and Kiers and her colleagues analyzed the number of moth eggs found in the aborted flowers. Those cradling one egg weren't more likely than egg-free flowers

ATSUSHI KAWAKITA

The *Epicephala* moth may cheat its partner tree by laying an egg in a flower that already contains an egg.



Figgy falsification Cheating can creep into the close relationship that fig wasps have with their partner fig. The diagram above shows how the fig-wasp mutualism generally plays out (1–6a)—wasps trade infant care for pollen delivery. But in some cases a female wasp can leave her childhood home without collecting pollen (6b–7). If she lays her eggs in another fig without fertilizing it, the tree may abort fruit containing the cheater's eggs.

to hit the ground, but blooms with two or three moth eggs grew progressively more likely to be dropped.

Since flower drop dooms any moth developing inside, the trees seem to be punishing moths that fail to search out untouched flowers and thus impose too much of a burden, Kiers and her colleagues propose.

This scenario echoes the smackdown that yucca plants can give unsatisfactory moths. Described in 1994, this response was the first clear-cut case of punishment in a mutualism. Yuccas depend on specialized moths for pollen delivery and offer those moths floral cradles. And yuccas tend to abort flowers that get overburdened with eggs (like the Asian trees) or that are neglected by pollinators, according to Olle Pellmyr, now at the University of Idaho in Moscow, and his colleagues. Although not closely related botanically, the Asian trees and the yuccas face similar risks in their mutualisms and have converged on similar punishments.

In fig trees, lethal punishments appear worthwhile. Pollinators of more punitive fig species seem to be better behaved than pollinators partnering with laxer figs, says Allen Herre of the Smithsonian Tropical Research Institute's station on Barro Colorado Island in Panama.

Like yuccas and the Asian trees, figs trade infant protection for pollen delivery. Each of the more than 700 known fig species partners with just a few species of tiny, highly specialized wasps. The female wasps wriggle into closed pouches holding the trees' flowers and lay eggs there. The figs face the usual downside of these day-care deals: Raising baby pollinators means the plants produce fewer seeds of their own.

Herre's colleague, Charlotte Jandér, now at Cornell University, collected several thousand fig wasps near the Panama Canal and checked them for pollen. In four fig species, wasps preparing to leave

NICOLLE RAGER FULLER

their childhood home usually rummage through the flowers and pack pollen to go. But on occasion, from about 0.3 percent to 5 percent of the time, depending on species, the wasps shirk the task and fail to deliver pollen, Jandér and Herre report in the May 22 issue of *Proceedings of the Royal Society B*.

They also assessed the ferocity of the partner trees' punishments by coaxing pollen-free wasps into the flower pouches to see what happened. Tree species varied in how readily they aborted fruit (and thus killed the young wasps) when the insects didn't live up to their duties. For fig species that slammed nonpollinator wasps with tough punishments, "you find very assiduous, meticulous, hardworking wasps," Herre says. For laxer fig species, "that's where you find more lazy, cheater, ne'er-do-well wasps."

Fig trees are no angels either. Herre points out that almost half the known fig species have evolved a pollination system that abuses partner wasps by luring them into specialized female-only flower pouches that accept pollen but kill the wasps' young. Herre says wasps don't yet seem to have evolved a way to punish the plants.

Tough beans

Beans don't go so far as to sacrifice their own flowers to punish a cheater — still, a legume is not be trifled with.

From soybeans to sweet peas to flamboyant tropical trees, the world's legumes negotiate intricate mutualisms with nitrogen-fixing bacteria. Recruited from the soil, rhizobial bacteria reside in custom-built nubbins of root tissue where the plant feeds them carbohydrates. Once in the new quarters, bacteria start using their unusual enzymes to crack the strong bonds of paired nitrogen atoms, thus supplying the plant with nitrogen in the more usable form of ammonia.

To see what a plant might do to slacker bacteria that don't pay their rent, Kiers and her colleagues forced the bacteria to cheat on command. Using air-tight containment areas, the researchers isolated individual root nodules of a single plant inside their own atmospheres. When Kiers filled a nodule's zone with a largely argon atmosphere, the bacteria in the nodule couldn't get atmospheric nitrogen as a raw material. It wasn't their fault, but they failed in their obligations.

The plants retaliated by changing nodule permeability, cutting back on the bacteria's oxygen supplies. The sudden oxygen reduction halved the rhizobial bacteria's usual rate of reproduction.

Cheating rhizobia, known in agriculture, have now been found in the wild.

Joel L. Sachs of the University of California, Riverside and his colleagues collected and analyzed root bacteria from four *Lotus* legumes growing in Bodega Marine Reserve and Sonoma Coast State Park. One rhizobial strain the team collected, belonging to the nitrogen-fixing genus *Bradyrhizobium*, proved to be a miscreant that induced lab plants to grow nodules but then just sat inside providing nothing in exchange. In lab tests, the freeloading strain reproduced more abundantly than the dutiful strains, Sachs and his colleagues report in the May *Journal of Evolutionary Biology*. *Lotus* in the wild might find it handy to dial down oxygen on goof-offs.

Outright punishments aren't the only choice for coping with scam artists, though. Some mutualists appear to reward good behavior, an approach James Bever of Indiana University in Bloomington calls preferential allocation.

Spare the rod

Bever works with a large group of fungi called arbuscular mycorrhizae. When these fungi encounter a plant root of a species they can work with, they poke through the outer wall of root cells and branch into treelike tangles. The tangles press against the inner cell membrane, which bulges around them. "It's like sticking your hand into a balloon," Bever says. The fungi feed on plant carbohydrates and pass along phosphorus from the soil.

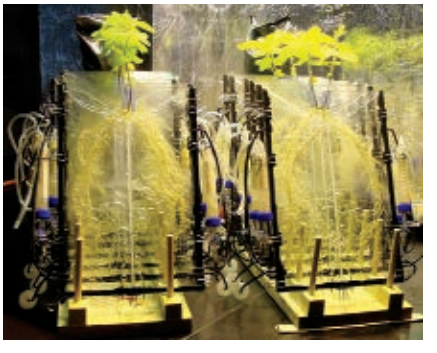
In lab tests of wild garlic plants with roots divided in two parts, roots partnered with more productive fungi carried extra carbohydrates to the star performers. The other root bunch, forced to associate with a less productive fungal strain, carried less, thus shorting the slackers, Bever's team reported in 2009. What actually happens in real soil is the next big question.

Bever doesn't classify this as punishment, though, because the fungi don't appear to suffer much. They can draw the needed nutrients from other plant partners or survive on their own. "If you don't give a child a lollipop, is that punishment?" he asks. He doesn't think so. Of course, the child might disagree.

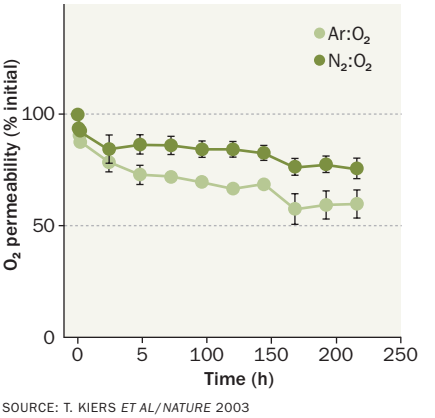
Large reef fish that rely on smaller ones for grooming use a mix of mild punishments and tools of the marketplace to get good service. On reefs, big fish itchy with parasites swim to spots frequented by small specialist cleaner fish. As the bigger fish hovers, the cleaners work the client over, nipping off the parasites.

Experiments offering cleaner fish a

Take that In lab experiments (shown), researchers forced some rhizobial bacteria to cheat a partner plant by isolating them in an argon-filled atmosphere. Without nitrogen, bacteria couldn't pay their rent. As a response, plants reduced oxygen available to the cheaters by reducing nodule permeability (bottom).



Oxygen permeability in root nodules



SOURCE: T. KIERS *ET AL*/*NATURE* 2003

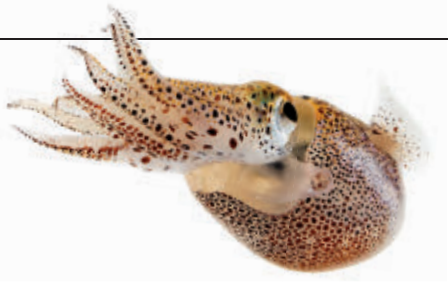
BOB ROUSSEAU

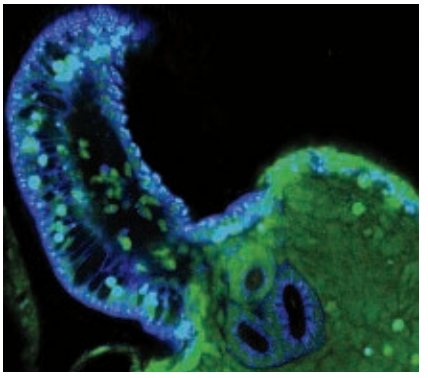
choice of snacks have established that the cleaners will eat the parasites but prefer the clients' protective mucus coating. Should a cleaner cheat and nip off a bit of mucus, though, the client darts after the small fish in a snapping, menacing chase.

After all the plant violence, a mere chase may not seem like much of a threat, but clients often have another recourse: They can take their business elsewhere. And a paper in the January 8 *Science* found that cleaners themselves occasionally get upset. The team argues that males will chase a female cocleaner at a family-run station if she nips a client's mucus, thus threatening mutual interests by scaring away business.

Meanwhile, bobtail squid swimming around the Hawaiian Islands may follow the same advice that fretting mothers deliver to teens: Be careful in screening partners before intimate involvement.

The squid *Euprymna scolopes* hunts at night and allows luminous strains of *Vibrio fischeri* bacteria to colonize an organ in its body cavity, creating an internal night-light. With bacteria at work, the soft glow disguises the squid's silhouette from creatures swimming below. To move in, however, a bacterium needs to respond just right to chemical signals from the squid. "A series of locks and keys" is how Margaret McFall-Ngai of the University of Wisconsin–Madison describes the back-and-forth of biochemical interactions. In 2009 a team of researchers identified a gene form that is found in the strains of light-producing bacteria that colonize squid but not in strains that colonize fish.





Hawaiian bobtail squid (above) don't let just any bacteria in. A chemical back-and-forth ensures that the strains will help the sea creature's light organ (part of a juvenile organ, right) to glow.

If a lackluster strain does make it in, the squid have a back-up punishment plan, McFall-Ngai notes. They deny the bacteria sustenance.

Just deal with it

Some mutualists may not punish or goad substandard partners at all, treating them just as a nuisance to live with. Consider that flower that gets drained of nectar by a bee that doesn't pollinate. "A bunch of flowers get damaged — oops! You make more," says ecologist Rebecca E. Irwin of Dartmouth College in Hanover, N.H.

So far, scientists haven't found clear-cut evidence of punishment for potential pollinators that grab the nectar and run. That's true even though species such as the flower Irwin studies, the scarlet gilia, produce fewer seeds after burglaries. This situation suggests that the cheaters aren't destroying the partnership.

Bronstein also has studied plant-pollinator mutualisms and says they have left her cautious about automatically treating cheaters as horrible menaces that demand a response. In the jimsonweed that she studies, hawkmoths deliver pollen in exchange for nectar, but also lay eggs on the plants. If given the chance, larvae will quickly gnaw the plants' leaves down to nubs.

Instead of preventing caterpillar gorging, the plant seems to excel in recovering from damage. New leaves sprout quickly, and life goes on for the jimsonweed.

Though new research has uncovered cases where cheaters pay heavy tolls, Bronstein says she would like to know how widespread those outcomes are. A new generation of models suggest that it is not hard to come up with conditions that allow cheater species to persist without annihilating the mutualism.

"The idea that cheaters are incredibly costly is too general an idea," she says. Maybe the threat of cheating to the future of mutualisms is just exaggerated.

Cheaters would still have an effect, Bronstein says. They might change the evolutionary path of their teammates, but they might not end the partnership. Among critters, as among people, then, unfair behavior may amount to an annoying, persistent part of life. ■

Explore more

■ Joel Sachs and Ellen Simms. "Pathways to mutualism breakdown." *Trends in Ecology & Evolution*. October 2006.

Hey, stop that Large fish (*Acanthurus mata*, below) regularly visit cleaning stations where smaller fish (*Labroides dimidiatus*) nip off parasites for dinner. Lab work suggests a male cleaner will chase a female cocleaner if she bites the client fish's mucus instead. In the study, a male who chased a cheating female got an average of 0.4 additional food bits during a second cleaning session (chart, bars show interquartile range). Without chasing, the male lost out the second time.

SOURCE: N. RAIHANI *ET AL*/*SCIENCE* 2010

CLOCKWISE FROM TOP LEFT: MATTIAS ORMESTAD, KAHI KAI; M. MCFALL-NGAI/*CURRENT BIOLOGY* 2008; GERRY ALLEN, IMAGE COURTESY OF THE SWEDISH RESEARCH COUNCIL

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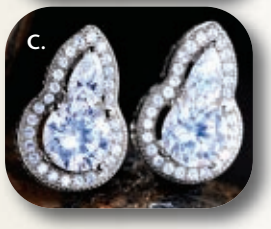

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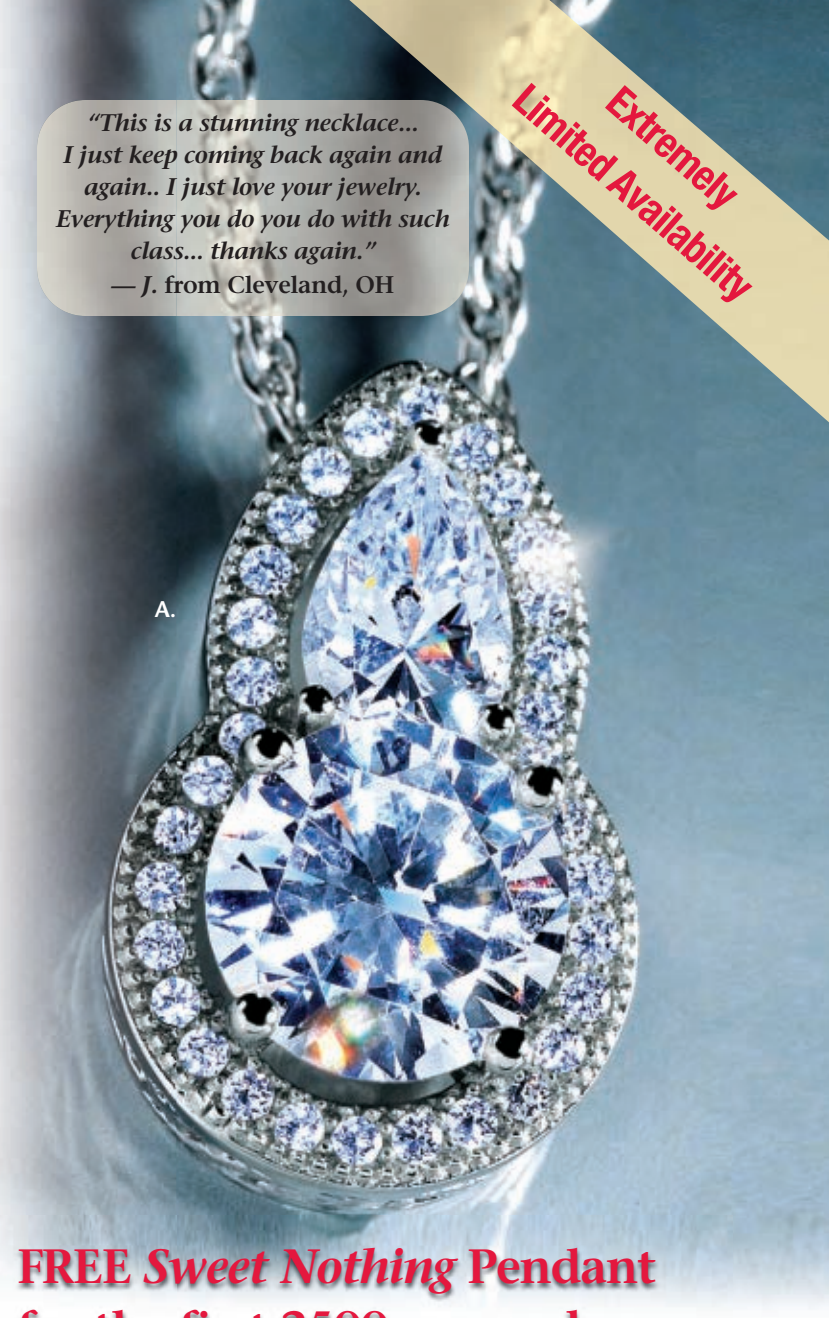

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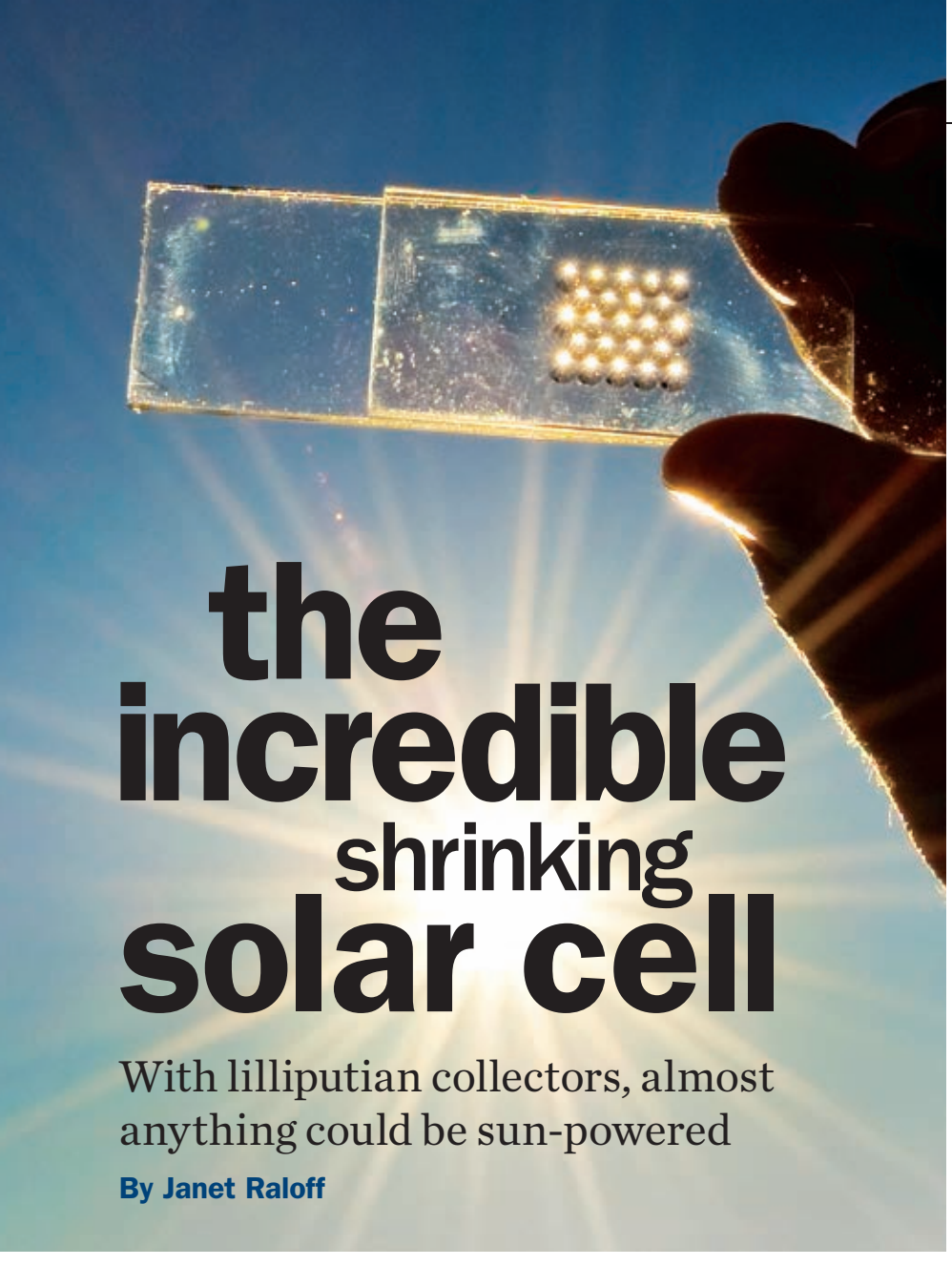


the incredible shrinking solar cell

With lilliputian collectors, almost anything could be sun-powered

By Janet Raloff

Researchers are creating miniature photovoltaic cells that promise to make solar power cheaper and more versatile.

The next generation of solar cells will be small. About the size of lint. But the anticipated impact: That's huge.

Some of these emerging electricity-generating cells could be embedded in windows without obscuring the view. Engineers envision incorporating slightly larger ones into resins that would be molded onto the tops of cars or maybe the roofs of buildings. One team of materials scientists is developing microcells that could be rubber-stamped by the millions onto a yard of fabric. When such cells shrink in size — but not efficiency — it becomes hard to imagine what they couldn't electrify.

"The idea is to develop ubiquitous solar power," says Greg Nielson of Sandia National Laboratories in Albuquerque. Foldable and moldable modules crammed full of photovoltaic cells could directly power devices or recharge batteries. "You can imagine putting them onto every surface," he says. "Your cell phone, laptop, backpack, tent — whatever."

The U.S. Department of Energy is funding more than a dozen labs to investigate photovoltaic physics "at the nanoscale," notes Linda Horton, who works in the agency's Office of Science in Washington, D.C. "Our goal," she says, "is to understand and improve at a very fundamental level the process by which energy from sunlight is translated into electrical energy."

Concentrate on this

The real trick to creating useful and affordable lilliputian solar cells is not just shrinking their overall size, but cutting the amount of silicon (or another costly semiconductor) that is needed for them to deliver a watt of power.

Most photovoltaic devices today are crafted from rigid wafers of costly silicon. At 20 micrometers thick, Sandia's little cells are less than 10 percent as chunky as the ones used in conventional photovoltaic devices. "And because ours are not just thin, but small laterally, we can do interesting tricks with them optically," Nielson says. For instance, his group has begun studding minute refractive lenses into glass or plastic plates. Each lens concentrates sunlight onto a solar cell, nearly as small as a pinpoint, that sits directly below.

Silicon is needed only at the focal point of each lens, further diminishing the required quantity to about 1 percent of what's needed per unit of light-collecting area with commercial photovoltaics. "So silicon is no longer the dominant cost, but a negligible one," Nielson says.

His group grows thin, pure crystalline silicon, then etch-cuts each wafer into a mass of separate hexagons anywhere from 250 micrometers to 10 millimeters in diameter. "We call them glitter," says Sandia's Murat Okandan, and they do sparkle in hues ranging from gold and green to dark purple. Each batch yields uniform and remarkably rugged cells. "We can easily pick them up with a tweezers, and they don't break," the electrical engineer says.

The Sandia program, which began in early 2008, is already turning out prototype cells with an energy conversion efficiency of about 15 percent. "And we anticipate getting over 20 percent," Nielson says. That wouldn't be far from the best commercial solar cells today,

RANDY MONTOYA/SANDIA

which sport efficiencies somewhat more than 25 percent, Okandan adds.

The small print

At the University of Illinois at Urbana-Champaign, John Rogers works with even thinner silicon — 10 to 15 micrometers thick — because when it's slim enough it flexes like a strand of hair. Although he's testing silicon even thinner than that, the material presents special challenges, he notes, "because even at 10 to 15 micrometers the silicon won't absorb all of the incident light." Much passes through.

By backing the cells with a reflective material, however, photons that initially evaded the silicon will bounce back for a second chance at collection. "We found that 15 micrometers is just about the right thickness for that kind of double-pass configuration," Rogers says. "It will collect about 90 percent of the light." And the efficiency of these cells is already good, he says, on the order of 12 percent.

The Illinois microcells also rely on concentrators to focus sunlight. Another key to keeping cell costs low, Rogers contends, will be avoiding a need to "pick and place" each cell individually within a module of perhaps legions of others, which is what the integrated circuit industry does today. In the February *Energy & Environmental Science*, Rogers' team describes a way to simultaneously lift and transfer thousands of microcells.

After building a block of pure crystalline silicon, the researchers etch out thousands of tiny cells from its surface by cutting around the sides of each one and even underneath. After the etching process is finished, the only thing holding the cells to the starting silicon are tiny anchors of material left at either end of each cell.

The scientists then place a soft piece of slightly tacky rubber onto the batch of cells and press down just hard enough to fracture the anchors. When they lift this rubber pad up, the freed cells come with it.

"We can lift up thousands of these cells at a time and then simply rubber-stamp them down onto a surface" coated with a thin-film adhesive, Rogers says. "Our throughputs correspond to millions of devices per hour — much, much higher than can be achieved with even the most sophisticated tools for doing that [by] pick-and-place."

Sparse pile

Caltech scientists have upended the silicon elements in their microcells and jettisoned the concentrator. In the April *Nature Materials*, the team describes a prototype that resembles a sparse carpet of tiny fibers that stretch up toward the light. In the latest designs the fibers are 100 micrometers long and 1 or 2 percent as wide.

Some photons entering the carpet will immediately hit a semiconductor fiber. Many more will miss the wires, which cover only 1 to 5 percent of the carpet's footprint. But by making the wires effectively long and the carpet's bottom reflective, photons not initially collected will ricochet repeatedly within the carpet until the silicon collects most of them, explains team leader Harry Atwater.

To protect and hold the fibers, the Caltech scientists pour a liquid akin to clear bathroom caulk (a polymer that solidifies into a pliable plastic) to fill space separating the carpet's sparse pile.

"We can now peel this composite array of wires and polymer off the starting substrate just as if it were a piece of Scotch tape," Atwater says. The solar cell — this wire-studded polymer — "has the mechanical properties of a plastic bag," he notes. "So you can roll it or bend it and the wires won't break."

University of Illinois solar microcells can be stamped onto a flexible surface.

By maximizing photon ricochets within the carpet, the applied physicist explains, "you're getting the same light absorption as you would from a sheet that's 100 percent silicon," but using only 1 percent as much of the pricey material.

Unlike systems that rely on concentrators, which don't work well on cloudy days, "this kind of cell has equally good absorption for light entering at oblique angles — like when the sun is low in the sky or when light is scattered by clouds."

Prospects

Although none of the emerging designs are quite ready for prime time, several groups think that products based on their innovations could enter the marketplace in as little as three to five years.

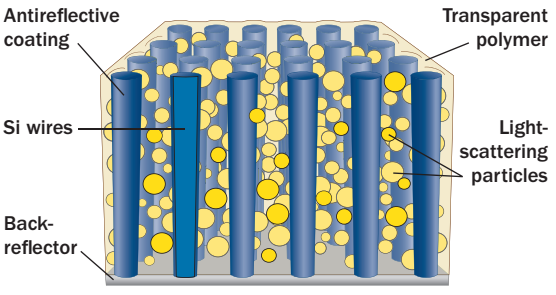
"Right now the solar industry is kind of in a race to bring costs down to $1 per watt," Nielson says. "From our cost models, it looks like we can get well below that with high-volume production." But that's a ways off, he concedes, since his team has only just begun networking individual glitter cells to make coordinated modules.

Atwater has conducted all of his experiments with silicon carpets a few square centimeters in size. "The technology looks promising," he says, "but you have to ask: Will everything translate when you scale up to very large areas?" ■

Explore more

- U.S. DOE Solar Program photovoltaics page: http://bit.ly/a7fUrV

Outdoor carpet Caltech scientists have created a solar collector that bounces sunlight through a forest of silicon semiconductor wires until most of the energy is absorbed.



FROM TOP: J. ROGERS; MICHAEL KELZENBERG/CALTECH, ADAPTED BY E. FELICIANO

Wisdom: From Philosophy to Neuroscience

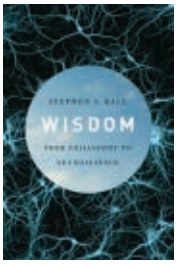
Stephen S. Hall

Of all human attributes, wisdom is perhaps the most vaunted. Yet ask someone to define the trait and the answer will probably echo the test applied to obscenity in 1964: I know it when I see it.

In his latest book, Hall, a science writer, attempts to tackle the question of what defines wisdom and what science has learned to date about this elusive characteristic. What results is a comprehensive and thought-provoking book that examines the difficult topic of wisdom in a fair — even wise — manner.

Hall begins by surveying early attempts to understand wisdom, including biblical stories (think King Solomon) and the musings of ancient philosophers. He then fast-forwards to modern neuroscience's take on wisdom, where his model breaks wisdom down into eight major parts. These "neural pillars of wisdom," as Hall calls them, range from emotional regulation — essentially coping ability — and moral reasoning to altruism and compassion.

Interviews with leading neuroscientists describe experiments that attempt to reveal the inner brain workings behind these pillars. Researchers have examined, for instance, the brain activity of a Tibetan monk practicing meditation and the cognitive processes of volunteers deciding between receiving a smaller gift certificate now or a larger one later.



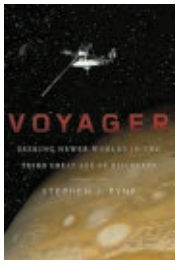
The overarching goal of this research is to explore broader questions such as whether wisdom is innate, learnable or a bit of both, and if wisdom is a uniquely human trait. There are no easy answers, Hall notes. Science may one day succeed in taking wisdom apart to study its pieces, but some mystery will remain about how these elements coalesce to make a person wise in an often foolish world. — *Rachel Zelkowitz*

Alfred A. Knopf, 2010, 333 p., $27.95.

Voyager: Seeking Newer Worlds in the Third Great Age of Discovery

Stephen J. Pyne

What with Mars rovers that tweet and space telescopes with Facebook fan pages, one might think space exploration today is just another part of modern life. In this new book, however, environmental scholar Pyne reminds readers of the rich cultural history that underlies humankind's exploration of the cosmos.

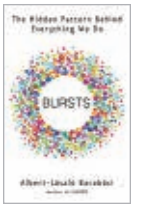


To frame his story Pyne chooses the twin Voyager missions, launched in 1977 to study Jupiter and Saturn but later extended for a "Grand Tour" that also took in Uranus and Neptune. The probes, he argues, symbolize a Third Age of exploration — the first being the 15th century ocean voyages pioneered by the Portuguese and the second the land-based exploration of the 18th century, driven in large part by rivalry between England and France.

Planetary exploration, Pyne says, was a natural successor, stimulated in the 1950s by technological advances and by the space race of the Cold War. His narrative is a remarkable intermingling of the story of the Voyager probes — their birth at NASA's Jet Propulsion Laboratory in California, their long slow cruise through interplanetary space — with a historian's take on how space exploration sprang from timeless yearnings to push frontiers.

Today both Voyagers are still in operation and are passing beyond the edge of the solar system, serving as distant ambassadors for humankind. In this book, Pyne puts that quest in grand perspective. — *Alexandra Witze*

Viking, 2010, 425 p., $29.95.



Bursts: The Hidden Pattern Behind Everything We Do

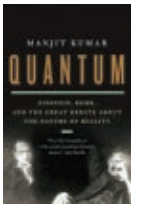
Albert-László Barabási

Mining digital data reveals patterns in seemingly spontaneous human behavior. *Dutton, 2010, 310 p., $26.95.*

Professor Stewart's Hoard of Mathematical Treasures

Ian Stewart

The math professor returns with more brain teasers, puzzles and facts designed to reveal the fun side of the subject. *Basic Books, 2010, 339 p., $16.95.*



Quantum: Einstein, Bohr, and the Great Debate About the Nature of Reality

Manjit Kumar

The story of quantum mechanics and the decades-long argument about how to interpret it. *W.W. Norton & Co., 2010, 448 p., $27.95.*

Dogs: Domestication and the Development of a Social Bond

Darcy F. Morey

An anthropologist describes the evolution of the dog and explores how this creature became man's best friend. *Cambridge Univ. Press, 2010, 356 p., $45.*

Growing Patterns: Fibonacci Numbers in Nature

Sarah C. Campbell

Kids can learn about this special set of numbers from color nature photos. *Boyds Mill Press, 2010, 32 p., $17.95.*

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A placebo's true nature

There is a serious misconception put forth in the letter from William Davis (Feedback, *SN: 5/22/10, p. 31*). The placebos used for placebo-controlled, double-blind studies of pharmaceuticals are not "sugar pills." These placebos are made from the same inactive ingredients in the same proportions used to make the dosage form containing the drug under study. These inactive ingredients seldom include sugar(s). These are the ingredients that make the dosage form easy to handle (fillers), hold together as tablets (binders), dissolve quickly in the stomach (disintegrants), etc. In that sense, the ingredients are not "inert" as Davis calls them; they have very specific functions in the drug.

The purpose of a placebo-controlled study is to separate the effects, if any, of these ingredients in the body from those of the drug under study. Another purpose is to assess the effect, if any, of the psychological "placebo effect" that some patients exhibit due to an expectation of some effect from having taken the drug or placebo.

Gregory R. Daigneault, Director of Chemistry, Geneva Labs, Elkhorn, Wis.

No fear of science

I disagree with Glenn McGee (Comment, *SN: 6/19/10, p. 32*) that people in general are afraid of science or scientists. I am 71 and have met a lot of people over the years, and I have never met such a person. People are afraid of fraud, but everyone I meet loves science and real scientists.

Alan D. Arnold, Gansevoort, N.Y.

Burnt out on smell

After reading that nerves in the nose can transport soot as well as metals and other nanoparticles to the brain, where they do significant harm ("Destination brain," *SN: 5/22/10, p. 16*), I wonder whether our ancestors began to lose some of their sense of smell just as they domesticated fire. Fewer olfactory cells might have limited brain damage from chronic exposure to smoke, especially in cold climates where fire was used to heat and cook inside shelters with poor ventilation.

Eric Seldner, Eatontown, N.J.

Measuring dementia care's risk

The question to ask, after reading that spouses caring for a husband or wife who has dementia suffer a much higher risk of having the same problem ("Dementia care may boost risk," *SN: 6/19/10, p. 13*), is whether the same is true of any long-term caretakers. Such a study should indicate whether the stress of a loved one having dementia and/or the shared environment might be causative factors.

Nelson Marans, Silver Spring, Md.

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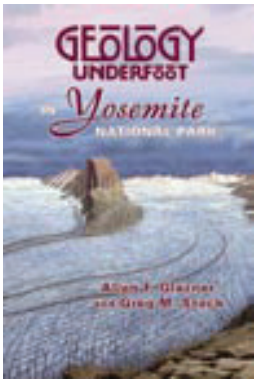

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A university strives for the high road to sustainability

Many universities are trying to bring sustainability to campus through measures such as serving organic food in dining halls, using carbon-neutral power sources and constructing buildings that qualify for LEED (Leadership in Energy and Environmental Design) certification developed by the U.S. Green Building Council. Yet some institutions have expressed concern that some of these efforts do little to reduce environmental impact. Chemist David Oxtoby, president of Pomona College in Claremont, Calif., recently sat down with Science News *writer Rachel Ehrenberg to discuss walking the green line.*

Outside of curriculum changes, how has Pomona approached sustainability?
Just before I arrived, the college had developed a policy on building standards for sustainability, but we've pushed that forward in several directions. In particular, we now have a policy of LEED Gold for all new construction, and if anything, to go beyond LEED Gold. We're really trying to develop our own standards, which are in some cases California-specific. The LEED standards are fine in general across the country, but one of the things we find is that water use is so important in California, but it may not be as important in some other part of the country. The LEED standards are really too generic, so we're going beyond those standards.

There are always challenges, certainly with the balance between LEED standards, on the one hand — reducing energy costs and sustainability — and the aesthetics. We just have a new residence hall underway. And there were two groups, both on campus and on the board of trustees, and one group wanted to build a traditional building that in California would have red tile roofs, and another group wanted solar panels covering the roofs. We decided with the latter. We went in the sustainability direction partly because it was on the edge of the campus. If it had been at the core, we might have decided we wanted to have that character.

I'm personally pretty critical of the LEED-standard approach because there are things where if you put on a solar roof, it will get you one point and that will cost you say, a million dollars. And if you put in some bike racks, that will get you one point, which costs you nothing. So the gamesmanship bothers me. So although we are designing to LEED Gold, we are trying to be much more serious and spending the money that it takes to build buildings that really are sustainable.

We could spend some money to become carbon neutral immediately, just by buying carbon credits. I think that's a really false sense of sustainability.

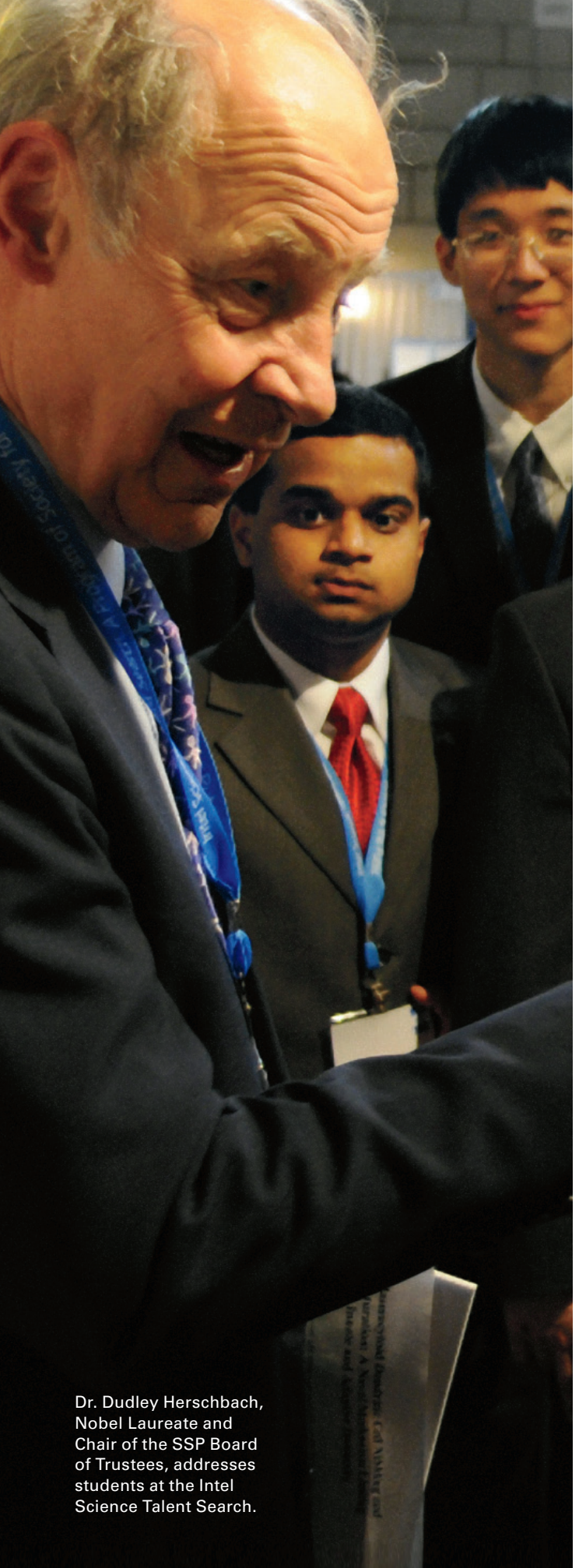
You also have criticisms of the carbon credit approach. Why?
It's not that I'm totally opposed to it. I'm a skeptic about the zero-carbon concept and, in particular, about moving toward that by buying carbon credits.

There are certainly students who think we should go carbon neutral immediately. We have an endowment, we're a relatively well-off college, why don't we just start buying these carbon credits? And we could. If we wanted to, we could spend some money to become carbon neutral immediately, just by buying carbon credits. I think that's a really false sense of sustainability. In my view carbon credits are underpriced — the cost of serious investment to reduce energy [use] is much higher than that. We're spending more money than that, for example, to build solar roofs, and if we were to divert that into carbon credits, it would save us money — but I don't think it would accomplish the goal of reducing our use of energy.

Frankly I see it as somewhat arrogant. We'll go ahead and spend lots of money on air-conditioning or whatever, but we'll pay someone else to reduce their energy costs in some way. So we'll buy our way out of it. I think there are many people who are skeptical about the global market for carbon credits and how well-regulated they are and whether it's really clear that the projects [that the credits fund] would have been done anyway, for example.

How do you balance sustainability against other concerns?
We had a sort of funny discussion. Several people on campus, both faculty and students, were arguing that Pomona should change the fundamental nature of our students, that we were being very nonsustainable by drawing students from all over the country because of course they fly long distances to get there ... so we should just be local. So you can go too far in that direction. To me the goal of getting a group of students together and teaching them outweighs the fact that some of them have to fly long distances. So you need to take everything with a grain of salt. If you try and make everything as carbon neutral as possible, then you are not going to be, in the long run, creating the educational experience that's going to create the future scientists who are going to solve a big problem. ■

POMONA COLLEGE



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