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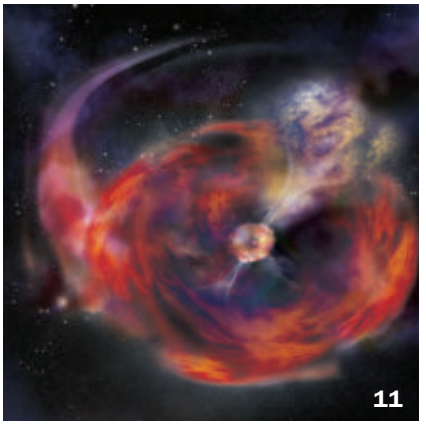
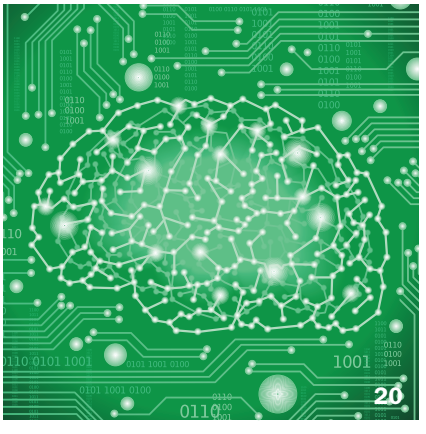
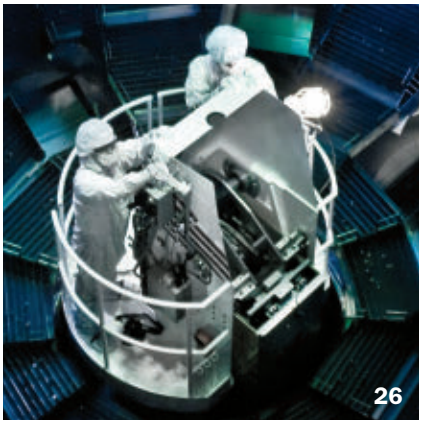







# ScienceNews

## In The News

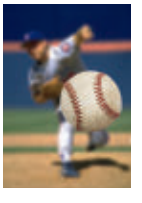


## Features



## Departments





**COVER** New research shows how top-notch athletes' brains focus on the task at hand and anticipate what's coming next. *Ball: Mark Weiss/Getty Images; Pitcher: Stephen Dunn/Getty Images*

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FROM THE EDITOR

# Artificial or otherwise, athletes need intelligence

Suppose you could build an artificial brain that could think scientifically, able to identify general principles of nature by studying results from many experiments. Scientists could gather a lot of data and then let the computer discover the secrets hidden in the numbers.

Sure, it sounds like science fiction. But computers capable of such scientific creativity already exist, as Rachel Ehrenberg reports in this issue (Page 20). In particular, a project called Eureqa (weird spelling of an Archimedean historical allusion) has shown surprising skill at turning raw data into equations capturing well-known physical laws.

It's unlikely that scientists will give up using their own brains to seek discoveries anytime soon. But Eureqa and similar systems could provide a helpful aid in dealing with the deluge of data that modern technologies produce. You could imagine methods for diagnosing diseases that not only detect known disorders, but also identify previously unrecognized maladies.

Just a bit more fancifully, you could conceive of thinking machines helping sports coaches know whom to draft by analyzing activity in athletes' brains. Size, speed, strength and stamina can be easily measured at tryout camps, but such objective physical measures frequently fail to predict who will become a champion and who will consistently choke in the fourth quarter of every NBA Finals game.

It turns out, as Nick Bascom reports (Page 22), superior athletic performance often depends as much on the brain as on the body.

It's not just about making better strategic decisions, such as knowing when to take a pitch or when to swing away. It's about coordinating what the brain is thinking with what the muscles should be doing, knowing how to maintain mental focus and especially knowing how to keep the mind from being distracted by the emotional stresses of the situation.

Eliminating such stresses is what computers are really good at, of course. So you could imagine that someday the NFL's top draft choice would be a computer-human hybrid, merging top physical skills with the sharpest mental focus. And perhaps coaches would be equipped with a Eureqa-like program for finding equations that guarantee play-calling success. But a good coach would have to be able to veto the computer's play calls. To make the best use of artificial intelligence, it helps to have some of the real thing. — *Tom Siegfried, Editor in Chief*

JIM WEBB

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- These sets marked the very *first commemorative U.S. Proof Sets & Mint Sets* ever issued.
- These sets were also the first Proof & Mint Sets to *include a Silver Dollar*.
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15 of the 42 coins within this collection are proofs. Americans love proof coins because each proof is struck twice from specially prepared dies and has deeply-mirrored surfaces and superb frosty images.

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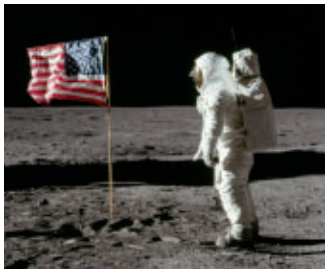


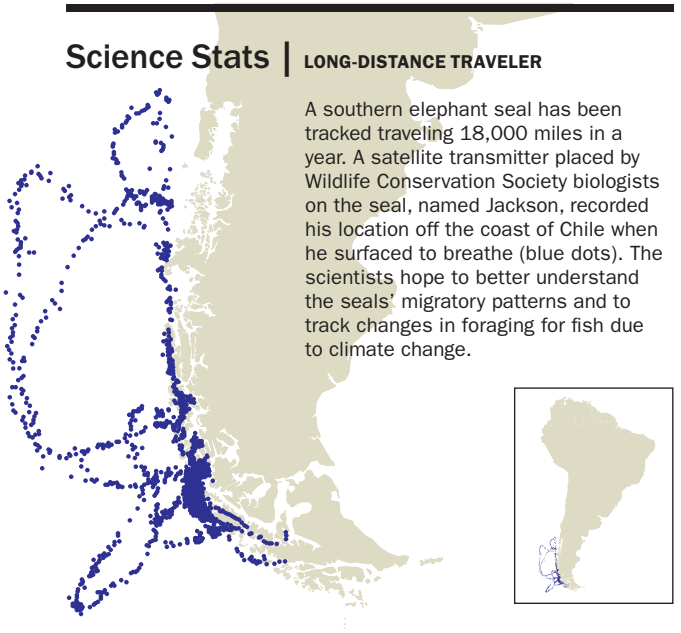
## Say What?

**Tranquillityite** *tran-KWIL-uh-tee-ite*\, *n*. A mineral first identified from rocks collected by Apollo 11 astronauts in the Sea of Tranquillity on the moon. Tranquillityite has since been found in other lunar rocks and in lunar meteorites, and geologists have now discovered the first occurrence of the mineral on Earth. It appears in six outcrops in Western Australia dating back just over 1 billion years. Made in part of silicon, zirconium, titanium and iron, tranquillityite could be a widespread if rare mineral on Earth, the scientists say. Birger Rasmussen of Curtin University in Bentley, Australia, and his colleagues describe the discovery in the January issue of *Geology*. —*Alexandra Witze*

## Science Past | JANUARY 13, 1962

MOON RACE WILL INCREASE — The race for the moon will become more competitive in 1962 in prestige, military and scientific aspects. Foremost there is developing a national will or desire to explore the moon and put an American landing party on the natural satellite of the earth. This is an objective set forth by President Kennedy last May for an accomplishment of this decade. The U.S. would like to beat the Russians to it. There is a major effort to this end by both National Aeronautics and Space Administration (NASA) and the U.S. Air Force. Major space industries are being given large amounts of public money to work out plans and mechanisms to get to the moon.


## Science Stats | LONG-DISTANCE TRAVELER



A southern elephant seal has been tracked traveling 18,000 miles in a year. A satellite transmitter placed by Wildlife Conservation Society biologists on the seal, named Jackson, recorded his location off the coast of Chile when he surfaced to breathe (blue dots). The scientists hope to better understand the seals' migratory patterns and to track changes in foraging for fish due to climate change.

## Science Future

**February 15**
"Matchmaking in the Digital Age" at the New York Academy of Sciences looks at the computer algorithms behind online social sites and what can be learned from them. See bit.ly/oVX2oy

**February 16**
The "Hugs and Hisses" event at the Denver Museum of Nature & Science gives an up-close view of the world of reptiles. Visit bit.ly/tzHvOB

**February 18**
Get hands-on at the annual Discover Engineering Family Day at the National Building Museum in Washington, D.C. See www.eweekdcfamilyday.org

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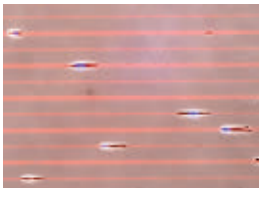
**SCIENCE & THE PUBLIC BLOG**
A government panel wants *Science* and *Nature* to withhold data that could be used to make bird flu more deadly. See "Researchers, journals asked to censor data."

**ENVIRONMENT**
Survival rates of young fish could suffer from ocean acidification levels expected this century. Read "Acid test points to coming fish troubles."

**ON THE SCENE BLOG**
Tiny competitors raced (below) as a way to learn how cells move. Learn more in "Vying for the title of World's Fastest Cell."



**HUMANS**
A big New World population decline after European contact left a genetic mark. See "DNA highlights Native American die-off."

CLOCKWISE FROM TOP LEFT: NASA; WORLD CELL RACE; MALERAPASO/ISTOCKPHOTO; WILDLIFE CONSERVATION SOCIETY. ADAPTED BY E. FELICIANO

## For Daily Use

The caffeine in a serving of espresso can vary by a factor of six, a new study finds, delivering up to 322 milligrams — more than six times the published estimate for a cup of strong coffee. Researchers at the University of Glasgow College of Medical, Veterinary and Life Sciences analyzed 20 commercial espressos and now attribute a wide range of observed chemical differences to how the drinks were prepared. "Consumers at risk of toxicity, including pregnant women, children and those with liver disease may unknowingly ingest excessive caffeine" from a single espresso, the researchers write online November 30 in *Food & Function*. —*Janet Raloff*

“If you asked me to tell you what those fins do just by looking at them, I’d give you a thousand functions, and walking wouldn’t be one of them.” —NEIL SHUBIN, PAGE 12

# In the News



STORY ONE

## Satellites show groundwater dropping globally

### GRACE mission finds supply falling mostly due to irrigation

**By Devin Powell**

SAN FRANCISCO — Groundwater levels have dropped in many places across the globe over the last nine years, a pair of gravity-monitoring satellites finds. This trend raises concerns that farmers are pumping too much water out of the ground in dry regions.

Water has been disappearing beneath southern Argentina, western Australia and stretches of the United States. The decline is especially pronounced in parts of California, India, the Middle East and China where expanding agriculture has increased water demand.

“Groundwater is being depleted at a rapid clip in virtually all of the major aquifers in the world’s arid and semiarid regions,” says Jay Famiglietti, a hydrologist at the University of California Center for Hydrologic Modeling in Irvine, whose team presented the trends December 6 at a meeting of the American Geophysical Union.

Famiglietti and his colleagues detect water hidden below the surface using the modern equivalent of a dowsing rod: a pair of half-ton satellites, nicknamed Tom and Jerry, that are especially sensitive to the tug of gravity from below.

As the spacecraft chase each other around the planet like their cat and mouse namesakes, they are pulled apart and pushed together by areas of higher or lower gravity. Mountains and other large concentrations of mass have a big, obvious effect that’s consistent from month to month. But water moves around over time, creating small gravity fluctuations that the satellites’ orbital motions respond to.

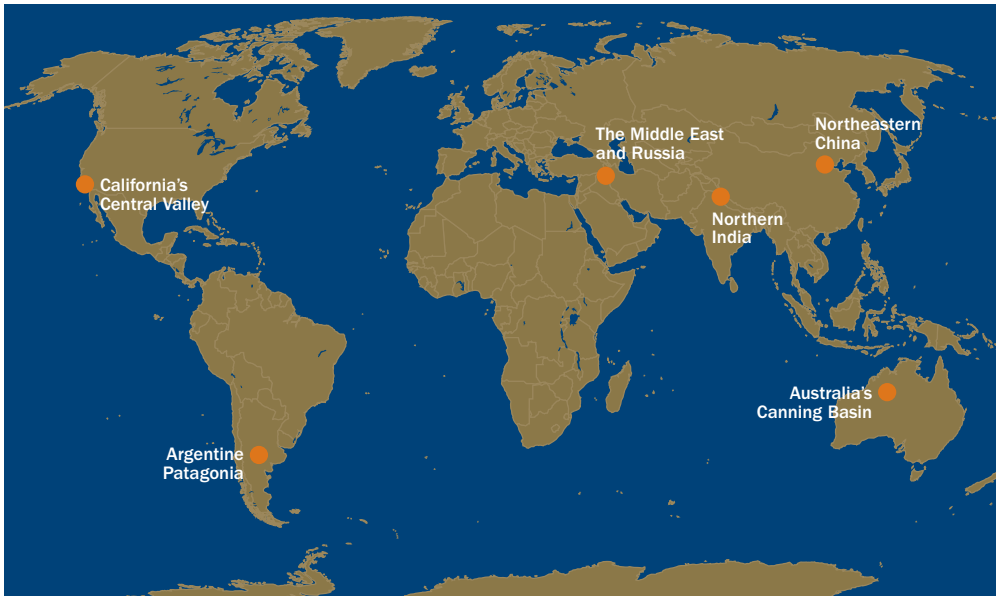
It takes a lot of flow to noticeably change the distance between the satellites. After subtracting the contributions of snowpack, rivers, lakes and soil moisture, the scientists can detect a centimeter rise or fall in groundwater over an area about the size of Illinois.

This joint mission between NASA and the German Aerospace Center — called the Gravity Recovery and Climate Experiment, or GRACE — has been creating monthly snapshots of global groundwater since 2002. The trends identified in this data help fill in monitoring gaps and confirm problems in places where official groundwater information is unreliable or nonexistent.

“GRACE is very good for areas of the world where we don’t have good ground observations,” says Marc Bierkens, a hydrologist who studies groundwater at Utrecht University in the Netherlands.

China, for example, has been shown to underestimate groundwater use. The country lacks the nationwide network of monitoring wells found in the United States. GRACE’s measurements suggest that water levels have been dropping six or seven centimeters per year beneath plains in the northeast.

In some areas, short-term climate variability may be to blame. For example,




**Water woes** Groundwater levels have fallen substantially over the last decade in certain arid and semiarid regions (labeled above). Some declines can be blamed on short-term climate events, but the biggest seem to be caused by unsustainable pumping of water for irrigation.

GEOATLAS/GRAPHI-OGRE, ADAPTED BY E. FELICIANO

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**GRACE's twin satellites (illustrated here) dance toward and away from each other depending on the strength of the gravitational pull they feel from below. Onboard instruments can detect a micrometer change in distance between the spacecraft.**

the plains of Patagonia in Argentina and areas across the southeastern United States — areas that have been hit hard by droughts — store less groundwater today than they did in 2002.

But there's little doubt about what's behind the biggest drops: farming. An agricultural boom in northern India has helped to squeeze nearly 18 cubic kilometers of water from the ground every year (*SN: 9/12/09, p. 5*). That's enough water to fill more than 7 million Olympic swimming pools. And in California's Central Valley, which supports about one-sixth of the nation's irrigated land, the ground has been sinking for decades as landowners drill more wells and pull out almost 4 cubic kilometers of water per year (*SN: 1/16/10, p. 14*).

"People are using groundwater faster than it can be naturally recharged," says Matthew Rodell, a hydrologist and GRACE team member at NASA's Goddard Space Flight Center in Greenbelt, Md.

Agricultural pressures are particularly worrisome in places like the Middle East, another hot spot on the new GRACE map. Water being pumped from the Arabian aquifer system beneath Saudi Arabia and surrounding countries today fell as rain tens of thousands of years ago. Once this fossil water disappears, there's little new rainfall to replenish it.

Climate change will only worsen the problem, says Famiglietti. Precipitation patterns are becoming more extreme, increasing the severity of droughts. Wet areas are becoming wetter and dry areas drier, which may accelerate declines in groundwater in some places.

But even as the researchers sound the alarm, they don't know how loud to crank up the volume. GRACE reveals only changes in groundwater. It doesn't divulge how much water is left.

"We don't really know how stressed the world's largest aquifers are," says Sasha Richey of the University of California Center for Hydrologic Modeling.

Some reservoirs, like the giant Nubian aquifer that underlies North Africa, may be large enough to meet demand for centuries. But few reliable estimates exist of the amount of groundwater stored in the world's aquifers.

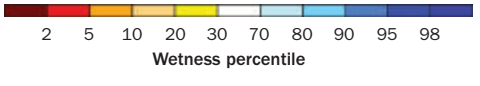
Despite the uncertainties, Leonard Konikow, a hydrogeologist at the U.S. Geological Survey in Reston, Va., says that water use has become unsustainable in many places. Better irrigation systems that use less water could help to curb the problem, he says. So could channeling water during especially wet periods into aquifers instead of letting it run off into the ocean.

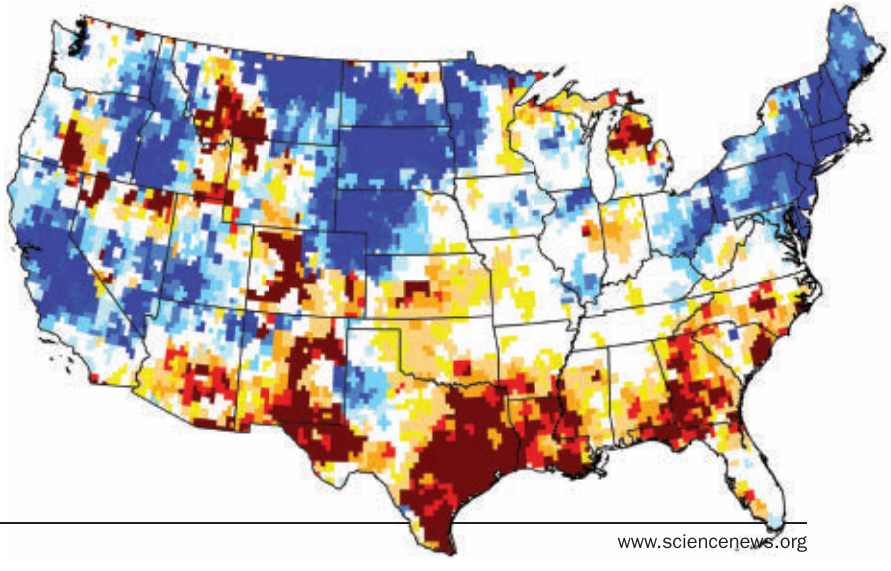
"There are too many areas in the world where groundwater development far exceeds a sustainable level," says Konikow. "Something will have to change." ■

FROM TOP: NASA; NASA/NATIONAL DROUGHT MITIGATION CENTER AT THE UNIVERSITY OF NEBRASKA-LINCOLN

## Back Story | DRY AS TEXAS TOAST

Useful for tracking long-term groundwater trends in areas with poor monitoring, GRACE data can also yield insights about places with well-tracked conditions. For the continental United States, a computer combining GRACE data with meteorological records can simulate the movement of rainwater into and out of the ground. One simulation's output, shown here, reveals the situation on November 28, which saw supplies in many locations reduced to levels seen only 2 percent of the time since 1948 (wetness percentile).



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# Face memory deficit holds object lesson

## Recognizing mugs may not be so special in the brain

**By Bruce Bower**

A brain-damaged man who can't remember faces has nosed into a scientific debate about how people learn to recognize other complex objects. Deaf users of sign language also have a hand in this dispute.

The man's facial failures are one symptom of a general inability to perceive configurations of object parts, suggests a new investigation led by psychologist Cindy Bukach of the University of Richmond in Virginia. The man stumbles at identifying not only people's faces but also computer-generated, three-part objects called Greebles, even after extensive training, Bukach's team reports online December 8 in *Neuropsychologia*.

Bukach and her colleagues studied LR, a man who fails to recognize his daughter when shown a picture of her but remembers distinctive facial features, such as Elvis' sideburns. Damage in a car accident to a brain area just under the right temple caused this condition, called prosopagnosia.

"There are many ways in which face recognition can be disrupted, but our evidence shows that LR's type of prosopagnosia impairs recognition of objects with multiple parts, with faces as the most obvious example," Bukach says. Relative positions of the eyes, nose and mouth, as well their shapes, contribute to perceiving a face as a single entity.

In a 2006 report, her team designed a collection of eight faces using different combinations of two sets of eyes, noses and mouths. After briefly viewing a face, LR correctly selected it from all eight faces 25 percent of the time — about what would be expected if he based choices on a single facial feature, Bukach says. Further testing showed that LR homed in on the mouth.

**A man fails to recognize his daughter, but remembers distinctive facial features such as Elvis' sideburns.**

In the new study, the researchers designed eight Greebles, using different combinations of two versions of three distinctive appendages. LR recognized Greebles he had just seen 31 percent of the time, improving little after several one-hour, weekly training sessions. Four healthy volunteers struggled at discerning Greebles at first but recognized most of them after training.

Bukach opposes an influential view that the brain evolved systems for dealing with key types of knowledge, including face recognition (*SN: 7/7/01, p. 10*). A proponent of that view, psychologist Bradley Duchaine of Dartmouth College, previously reported that another prosopagnosia patient learned to discriminate Greebles but not human faces.

If face recognition depends on a general capacity for learning to recognize multipart objects, Duchaine holds, healthy volunteers should recognize novel Greebles as poorly as prosopagnosia patients do at first but perform better than patients after seeing lots of Greebles. LR's Greeble difficulties exceeded those of healthy volunteers from the start, a sign of fundamental object-recognition problems that make the results hard to interpret, Duchaine contends. "These new results don't help us understand mechanisms used for face processing," he says.

LR's poor Greeble recognition before and after training indicates that he focused on only one appendage when trying to tell the funny-looking objects apart, Bukach responds.

Support for the idea that brains use a general mechanism to recognize complex objects comes from deaf people who communicate with American Sign Language. Just as upside-down faces look weird and often unrecognizable to healthy volunteers, so do upside-down signs shown to fluent ASL users, say psychologists David Corina of the University of California, Davis, and Michael Grosvald of the University of California, Irvine.

Because healthy individuals perceive faces as whole entities, topsy-turvy faces look bizarre, Corina says. Likewise, ASL users learn to see signs as integrated sets of movements that look peculiar when inverted, the pair proposes in a paper published online December 6 in *Cognition*.

Many researchers assume that people understand sign language by breaking each sign down into hand shapes, arm movements and other elements.

Corina and Grosvald also find that deaf ASL users are faster than hearing nonsigners at recognizing videos of head scratching and other common grooming actions. Sign language exploits brain areas devoted to detecting human actions in general, they propose.

Psycholinguist Karen Emmorey of San Diego State University calls new evidence that fluent signers perceive signs as whole entities "a key insight." Further work needs to confirm that learning a sign language modifies action-related brain areas, she adds. ■

C. BUKACH

**A brain-damaged man who can't recognize faces also fared poorly at learning to distinguish computer-generated "Greebles" (such as these) from one another. Each Greeble displays a distinctive configuration of three appendage types.**

**32 percent** | Fraction of stay-at-home kids in Ghana with schistosomiasis

**6 percent** | Fraction of school-going kids in Ghana with schistosomiasis

# Gene therapy helps hemophiliacs

## Virus induces liver to generate blood-clotting factor

**By Nathan Seppa**

A gene therapy based on a cargo-toting virus that gravitates to liver cells might provide hemophilia B patients with long-lasting protection against bleeding, an international team of scientists reports online December 10 in the *New England Journal of Medicine*.

Hemophilia B is the second most common form of hemophilia, a hereditary disorder in which blood fails to clot properly. Patients must receive preventive injections of a clotting compound called factor IX to prevent bleeding from cuts, scratches or bruises. In the new study, four of six hemophilia B patients given the gene therapy no longer needed the clotting compound.

The work "is truly a landmark study, since it is the first to achieve long-term expression of a blood protein at therapeutically relevant levels," physician Katherine Ponder of Washington University in St. Louis, who wasn't part of the study team, wrote in the same issue of the journal.

British researchers treated six men ages 27 to 64 with the gene therapy, an innocuous virus coupled with components that induce liver cells to make factor IX. Before the study, the men had been getting intravenous infusions of factor IX two to three times a week, says study coauthor Andrew Davidoff, a surgeon at St. Jude Children's Research Hospital in Memphis, Tenn.

Each patient received a single infusion of the therapy, called serotype-8-pseudotyped, self-complementary adenovirus-associated virus vector. Four patients who received medium or high doses of the therapy have made enough factor IX themselves to cease getting the preventive infusions of it. Two patients who were given low doses of the gene therapy are making less. While they still need factor IX infusions, they have cut back to one every 10 to 14 days, Davidoff says.

The virus used, known as AAV-8, targets liver cells, which naturally make factor IX. Although AAV-8 enters a cell, it doesn't integrate with material in the nucleus, greatly reducing the risk that the therapy will interfere with normal cell function.

Because of these attributes, "there's a modest level of excitement" about this approach, says hematologist W. Keith Hoots of the National Heart, Lung and Blood Institute in Bethesda, Md., which funded the study in part. The treatment cannot be repeated in a patient, however, because the immune system would recognize AAV-8 the second time around. Even so, the approach has promise because there are dozens of other AAVs that are still untapped, Hoots says.

Two of the patients were given a brief course of steroid drugs when they showed signs of liver inflammation, but no other side effects emerged. Earlier tests in large animals had shown that this therapy could last 10 years or longer. Further testing in people is planned, Davidoff says. ■

## NEWS BRIEFS

### Chronic fatigue paper pulled

The editors of *Science* fully retracted a controversial paper that claimed a virus called XMRV might be to blame for chronic fatigue syndrome. Since the paper's publication in *Science* in 2009, multiple researchers, including some of the scientists who originally claimed to have found the link, failed to detect the XMRV virus as well as closely related viruses in blood samples from people with chronic fatigue syndrome. What's more, the original report didn't include key controls and left out vital information, *Science*'s editor-in-chief, Bruce Alberts, wrote in the December 23 retraction. "We regret the time and resources that the scientific community has devoted to unsuccessful attempts to replicate these results," Alberts writes. —*Laura Sanders*

### School doesn't bug some kids

Rural African children who go to school are much less likely to contract a serious parasitic infection than kids not in school, researchers at the University of Ghana in Legon reported December 7 in Philadelphia at a meeting of the American Society of Tropical Medicine and Hygiene. The researchers analyzed samples from more than 300 children and found that 32 percent of kids who stayed home were infected with *Schistosoma mansoni*, a parasitic worm that can cause fever, blood loss and lethargy. Only 6 percent of children in school had the parasite. Stay-at-home kids typically help with farming and are exposed to irrigation canals and other water sources that harbor the parasite, Tandoh said. —*Nathan Seppa*

### The heights of power

Powerful people overestimate their height, a result that makes it easier than ever to look down on the little guy. In a new study, subjects were asked to describe a situation in which either they were powerful or someone else held power over them. People primed to feel powerful underestimated the height of a pole and chose taller avatars, Michelle Duguid of Washington University in St. Louis and Jack Goncalo of Cornell University report in an upcoming *Psychological Science*. —*Laura Sanders*

# Atom & Cosmos

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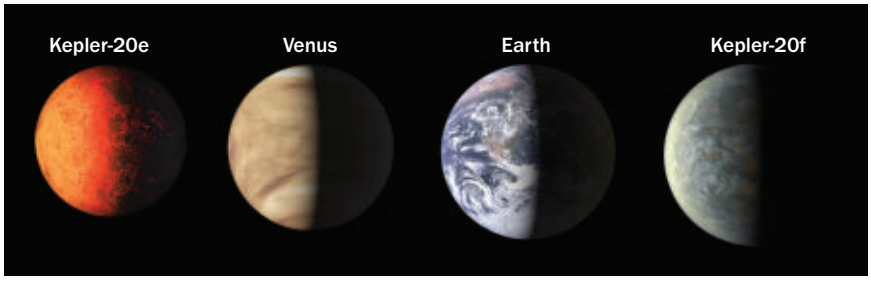
## First Earth-sized planets netted

### Kepler telescope finds two orbs of terrestrial proportions

**By Nadia Drake**




**The first two Earth-sized exoplanets found, Kepler-20e and Kepler-20f, are slightly smaller than Venus (20e) and slightly larger than Earth (20f).**

The newest exo-apples of the planet-hunting Kepler telescope's unblinking eye are two rocky, Earth-sized planets hovering around Kepler-20, a sunlike star 950 light-years away.

Though snuggled too close to their star to be habitable, these first Earth-sized worlds confirmed by the Kepler team are another big step forward for the planet hunters, who recently found a planet somewhat larger than Earth orbiting a sunlike star at a distance hospitable to life (*SN: 12/31/11, p. 11*). Finding habitable distant worlds — Earth-sized planets at the right distance from their stars to allow the presence of liquid water — is the team's ultimate goal.

"The hunt is on to find a planet that combines the best of both of these worlds — a true Earth twin," says David Charbonneau, an astronomer at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., and a coauthor of the study describing the small planets, which appears online December 20 in *Nature*.

One of the planets, Kepler-20e, is a bit smaller than Venus — 0.87 times as wide as Earth — and completes a trip around the star every 6.1 days. The other, Kepler-20f, is 1.03 times as wide as Earth, and a year on that planet would last just 19.6 days. Because the planets are so small, they're probably made of ingredients similar to Earth's.

Depending on where and how it formed, Kepler-20f could even have developed a water vapor atmosphere, says planetary scientist Jonathan Fortney of the University of California, Santa Cruz. "If it started out with the amount of water we had on Earth and Venus, it's probably long gone — just like it is on Venus," he says. "But if that planet had a tremendous amount more water, then it might have some left over."

The Kepler-20 system is a quintet comprising three large planets (Kepler-20b, c and d) and the two Earth-sized ones, all tucked in nearer to their star than Mercury is to the sun. Moving out from Kepler-20, the five spheres alternate in size, with the runts of the planetary litter bracketed on either side by their bigger siblings.

"It's one of the most shocking architectures we've seen," Charbonneau says. "Exoplanets have had a lot of surprises, but this is going to be very difficult to explain."

## Behemoth black holes

Two galaxies are racing to bust the record for harboring the biggest, baddest central black hole. The galaxies NGC 3842 and NGC 4889 surround black holes nearly 10 billion times as massive as the sun, a team of U.S. astronomers reports in the Dec. 8 *Nature*. One of the bruisers, churning away in NGC 3842, has a radius seven times bigger than that of Pluto's orbit. The previous record-holding black hole, Messier 87, comes in at a comparably paltry 6.3 billion solar masses.

Scientists had predicted the existence of such enormous mass gobblers (*SN: 10/25/08, p. 18*) but hadn't found any until now. Such large black holes might have formed after several smaller galaxies merged. The behemoths (an artist's conception of the region surrounding one is at left) are believed to be the relics of quasar-powering monsters — the enormous black holes that fueled extremely bright active galactic nuclei in the early universe. — *Nadia Drake*

FROM TOP: TIM PYLE; LYNETTE COOK, GEMINI OBSERVATORY/AURA

**1,088 seconds** Duration of Christmas 2010 gamma-ray burst

**48 seconds** Median duration of long gamma-ray bursts detected by Swift

# A mysterious burst in the universe

## Gamma-ray excess may have come from collision or merger

**By Nadia Drake**

The unusually bright and long-lived gamma-ray burst that appeared in the skies on December 25, 2010, is an enigmatic holiday gift that isn't quite unwrapped yet.

A year later, scientists trying to catch the culprit behind the perplexing explosion detected by NASA's Swift satellite have arrived at two completely different answers, both presented in the Dec. 1 *Nature*. One theory involves a small object, such as an asteroid or comet, passing too close to a neutron star and going out in a gamma blaze of glory. The other theory suggests that a stellar merger followed by a dim supernova explosion delivered the bizarre Christmas burst.

**A neutron star merging with its companion (shown) may have triggered an unusual gamma-ray burst seen in 2010.**

AURORE SIMONNET, NASA, SONOMA STATE UNIV.

Christina Thöne, an astronomer at the Astrophysical Institute of Andalucía in Granada, Spain, says she and her colleagues considered "all kinds of weird theories" before settling on the stellar merger scenario. In that version, a neutron star slowly spirals in toward a massive helium star, eventually colliding and producing a cataclysmic explosion of gamma rays. Then, a faint supernova goes off roughly 10 days later, an event that could explain anomalies in the Christmas gamma-ray burst's fading light.

The second theory also required some creative thinking. Calculations by Sergio Campana, an astrophysicist at Italy's Brera Astronomical Observatory in Merate, and his team suggest that if an object half the mass of the dwarf planet Ceres were shredded by a neutron star, it would produce enough debris to trigger a prolonged gamma-ray expulsion.

Of course, the burst could still be the product of an even more exotic event, says astrophysicist Enrico Ramirez-Ruiz of the University of California, Santa Cruz. "I think this object is unique enough that it could certainly be attributed to something we haven't thought of."


# Life

For more Life stories, visit **www.sciencenews.org**

## African lungfish walk in water

### Study suggests four-legged locomotion began at sea

**By Nick Bascom**

African lungfish walk and bound along the bottoms of water tanks on their slender, whiplike pelvic fins, a new study finds.

Lungfish are closely related to some of the earliest four-legged terrestrial vertebrates, or tetrapods. The findings suggest that these transitional creatures learned to scuttle across the floors of ancient seas before they took to land and developed more complex limbs with digits, biologist Heather King and colleagues at the University of Chicago suggest online December 12 in the *Proceedings of the National Academy of Sciences*.

"The cool thing about the lungfish is that it's walking underwater," says King. "And if lots of tetrapods were also doing this, it could mean that the first step in the evolution of vertebrate walking took place underwater."

Around 400 million years ago, certain species of bony fish — called the lobe-finned fishes for their muscular, fleshy fins — began to evolve features such as larger limbs with digits, which allowed them to move onto land. "We have a whole series of fossils that show this transition from lobe-finned fishes to tetrapods," says King. Until now, however, scientists didn't have a clear idea of the order in which these features emerged.

"The fossil record has limitations," says study coauthor Neil Shubin. "Living organisms are far weirder than you can imagine, and the more you look the more you find."

To get a closer look at one of the last living species of lobe-finned fish, the research team plopped African lungfish of the species *Protopterus annectans* one at a time into a tank with a plastic mesh bottom and trained several cameras on them. From various angles, the scientists captured video of the lungfish ambling and leaping using their pelvic fins.

"If you asked me to tell you what those fins do just by looking at them, I'd give you a thousand functions, and walking wouldn't be one of them," says Shubin. "But that's what they do."

Watching the strange aquatic critters hop and hobble may be the best way to study this important transition in the history of vertebrate locomotion.

"We're really beginning to see the sequence in which tetrapod gaits came about," says Shubin. "And we're seeing that they came about underwater."

Shubin sees the aquatic environment as an important testing ground for vertebrate locomotion. "Water is unconstrained," he says. "Gravity is not as limiting, so you can get by with a variety of motor styles." The extra buoyancy of primitive lungs, which probably evolved from the air bladders found in fish, may have helped get these early transitional organisms on the move, too.

"It seems possible that tetrapod walking would begin with underwater walking in lobe-finned fish," says evolutionary biologist Per Ahlberg of Uppsala University in Sweden. Though he has no criticism of the actual study of African lungfish and what they do, he disputes the paper's claim that some of the fossil tracks traditionally attributed to early tetrapods might have been generated by lobe-finned fish learning how to stroll.

"There would be a lot of body drag evident, and finprints wouldn't look like footprints," he says. "But underwater walking in fish has been well documented." ■

© TIM LAMAN

## Apes' boom-bust diet

The near-vegan lifestyle of wild orangutans in Borneo's forests means the apes face recurring protein droughts severe enough that their body tissues start to waste away. The forests of Borneo, one of only two natural habitats for wild orangutans, produce abundant fruit only about every five years. In bad years, the animals make do with leaves and bark. During such tough times, the apes average only about 1.4 grams of protein per kilogram of body mass per day, a tenth of what mountain gorillas consume, Nathaniel Dominy of Dartmouth College and his colleagues report online December 14 in *Biology Letters*. Knowing these protein budgets is important for understanding how orangutans have adapted to survive in places with resources that fluctuate so extremely, says Mark E. Harrison of the University of Leicester in England, who also has studied orangutan feeding ecology. —*Susan Milius*

"Bird remains in a cat's guts don't mean that it was hunting and catching birds in trees." —JERRY D. HARRIS

# Mere fear shrinks bird families

## Sounds of predators caused sparrows to raise fewer babies

**By Susan Milius**

Nothing to fear but fear itself can actually be dangerous for nesting birds.

Song sparrows protected from attack but subjected to recordings of predator yowls and leaf-crunching noises raised 40 percent fewer offspring in a year compared with neighbors hearing innocuous broadcasts, says population ecologist Liana Zanette of the University of Western Ontario in Canada. Predators do not need to kill a single creature to have a big effect, she says.

**Predator sounds spook song sparrow parents so much that they slack off in feeding their nestlings.**

Scary noises, broadcast where the sparrows nested in the wild, took a toll throughout the breeding season, Zanette and her colleagues report December 9 in *Science*. The alarmed sparrows laid fewer eggs to begin with, and the parents proved so skittish and cautious that they reared a smaller percentage of hatchlings than neighbors did.

Biologists have tended to focus on the direct effects of predators killing prey, says evolutionary ecologist Thomas Martin of the U.S. Geological Survey in Missoula, Mont., who was not part of the sparrow research. This new study, he says, suggests theorists have underestimated the impact of predators.

"Predators shape everything," Zanette says. Wolves that eat elk give more plants a chance to survive, which in turn changes which other creatures thrive.

Previous work, including Zanette's, suggested that fear of predators could affect the number or size of eggs birds lay. Yet separating the effects of fear from those of actual predator attacks took years of preparation, she says.

Working on small, uninhabited islands off the western coast of Canada, Zanette and her colleagues set out cameras to identify which predators were feasting on the vulnerable, open-cup nests of song sparrows there. Researchers then devised obstacles to those predators, fencing 24 nest sites to keep away raccoons and building little teepees swathed in netting to keep out ravens and owls while allowing tiny sparrows to dart through.

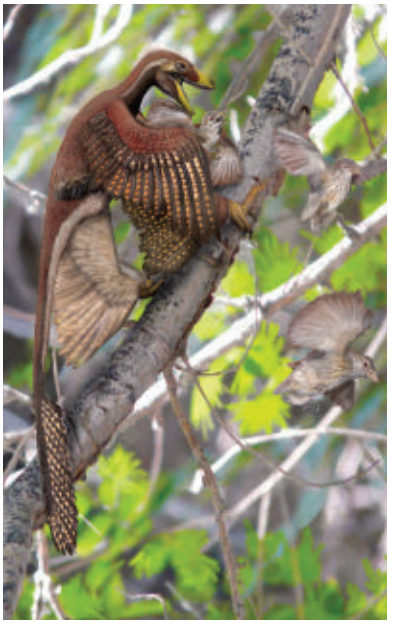
For half the birds, researchers played recordings of some predator sound every few minutes in random order around the clock for four days at a time, allowing four-day sound vacations between broadcast stints to keep sparrows from getting used to the recordings. The sounds stretched over a whole breeding season of raising two batches of young per family. The other half of the sparrows heard unalarming broadcasts, such as recorded goose honks and loon wails.

Before this, no one had tracked effects of predator sounds during an entire bird breeding season, Martin says. And, he adds, the study neatly isolates the effects of predator risk.

What ornithologist Sönke Eggers of the University of Agricultural Sciences in Uppsala, Sweden, would like to know now is whether those chicks lost to indirect effects would have been eaten anyway in the real world.

Zanette predicts that fear does take a toll on real-world nests beyond direct attacks from predators. A predator's noises can scare every little bird within earshot even when the predator doesn't catch them all. ■

FROM LEFT: COURTESY OF L. ZANETTE; BRIAN CHOO



# Feathered dino feasted on birds

A fossil *Microraptor gui* from northeastern China—still a dinosaur despite winglike feathers on all four limbs—has bird bones in its abdomen, report Jingmai O'Connor and her colleagues at the Chinese Academy of Sciences in Beijing. The position of the bird feet and partial wing suggest the dinosaur swallowed a now-extinct, tree-perching bird whole, the researchers contend in the Dec. 6 *Proceedings of the National Academy of Sciences*. They propose that *Microraptor* (shown dining in illustration above) frequented trees and hunted deftly enough to snag what was probably an adult bird.

Possible, but not the only possibility, cautions paleontologist Jerry D. Harris of Dixie State College in St. George, Utah. Structure analyses of *Microraptor* and its relatives suggest ground-based hunting. Today's cats certainly get into trees, and perching birds visit the ground, Harris says, but "bird remains in a cat's guts don't mean that it was hunting and catching birds in trees." —*Susan Milius*

# Humans

For more Humans stories, visit **www.sciencenews.org**

## Tools make early Arabia-Africa link

### Artifacts suggest Red Sea crossings 106,000 years ago

**By Bruce Bower**

Culturally speaking, ancient East Africans were a stone's throw away from southern Arabia.

Stone tools collected at several sites along a plateau in Oman and dated to roughly 106,000 years ago match elongated cutting implements previously found at East African sites from around the same time, say archaeologist Jeffrey Rose of the University of Birmingham, England, and his colleagues. New finds also include cores — or rocks from which tools were pounded off with a hammer stone — that correspond to East African specimens, the researchers report online November 30 in *PLoS ONE*.

East African sites that have yielded these distinctive stone artifacts extend southward along the Nile River to the Horn of Africa.

"In the mountain of papers speculating about human dispersal out of Africa, a link between southern Arabia and the Nile Valley has never been considered," Rose says.

Either Africans crossed the Red Sea and trekked into southern Arabia well before an African exodus around 60,000 years ago, or ancient people from Arabia influenced African toolmaking, the scientists suggest.

"The finds in Oman are rather spectacular," comments archaeologist Michael Petraglia of the University of Oxford in England. "They have a date that is earlier than similar African artifacts, which could imply a migration back to Africa or at least a flow between African and Arabian populations."

Although human fossils haven't turned up at the Arabian location or at related African tool sites, *Homo sapiens* bones date to as early as 195,000 years ago in East Africa.

It's unclear whether toolmakers in ancient Oman continued eastward to South Asia or stayed put. Their distinctive toolmaking style doesn't appear at Indian sites dating to around 74,000 years ago, Petraglia says.

Rose sees similarities between the Oman tools and 50,000-year-old stone implements previously excavated in and around modern-day Israel. He speculates that plentiful rainfall between 60,000 and 50,000 years ago made inner parts of Arabia habitable and enabled people in southern Arabia to spread northward and influence toolmaking techniques.

The new discoveries in Oman add to evidence that people reached Arabia's east coast as early as 125,000 years ago and a northern inland area by 75,000 years ago.

> "The story of migration and survival ... is much more complex than we have imagined."
> MICHAEL PETRAGLIA

At least two culturally distinct human groups inhabited Stone Age Arabia, Rose suspects: one in the south and another in the north and east. Intriguingly, DNA studies indicate that people interbred with Neandertals soon after leaving Africa. An ice age between 75,000 and 50,000 years ago may have driven people and Neandertals into parts of Arabia that still had water sources, where interbreeding probably occurred, Rose hypothesizes.

The stone tools found in Oman display few similarities to those found at Arabia's two other early *H. sapiens* sites, in Petraglia's view. "This must mean that the story of migration and survival, and out-of-Africa dispersals, is much more complex than we have imagined," he says. ■

M. SMITH

## Old head gets mummy makeover

Officials at a British witchcraft museum have received an unusual heads-up. A preserved human noggin in their collection thought to be that of a medieval execution victim in Europe actually comes from an Egyptian mummy, say biological anthropologist Martin Smith of England's Bournemouth University and his colleagues. CT scans and microscopic and chemical analyses of the head (shown above) revealed Egyptian mummification techniques, including breaking of nasal bones to remove the brain, the researchers report online November 24 in *Archaeological and Anthropological Sciences*. Radiocarbon dating places the specimen at between 2,370 and 2,120 years old, during the heyday of Egypt's Ptolemaic Kingdom and well before medieval times. *—Bruce Bower*

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# Genes & Cells

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## Microbes sleep to evade detection

### Stressed bacteria can dodge screening tests by laying low

**By Janet Raloff**

Researchers think they now know why a particularly virulent form of *E. coli* that swept through northern Germany last May was so hard to trace: The germs responsible eluded detection by going into a self-induced deep sleep.

Two new studies show that when stressed, *E. coli* can turn off most signs of life. That's a problem for food-safety officials because their germ-screening techniques rely on germs reproducing to detect live bacteria.

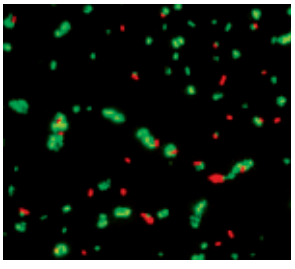
Scientists have watched dozens of kinds of bacteria enter a dormant state in the lab but don't know to what extent living germs do so in the environment or on foods, says microbiologist James Oliver of the University of North Carolina at Charlotte. And that, he says, points to the importance of the two new studies.

In one study, microbiologists at the Robert Koch Institute in Wernigerode, Germany, tested *E. coli* O104:H4 isolated from patients who fell ill in last year's massive food poisoning outbreak. O104:H4 germs don't ordinarily produce deadly toxins or bloody diarrhea. But this strain, which probably traveled and spread on tainted sprouts, did both, killing more than 50 people and sickening more than 3,700.

The scientists stressed the germs by exposing them to copper. Within a few days, many of the bacteria went dormant and stayed that way until the researchers removed copper from the germs' growth medium. Once resuscitated, the germs still had all of the features needed to be infective, Antje Flieger and her colleagues report in the December *Environmental Microbiology*.

To simulate what might happen in farm fields, microbiologists at Agriculture and Agri-Food Canada in Summerland, British Columbia, inoculated lettuce with either of two strains of *E. coli* O157:H7, a germ linked to deaths from eating tainted hamburger, lettuce and other types of produce.

Withholding the nutrients these bacteria would ordinarily acquire while passing through the gut caused the germs to enter hibernation. Within a few days, says study coauthor Susan Bach, more than half of the germs were still alive but could not be cultured. "We showed they remained active metabolically, but at a very low level," she says. Moreover, even in dormancy the cells were a source of toxin, the researchers report in the December *Applied and Environmental Microbiology*.



**Some of these *E. coli* cells found on lettuce are dead (red), but most are in a dormant state (green) that makes them hard to detect.**

One limitation of the new *E. coli* studies: Neither proved that once resuscitated, the germs would still induce disease. But that's certainly the expectation, Oliver says. His team has shown that *Vibrio* bacteria that frequently taint shellfish are still infectious — and lethal — after resuscitation from a chill-induced hibernation.

## DNA to flutter by

Scientists have deciphered the complete genetic instruction book of monarch butterflies. It is the first butterfly genome completed and the first of a long-distance migrating insect. Steven Reppert of the University of Massachusetts Medical School in Worcester and his colleagues found genes that may help the insects sense the sun's position and navigate to forests in Mexico where they spend the winter. Reporting in the Nov. 23 *Cell*, the team also notes that, when in migration mode, monarchs make more of certain small genetic molecules, called microRNAs, that are involved in building muscle, regulating temperature sensitivity and storing fat. The 273 million DNA units that make up the monarch genome also include a complete set of genes for producing juvenile hormone, which summer butterflies use to kick-start reproduction. Migrating males use different strategies than females do to turn off the hormone, the team discovered. —*Tina Hesman Saey*

FROM TOP: C. HARLTON AND M. WEIS/AGR. AND AGRI-FOOD CANADA; OGPHOTO/ISTOCKPHOTO

"It's as if, in the naked mole rat, acid is acting like a local anesthetic." —GARY LEWIN

# How mole rats shrug off burn

## Research suggests why acid doesn't hurt digging rodents

By Tina Hesman Saey

When life gives naked mole rats lemons, the wrinkled, bucktoothed rodents probably don't care. They are impervious to the sting of acid.

Now scientists in Berlin are onto the secret of the social rodents' insensitivity to acid. Naked mole rats' acid sensors work just fine. But a protein responsible for relaying messages about acid's presence to the nervous system is easily blocked by the same positively charged hydrogen ions that lend substances acidity, researchers report in the Dec. 16 *Science*.

Mole rats live in large social groups in burrows underground. The crowded, confined conditions cause carbon dioxide levels to rise to a concentration that would cause a person to pass out within five to 10 minutes. High carbon dioxide and low oxygen levels make body tissues acidic, something that is very painful for nearly all mammals. If mole rats had not evolved a way to ignore acid, the little rodents would be in constant agony, says Gary Lewin of the Max Delbrück Center for Molecular Medicine in Berlin, who led the new research with postdoctoral researcher Ewan St. John Smith.

Most researchers thought the rats' acid insensitivity probably stemmed from a lack of functional acid sensors in pain nerves, says Harold Zakon, a neurobiologist at the University of Texas at Austin.

But naked mole rats have fully functional acid sensors. "To our great surprise they are all there and are even more active and easily opened" than similar acid sensors in mice, he says. "That left us in a bit of a puzzle."

Usually when sensors detect acid or other substances, nerve cells change their electrical properties, then fire off an electrical message to the rest of the nervous system. The pain nerves in naked mole rats change their electrical properties but never send the message, the researchers found.

**Naked mole rats can withstand acidic environments because of the way the animals relay pain signals to the brain.**

© MAX DELBRÜCK CENTER FOR MOLECULAR MEDICINE

"It's as if, in the naked mole rat, acid is acting like a local anesthetic," Lewin says.

The team traced the missing message to a protein called a sodium channel in the pain nerves. Naked mole rats have a slightly different version of the sodium channel — named Nav1.7 in most mammals and SCN9A in humans — than most other mammals, except for cave-dwelling microbats, which also live in chemically challenging environments.

The mole rats and bats have three amino acids near the hole of the doughnut-shaped sodium channel that are negatively charged. Those amino acids apparently attract hole-blocking hydrogen ions more strongly than the amino acids found in the human and mouse versions of the protein. When the researchers engineered human cells with the naked mole rat version of the sodium channel, the human cells reacted like the mole rat cells do.

If researchers can figure out how to block the same part of the sodium channel in humans, the result could be a painkiller that takes away pain but doesn't make people groggy the way many analgesics do now, says Geoffrey Woods, a clinical geneticist at the University of Cambridge in England.

## NEWS BRIEFS

### Nano eavesdropping

Scientists have eavesdropped on the electrical missives of budding chicken heart cells using a minimicrophone made of a silicon nanowire and a silicon dioxide nanotube. The nanotube penetrates the cell, forming a tight seal between the cell membrane and the device, Harvard scientists report online December 18 in *Nature Nanotechnology*. The devices might be a good replacement for larger, clunkier patch clamps in use today. —*Rachel Ehrenberg*

### Magnetic bacteria

A newly discovered type of bacteria makes two types of magnetic particles, one made of an iron and oxygen compound called magnetite and the other an iron and sulfur compound called greigite, a team of researchers reports in the Dec. 23 *Science*. It was thought that magnetic microbes could produce only one type of magnetic particle. The new bacteria can switch production depending upon the amount of oxygen and sulfur in the environment, the team found. —*Tina Hesman Saey*

### Breast cancer's travel agent

Breast cancer tumors preparing to spread to the lungs send out an advance party of stem cells to make conditions in the foreign locale more hospitable. The cancer stem cells that reach the lung turn on production of a protein called periostin, Joerg Huelsken of the École Polytechnique Fédérale de Lausanne in Switzerland and colleagues report online December 7 in *Nature*. Blocking periostin production could prevent breast cancer's spread. —*Tina Hesman Saey*

**$38.51** Closing price of Citigroup stock on November 1, 2007

**$33.41** Closing price of Citigroup stock on November 7, 2007

# Uninformed may help democracy

## Indifferent individuals can help foster majority rule

**By Susan Milius**

Odd as it sounds, adding some wishy-washy members to a group can wrest control from a strongly opinionated minority and make collective decisions more democratic.

At least that's what happened in an experiment with schooling fish and three kinds of computer simulations described in the Dec. 16 *Science*. The study "supports a growing body of evidence that larger groups are better decision makers than smaller groups," says applied mathematician David Sumpter at Uppsala University in Sweden, who studies collective behavior.

The fish study grew out of computer simulations by Iain Couzin of Princeton University demonstrating the considerable power of opinionated minorities in otherwise indifferent groups, flocks or herds. When he mixed factions with different strengths of opinion in one simulation, as well as in two very different analyses of group behavior, he found peculiar effects of uninformed parties.

For an experimental test of the odd effects, study coauthor Christos Ioannou, now at the University of Bristol in England, worked with small freshwater fish called golden shiners, which have a very strong tendency to stick together in schools. Like other animals such as bees, these fish can learn to associate food with some colors (yellow for the fish) much more readily than with other colors.

**Adding some wishy-washy members to a group can wrest control from an opinionated minority.**

Ioannou, who was kept in the dark about the predictions of the computer simulations, trained shiners to swim toward either yellow or blue marks in a tank for a treat. Even after the same training, those aimed toward yellow were more committed to their color. So these became the fish version of individuals with stronger opinions.

When the researchers mixed a minority (five) of these strongly yellow-seeking fish with a majority (six) of less passionate, blue-seeking fish, the whole group swam toward the minority yellow mark in more than 80 percent of trials. When the researchers added five uninformed fish with no tendency to swim toward either mark, the whole group ended up at the minority yellow target only half the time. Adding another five untrained fish reduced the minority victories below 40 percent.

But human groups have significantly different dynamics than laboratory fish, says Carl Bergstrom of the University of Washington in Seattle. The fish are just influencing each other locally, he says, instead of proselytizing intensely and sharing information globally the way people do in modern democracies.

# Short spike suggestive of bear raid

## Trading data suggest 2007 effort to manipulate share price

**By Rachel Ehrenberg**

Two extraordinarily large trading days for Citigroup shares in the fall of 2007 hint that someone may have been manipulating the stock, say researchers from the New England Complex Systems Institute in Cambridge, Mass.

The analysts were examining stock trading data for the period January 2007 to January 2009 when they noticed two unusually large spikes in volume and other measures related to Citigroup shares. On November 1, 2007, the team noted, the number of borrowed Citigroup shares jumped by 100 million, reaching a value of $6 billion. Six days later, a similar number of borrowed shares were returned on a single day, the team reports online December 14 at arXiv.org. The estimated gain for investors who made the transactions was at least $640 million.

Such extreme events would be expected only once in a few hundred years, says Yaneer Bar-Yam, coauthor of the work. The likelihood of seeing those events six days apart is once in 4 billion years, the researchers' calculations show. This suggests to Bar-Yam and his colleagues that the stock was being manipulated to artificially drive down Citigroup's stock price.

The researchers were investigating short selling, whereby an investor borrows shares and sells them immediately, with the promise to buy them back at a later date to repay the loan. If the stock's price drops between the transactions, the borrower will make a profit.

Selling short can benefit the market by providing a check on overvalued stocks. But traders can also conspire to sell short with the intent of forcing a stock price down artificially. Such a move, known as a bear raid, is considered market manipulation.

Other researchers aren't so certain that manipulation was at play. The analysis is an interesting case study, says financial economist Ekkehart Boehmer of the EDHEC Business School in Nice, France. But if the Citigroup trades were truly manipulative, the price should have gone back up after the deal was done.

It didn't. Citigroup's price kept falling. In fact, Boehmer says the traders would have made 10 times the money by waiting another two months to sell.

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# Software Scientist

## With a little data, Eureqa generates fundamental laws of nature

By Rachel Ehrenberg

Games such as chess have long been mastered by thinking machines. But weightier intellectual feats, such as deducing the laws of nature, have remained the domain of living, breathing brainiacs — until now.

A new computer program called Eureqa comes up with fundamental mathematical laws, the great equations of textbooks and history, from scratch. Feed Eureqa a mess of raw data, and it will find the underlying rules describing the observations.

Consider the laws of motion and conservation of energy. Eureqa's creators, Cornell engineer and computer scientist Hod Lipson and then–graduate student Michael Schmidt, used a motion-tracking camera to capture the chaotic swings of two pendulums linked together. After measuring the pendulums' angles and velocities, the researchers fed the numbers to Eureqa. Without any knowledge of geometry or physics, the program came up with Newton's second law of motion and other equations governing the double pendulum's behavior.

Now Eureqa is analyzing even messier systems, those involving living things. Eureqa has figured out a set of seven known equations describing how the amounts of chemical compounds and enzymes fluctuate rhythmically in yeast cells deprived of oxygen, Lipson, Schmidt and colleagues reported in the October *Physical Biology*.

The yeast project came about after Lipson appealed to other scientists to give him projects for Eureqa to tackle. He wanted to show that a range of scientific disciplines can benefit from the program, ultimately demonstrating Eureqa's potential to uncover nature's basic rules rather than just re-create them. "It's not an artificial intelligence thing that someday will do something," Lipson says. "It can be applied to real problems."

### Evolution embracer

John Wikswo of Vanderbilt University in Nashville and Jerry Jenkins of the HudsonAlpha Institute for Biotechnology in Huntsville, Ala., had a good test for Eureqa. They gave Lipson the seven equations that describe yeast's glucose metabolism, but for all the Cornell scientists knew, the math could have represented the movements of celestial bodies. Lipson and Schmidt generated a data set from the equations and added a healthy dose of random error, a realistic bit of messiness that would be found in ordinary experimental data.

Eureqa took the information and started bumbling through equation space, creating and assessing different ways to describe the yeast results mathematically. Once it was done with the task, Lipson met with Wikswo and Jenkins at Vanderbilt, projecting the equations Eureqa had come up with onto a conference-room screen.

Jenkins was on the lookout for one mathematical term in particular that relates to how quantities of a certain molecule limit the transport of sugar in the cell. "That was the first thing I was looking for, since it is very difficult to estimate in practice," he says. "They had nailed it."

Part of what makes Eureqa so impressive is that the program assesses dynamic systems, which change over time and have parts that often change together. There are very clever "thinking machines" in existence today, such as Watson, the IBM computer that conquered *Jeopardy!* last year. But next to Eureqa, Watson is merely a glorified search engine.

"It's a tour de force," says David Waltz, director of the Center for Computational Learning Systems at Columbia University. What Eureqa does "is vastly more complicated than anything out there."

For all of its cold, hard computing power, Eureqa is surprisingly biological, embracing the random, stupid beauty of evolution. A key component of the program's power is replication with variation, an idea borrowed from life that has become popular among scientists using machine learning and artificial intelligence to solve all sorts of problems.

Say you feed Eureqa a spreadsheet. It may have 10 data points, or hundreds of thousands. You choose some mathematical operations, such as add, subtract, multiply or divide. (There's a default set of operations if you don't want to pick your own.) Then Eureqa looks at a chunk of the data and starts throwing together mathematical building blocks into equations.

LAPTOP: ANDERSPHOTO/SHUTTERSTOCK; SCREEN IMAGE: VLADGRIN/SHUTTERSTOCK

"You get a lot of random equations," Schmidt says. "At first, they are really poor hypotheses. They are all junk."

But by comparing those equations with a data sample, Eureqa can discern that some of the equations are ever so slightly less junky than others. Those slightly better equations are recombined: Terms are switched around and others are added, generating a new population of equations the way genetic material is recombined to make fresh versions of life.

As Eureqa comes up with new equations, it identifies and uses the data that will help it rule out bad equations most quickly. This process is repeated over and over again as Eureqa gets ever closer to equations that agree with observations. It can also request experiments that will generate helpful data, so some refer to Eureqa as a "robot scientist."

$$\frac{dS_1}{dt} = 2.5 - \frac{100*A_3S_1}{1+13.68*A_3^4}$$

$$\frac{dS_1}{dt} = 2.53 - \frac{98.79*A_3S_1}{1+12.66*A_3^4}$$

$$\frac{dS_2}{dt} = \frac{200*A_3S_1}{1+13.68*A_3^4} - 6*S_2 - 6*S_2N_2$$

$$\frac{dS_2}{dt} = \frac{200.23*A_3S_1}{1+13.80*A_3^4} - 6.87*S_2 - 6.87*N_2 + 0.95$$

$$\frac{dS_3}{dt} = 6*S_2 - 6*N_2S_2 - 64*S_3 + 16*A_3S_3$$

$$\frac{dS_3}{dt} = 6.00*S_2 - 6.00*N_2S_2 - 64.16*S_3 + 16.08*A_3S_3$$

Original equations

Eureqa-generated equations

**Yeast laws redone** After being fed data on yeast glucose metabolism, Eureqa reproduced the seven known equations that govern the process (three shown above). Notice that the formulas generally take the same form, for the most part differing only in their numerical constants.

SOURCE: M.D. SCHMIDT *ET AL*/*PHYSICAL BIOLOGY* 2011

### Cross-disciplinary queries

Lipson and Schmidt published the yeast and pendulum work, but Eureqa has many more papers with many different authors to its name. The program is openly available online and has been downloaded more than 25,000 times. In November Schmidt brought the program to the cloud, that computer in the sky that takes advantage of servers across the country to crunch data in moments rather than the hours it might take on a home machine.

Physicists have used Eureqa's brainpower to improve the resolution of their particle accelerators, while other scientists are evaluating speech recognition programs. Users have also queried Eureqa regarding stock market data, the growth of plant hairs and aircraft tire dynamics. One user is apparently feeding Eureqa information about his daily life, such as how many e-mails he receives, with the hope that the program will be able to mathematically discern happy days from sad ones.

By one yardstick, Eureqa has even discovered the answer to the ultimate question of life, the universe and everything, a problem tackled by the fictional computer Deep Thought in Douglas Adams' *The Hitchhiker's Guide to the Galaxy*. As part of the pendulum problem, Lipson and Schmidt were trying to ask Eureqa what in the system wasn't changing.

"Science is about finding the laws despite the complexity around us," says Lipson. "We want to know what, in the apparent chaos, is always constant."

Plenty of things don't change in a given experimental setup, such as the temperature of the room or the color of the walls, but the researchers were looking for meaningful invariance. In an early round, Eureqa failed to get the point. The way Lipson tells the story, the program replied to the invariance question with the same answer Deep Thought gave for the meaning of everything: 42.

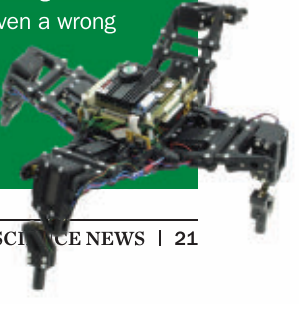
Among all that Eureqa has tackled, its truest tests are those that involve coming up with meaningful unknowns. Gurol Suel, a biologist at the University of Texas Southwestern Medical Center at Dallas, fed Eureqa data on the genetics of cell division and growth of a particular bacterium. While Suel came up with his own possible equation to describe the system, Eureqa found an even simpler one. Scientists are now trying to figure out what Eureqa's equation really means. ■

### Explore more

■ For more on Eureqa, visit: creativemachines.cornell.edu/eureqa

## Rules of self

Before designing Eureqa, a computer program that can come up with rules about the outside world, Cornell's Hod Lipson was focused on introspective robots. He and then–graduate student Victor Zykov, along with Josh Bongard of the University of Vermont, created a four-legged robot and tasked it with learning to walk. The robot (shown) didn't know what its own body looked like—whether it had four, eighteen or no legs, nor how those legs were arranged. But by interacting with the environment, the robot generated hypothetical models of itself and then carried out actions that would test those models. The more the robot learned, the more directed its actions became. By the 16th trial, the machine figured out it had four legs and how to lurch forward. "Even a wrong model is good because it can allow you to make decisions in the right direction," says Lipson, who has five Roomba vacuuming robots at home. —*Rachel Ehrenberg*

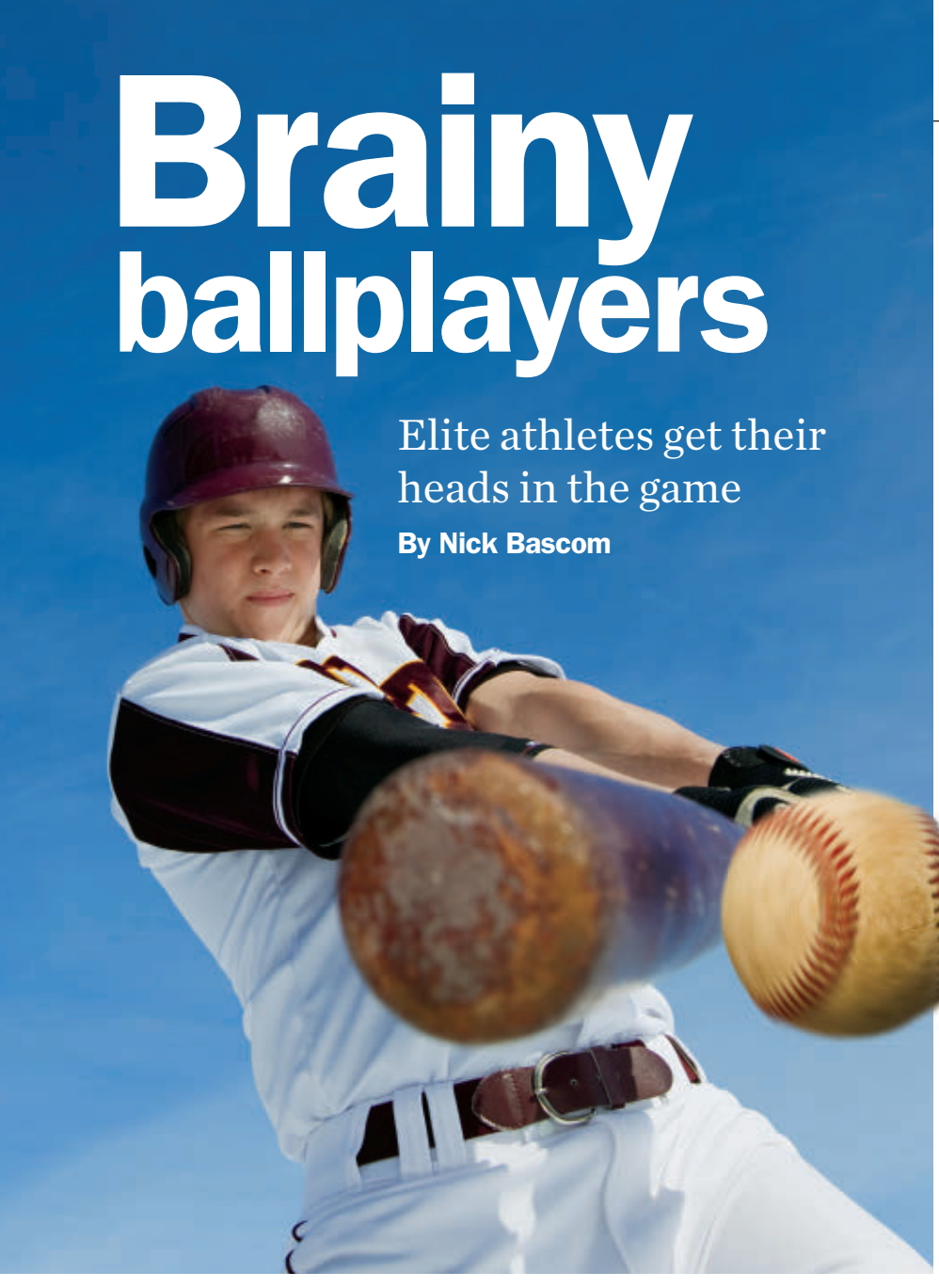


J. BONGARD, V. ZYKOV, H. LIPSON/CORNELL UNIV.

# Brainy ballplayers

## Elite athletes get their heads in the game

**By Nick Bascom**



Superstar athletes are revered for their physical prowess, not for what goes on between their ears. And most postgame interviews do little to challenge the notion that athletes have more brawn than brains.

But brainpower has a vital role in elite sports performance, recent research shows.

"Brawn plays a part, but there's a whole lot more to it than that," says John Milton, a neuroscientist at the Claremont Colleges in California.

Whether on the court, field or course, the body depends on the brain for direction. But the brain is a busy taskmaster, with duties beyond guiding motion, making it difficult to focus on that particular job. Like chess masters and virtuoso musicians, superior athletes are better than novices at turning on just the parts of the brain relevant to the desired task, Milton's work reveals. "In professionals, the overall brain activation is much lower, but certain connections are enhanced," he says. In other words, experts employ only the finely tuned neural regions that help enhance performance, without getting bogged down by extraneous information.

Elite athletes' ability to focus the brain might even explain their struggle to eloquently describe performance after the game. Like a starship captain diverting power from life support to bolster shields in a battle, professional athletes temporarily shut down the memory-forming regions of the brain so as to maximize activity in centers that guide movement.

"That's why they usually thank God or their moms," says cognitive psychologist Sian Beilock of the University of Chicago. "They don't know what they did, so they don't know what else to say."

It's not stupidity; it's selectivity. And in the last few years scientists have been able to visually capture this concentrated, purposeful neural concert that takes place in the expert athlete's brain. But even these vibrant brain scans reveal only part of the success story. Other recent studies demonstrate how athletes' brains seamlessly interact with the muscular system to perfect and deploy movements — and how the athletic brain anticipates actions in advance and updates planned responses as needed.

By examining how such brain processes lead to excellence in sports, as well as what goes wrong when athletes blow it in the big game, scientists think they can enhance training techniques and improve performance under pressure.

### In the zone

Using functional MRI scans to monitor blood flow in the brain, Milton and his colleagues have identified the regions essential for expert-level motor skill: the superior parietal and premotor areas. These regions, two of the brain's motor centers, primarily move the body toward a visually perceived goal and direct complex motion. In brain scans of professional golfers planning a shot, these areas showed heightened activity, Milton and colleagues reported in 2007 in *NeuroImage*. In contrast, the study found that the brains of beginner golfers preparing a swing showed much more dispersed activity — especially pervasive in the basal ganglia and limbic system, regions of the brain that control emotions and make people consciously aware of their movements.

STEVE MC/BIGSTOCK

Such differences in brain activity reflect the players' different concerns. "The novices were worried about all kinds of things — wind, water and sand," Milton says. "The pro golfers just hit the ball."

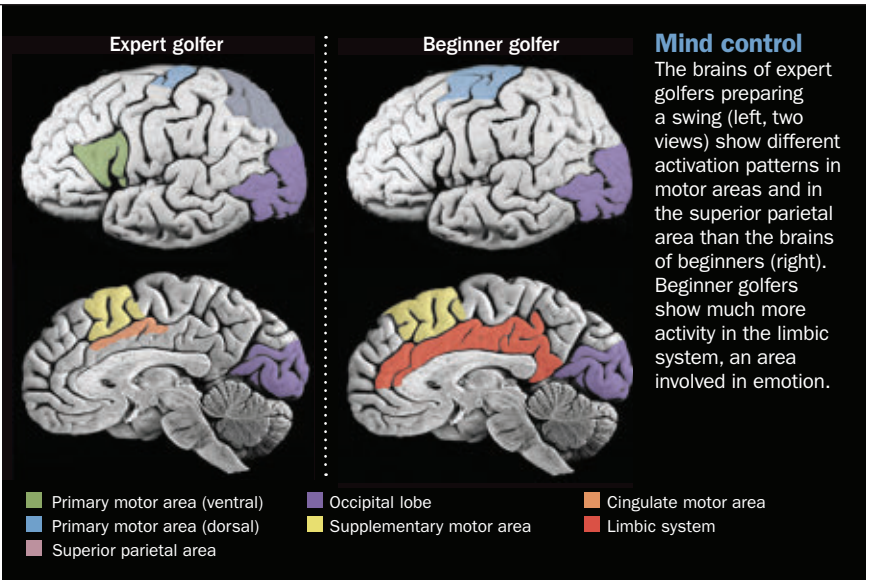
Yogi Berra once famously quipped that he couldn't "think and hit at the same time," and Milton believes that devoting too much conscious attention to swing mechanics could actually hurt performance, even among big leaguers. His research suggests that when professional golfers think too long about their shots, the athletes activate parts of their brains that they haven't used during golf since first learning the game, throwing finely tuned sensorimotor pathways out of whack. "This is because the expert's brain has already figured out the optimal solution, and anything they consciously change will disrupt that," Milton says.

The experience of "being in the zone" could simply be what happens when the brain regions making athletes conscious of their movements are finally quieted and motor centers get free rein to guide the players to victory.

Such an ability to perform a complex motor task without thinking, also called automaticity, gives an athlete a big advantage in competition. But to access a complex movement subconsciously, the athlete must first rehearse the motion countless times in training, fully developing the nerve connections essential for expert muscle control. "Practice may not make perfect, but it makes permanent," Milton says.

How close an athlete can get to perfection through training may be driven by attributes a person is born with. "It depends on the way the neurons connect to the muscles, and that can't change," says Daniel Wolpert of the University of Cambridge in England.

The way the nervous system interacts with the musculoskeletal system isn't flawless. Transmission errors along the way serve as a sort of sensory static, or "noise," that prevents the muscles from hearing the message the brain is sending. Static can also disrupt messages that sensory organs such as the eyes and skin send to the brain, leaving an athlete with a distorted image of the state of the game.




**Mind control** The brains of expert golfers preparing a swing (left, two views) show different activation patterns in motor areas and in the superior parietal area than the brains of beginners (right). Beginner golfers show much more activity in the limbic system, an area involved in emotion.

J.G. MILTON, S.L. SMALL AND A. SOLODKIN, ADAPTED BY JANEL KILEY

Players with less noise gumming up their sensorimotor systems are predisposed to athletic glory. With fewer disruptions, these athletes are able to elicit strong, fast muscle contractions that are incredibly accurate, cheating what scientists call the speed-accuracy, or energy-accuracy, trade-off. Unlike most people, expert athletes don't have to slow down to improve their execution.

A lucky few are granted this genetic head start, but anyone can "train muscles and refine a way of moving that reduces the bad consequences of the noise that's already there," Wolpert says.

So training is not only about building bulk to overpower an opponent, but also about teaching more nerve and muscle fibers to work in unison to hone one's movements. Scientists think brain cells known as mirror neurons may help.

## The value of reflection

When a person watches someone else performing an action, the same neurons that would fire if the observer were replicating that action become active — even if that observer is standing completely still. This neural activity is the brain's way of simulating the motion being witnessed, and can help an athlete reproduce those movements. Mirror neurons thus provide "a system for matching what you do with what you see others doing," says Salvatore Aglioti of Sapienza University of Rome.

The mirror system may also mediate another important function in the athlete's brain — anticipation. If mirror neurons are already simulating the motions of an opponent, an observing athlete might use information from those neurons to chart out the full course of the adversary's motion. In sports where time is of the essence, the ability to predict a movement offers a major leg up.

Based on his knowledge of the mirror system, Aglioti hypothesized that athletes focus attention not solely on the ball, for example, but also on their opponents' bodies to gain clues that will help in deciding whether to expend energy on a certain response. He studied how well expert basketball players, novices and expert watchers including coaches gauged the result of a free throw based solely on time-lapse photographs depicting various stages of another player's shooting motion, reporting the findings in 2008 in *Nature Neuroscience*. "Compared to novices and scouts, elite athletes were better at predicting the outcome of a shot after watching the body motion of basketball players," Aglioti says.

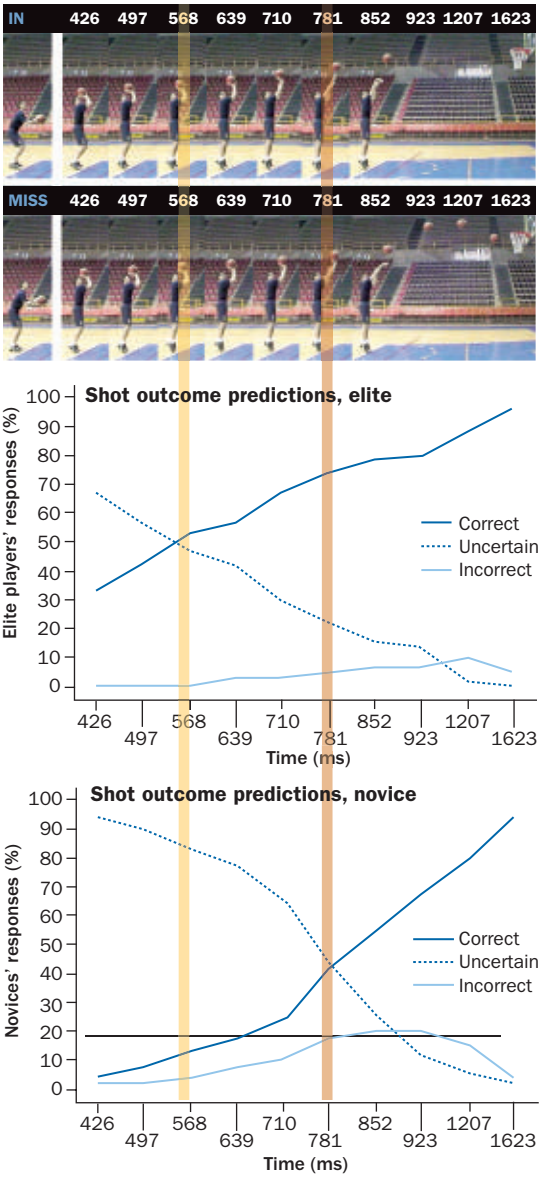
Expert cricket batters also appear to gain important information from the physical details of an opponent's throwing motion, suggests a team of Australian researchers. After showing study participants sequential photographs of a bowler in motion, the scientists found that elite batters' ability to predict the

final location of a ball in flight was impaired when the researchers blocked out the arm or hand of the hurling bowler. Novices were equally bad at predicting where the ball was headed regardless of whether they could see the bowler's arm or hand.

What's more, anticipation abilities improved among expert batters when they were allowed to fully swing their bat while making a prediction, compared with predicting while standing still or while only completing the lower-body motion of a swing, the Australian team reported last year in *Acta Psychologica*. Novices' predictive ability did not improve when they picked up the bat, suggesting that success in sports is partly dependent on how effectively the brain couples the body's perceptive machinery to its motor processes.

Milton has suggested that athletes in all fast-ball sports — including baseball and tennis — anticipate where the ball is headed based on information derived from watching their opponents' movements. What helps separate elite members of these sports from novices is a superior ability to sort out the relevant from the irrelevant physical cues.

Of course, once the brain gets the message, the body still has to react appropriately.




**Early clue** Expert players (top graph) were better than novices (bottom graph) at predicting the outcome of a basketball shot from video clips (top). For experts, correct answers surpassed uncertain ones (yellow line) before the ball was released. Novices needed more time (orange line).

## A model plan for the future

In the heat of the game, athletes have to process the sensory data they're taking in to automatically deliver the best motor response. To save precious time while performing such calculations, the brain builds a virtual representation of the world so it can predict what might happen next, new research finds. Called "forward models," these mental maps allow athletes to preplan "what they want to accomplish and how they're going to accomplish it," says Emanuel Todorov of the University of Washington in Seattle.

The brain readies commonly repeated actions in the motor cortex just like a torpedo is loaded into a firing bay. But the response action can't fire until the command to act is given by the forward model. If an athlete's forward model is working well, it determines the best countermove quickly, reducing delays in the body's movement.

Because they provide reference data, previous experiences are essential for crafting forward models. For example, if tennis star Rafael Nadal hits the ball with heavy topspin towards Roger Federer, Federer's brain computes bounce heights from previous topspin shots to determine how high the ball will bounce, so he can prepare a swing well before the ball rebounds off the ground.

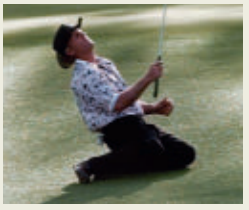
Forward models aren't set entirely in mental stone, however — a good thing, since rarely are multiple scenarios in sport exactly the same. The ball Nadal hits toward Federer might be slightly deflated or could glance off the baseline, causing the topspin shot to bounce lower than Federer would have predicted based solely on previous topspin shots. If Federer's forward model didn't make use of current sensory information to adjust predictions built on "priors" — the accumulated knowledge of all the topspin shots he has seen before — he wouldn't be able to react on the fly when something unexpected happens.

The brain's predictive machinery is constantly being updated with new sensory information as it executes a motion, a feedback loop that helps the body maintain control over its movement, Todorov says. "Given your goal, given where you currently are, the optimal feedback loop posits the best way to get there," he says.

Todorov and other scientists are finding that athletes' brains calibrate forward models in a manner consistent with Bayesian decision theory, a statistical approach that combines a continual stream of new information with previous beliefs. Because there is a level of uncertainty associated with sensory input, the brain has to decide whether it is going to rely more on the new data (which could be misleading) or on more credible (albeit potentially outdated) priors. Elite athletes, who have acquired more priors through frequent competition and practice and who have less noise in their sensory input and motor output, will have the edge, Todorov suggests.

S.M. AGLIOTI *ET AL./NATURE NEUROSCIENCE* 2008

**All choked up** Brain studies suggest famous choking incidents in sports (some highlighted below) may occur when athletes lose focus, allowing stress and other concerns to occupy their brains.



**Greg Norman, 1996**
For the first three rounds of the 1996 Masters Tournament, Australian golfer Greg Norman played spectacularly well. He tied the lowest opening round score ever at Augusta National in Georgia and was leading by six strokes heading into the final day of competition. But in the final round, the Shark suddenly lost his bite, shooting six over par to lose by five strokes.

**Jana Novotná, 1993**
After dropping the first set of the 1993 Wimbledon final in a tiebreak, Czech tennis player Jana Novotná started crushing her German opponent Steffi Graf. Novotná won the next set 6-1 and was serving to go up 5-1 in the pivotal third set. A double fault turned the tide. Novotná lost her service game and every game after that. Graf won the third set 6-4.

**Bill Buckner, 1986**
In game six of the 1986 World Series, the Boston Red Sox were up three games to two and tied with the New York Mets in the bottom of the 10th inning when Mets' speedster Mookie Wilson hit a slow roller to Red Sox first baseman Bill Buckner. Buckner let the routine ground ball run through his legs, allowing the Mets to score the winning run.

**Memphis Tigers, 2008**
With two minutes to go in the 2008 NCAA Men's Basketball Tournament, Memphis was leading Kansas by nine points. Down the stretch, Memphis All-Americans Derrick Rose (shown) and Chris Douglas-Roberts—who had collectively made their first six free throws of the game—made only one of their next five, allowing Kansas to tie the game and then win in overtime.

**Tony Romo, 2007**
In the first round of the NFL playoffs, the Dallas Cowboys were losing by a touchdown to the Seattle Seahawks late in the game. With one minute to go, the Cowboys scored, but when they went to kick the extra point, quarterback Tony Romo—also the team's placekick holder at the time—botched the snap, and the Cowboys lost by one.

FROM LEFT: PHIL SANDLIN/ASSOCIATED PRESS; BOB MARTIN/GETTY IMAGES; BOSTON GLOBE, GETTY IMAGES; MARK HUMPHREY/AP; CORBIS; JOHN FROSCHAUER/AP

## Buckling under pressure

Even the best athletes, though, don't always perform when the pressure is on.

"I don't rattle, kid," says Paul Newman, as Fast Eddie Felson, to another pool shark in *The Hustler*. Unfortunately for Eddie, this is true only when he heeds his own mantra and plays "fast and loose." When he starts to let self-doubt and other concerns slow him down, his pool cue stops feeling like it has nerves in it and the balls stop dropping.

Fast Eddie and real-world athletes might choke when it matters most because the stress of the situation or outside life seeps in, Beilock and colleagues reported in May in the *Journal of Experimental Psychology*. The team is investigating what happens in the brains of athletes who fail to perform to their potential when the stakes are highest.

"In these stressful situations, athletes become worried about the situation and its consequences, and these worries disrupt ability to allocate attention to where they need it," says Beilock.

Malfunctions of the prefrontal cortex, the center of the brain's reasoning, emotional control and focusing abilities, are primarily to blame, Beilock says. Stress prompts the prefrontal cortex to try to control information that should be left outside of conscious awareness, causing what she calls "paralysis by analysis."

Like Milton, Beilock studies golfers, and she has found that high levels of stress increase activation in the prefrontal cortex of experts, preventing scratch golfers from keeping their swings on autopilot. Such overanalyzing prevents the successful execution of fluid, habit-filled performances that should run automatically, she says.

When athletes think about mechanics too intensely, the pool cue, golf club or tennis racket can start to feel like a foreign and unwieldy instrument. Golfers prompted to weigh in on Tiger Woods' struggles following his personal problems and hiatus from playing in tournaments seemed to recognize the influence of thinking too much. Bubba Watson publicly suggested that Woods was too mental with his swing, saying Woods should drop his swing coach and "just go out there and play golf."

Though athletes can't avoid stressful situations altogether, being aware of the effect of stress on brain-body communication and coordination can help enhance training sessions, Beilock suggests. By putting players in high-stress, gamelike scenarios in practice, coaches can help athletes stay cool during competition.

And since the brain chemistry elicited by intense competition translates to other stressful situations, Beilock believes choke-prevention techniques derived from her sports research could also give college students an edge at exam time or help postgraduates ace a job interview.

Whether competing on the court or in the classroom, recent discoveries suggest that the key to living up to the potential you're born with is to train your brain well, and keep calm and focused. With such revelations as guidance, the coach of a faltering team might consider playing some En Vogue at halftime to get players in the right frame of mind. The '90s pop group said it best: "Free your mind, and the rest will follow." ■

## Explore more


■ S. Beilock. *Choke: What the Secrets of the Brain Reveal About Getting It Right When You Have To*. Free Press, 2010.

Researchers expect to achieve record-breaking pressures at the National Ignition Facility (target chamber shown).

# In a SQUEEZE

# Elements under pressure reveal secrets of extreme chemistry

**By Alexandra Witze**

Bruce Banner isn't the only scientist who could crush you with one mighty squeeze. These days, the Hulk's superhuman strength is matched by researchers who squish all kinds of stuff in superscience experiments.

The goal isn't to save the world from baddies, but to explore new frontiers in the nature of matter. After all, most material in the universe exists at bone-crushing pressures. Think massive stars and planetary cores — realms no comic book fan or other Earth dweller has ever seen.

Deep within the planet, rock experiences pressures more than 1 million times as great as the "1 atmosphere" that ordinary humans live under at sea level. Pressures at the centers of ultradense neutron stars are some trillion quadrillion times greater. Under such extreme conditions, atoms themselves begin to buckle.

To mimic these hellish realms, scientists are ramping up pressure in the lab, like the Hulk getting ever stronger as he gets madder. In the process, they're squeezing out some surprising insights.

One team has found a new kind of iron oxide, a compound that somehow had never been seen before, even though it contains two of the most common elements in Earth's crust. Another group argues that hydrogen's odd behavior at high pressures means that the cores of giant gas planets, such as Jupiter, are eroding in a slow hydrogen drip. Meanwhile scientists at the National Ignition Facility in Livermore, Calif., have squeezed diamond to record pressures, uncovering unexpected and exotic behaviors.

Chemistry, it seems, is a different beast under high pressure. "We're developing a whole new paradigm for understanding the nature of matter," says Russell Hemley, a chemist at the Carnegie Institution for Science in Washington, D.C.

## Hydrogen crush

The idea of squeezing materials to see what happens dates back at least to the 17th century, when British chemist Robert Boyle discovered that doubling the pressure on an ideal gas halved its volume. Around the same time, researchers at the Accademia del Cimento, a scientific society in Florence, Italy, were exploring whether liquids, too, could be compressed. The scientists filled a metal sphere with water and banged it with a hammer. Perhaps not surprisingly, the sphere leaked. But that experiment, Hemley says, set the stage for far more technologically adept investigations.

By the 20th century scientists knew that ordinary matter — be it solid, liquid or gas — behaves according to chemical rules laid out by its electrons, those negatively charged particles that buzz around atomic nuclei in well-defined regions known as orbitals. It turns out that squishing matter doesn't just compress its atoms so that they stack closer together, like a pile of well-arranged oranges at a farmers market. Compression also radically alters electron orbitals, in different ways depending on their original shapes.

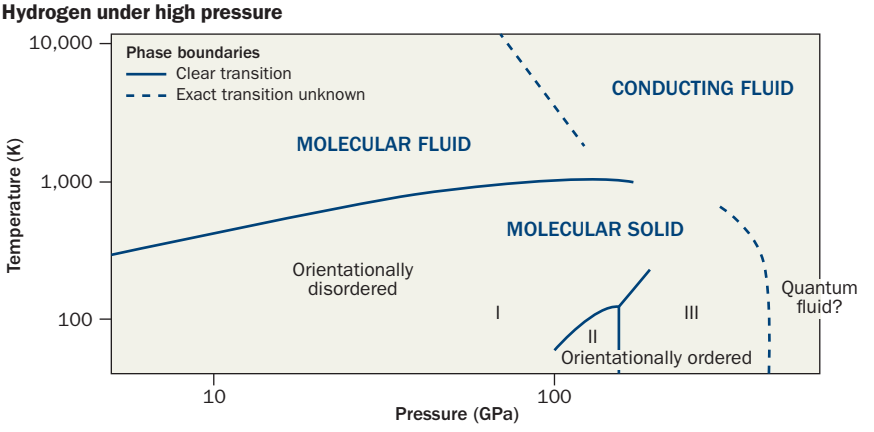
Suddenly electrons can zip around in places they haven't been before, and the rules typically governing the periodic table of the elements go out the window.

Perhaps the poster child for odd behavior at high pressures is hydrogen, the most common element in the universe. As the simplest element, with just one proton in its nucleus and one orbiting electron, hydrogen seems like it should behave in a straightforward way. But recent experiments have shown that, like Bruce Banner, it suffers from multiple personalities.

Most intriguing, scientists say, is the fact that if you squeeze hydrogen hard enough, this flighty gas transforms into a dense fluid whose electrons move in an ill-defined sea, allowing it to conduct electricity and behave as a metal. Understanding how two atoms linked as a gaseous $H_2$ molecule split and form single atoms flowing as a liquid could illuminate what happens to more complicated molecules under pressure, says physicist Alexander Goncharov of Carnegie. "Once we understand that simple system, others may become simpler," he says.

Goncharov, Hemley and many other scientists probe hydrogen and other materials by crushing them between two small diamonds in a machine known as a diamond anvil cell. The pointy ends of the cut diamonds narrow to a tiny tip where, when squeezed together, the pressure soars. In a small dent where the diamonds meet, an injected sample can be compressed to unfathomably high pressures.

**Simple element, many faces** Though hydrogen takes the form of a gas under normal conditions, at high temperatures and pressures (shown below) it behaves in surprising ways. In extreme cases, hydrogen's electrons flow in an ill-defined sea, conducting electricity like a metal.

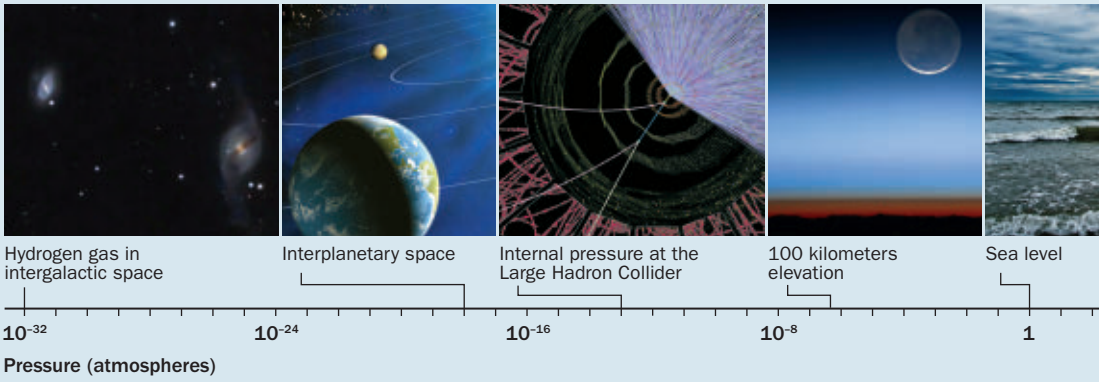



SOURCE: R.J. HEMLEY/*HIGH PRESSURE RESEARCH* 2010

FACING PAGE: LAWRENCE LIVERMORE NATIONAL LABORATORY; THIS PAGE: T. DUBÉ

## Within and out

Pressures in the cosmos span more than 60 orders of magnitude, from the near-vacuum of intergalactic space to the crushing force at the center of a neutron star.




Using such a device, scientists at the Max Planck Institute for Chemistry in Mainz, Germany, announced in *Nature Materials* in November that they had created metallic hydrogen at room temperature and pressures around 2.6 million times Earth's atmosphere (*SN: 12/17/11, p. 9*). If confirmed, the discovery would fulfill a long-sought goal; scientists first predicted the existence of metallic hydrogen in 1935.

But some experts are withholding judgment on the new work. It's one thing to squeeze materials at high pressures and see something unusual; it's another to establish conclusively what that unusual observation means. Several researchers say they have data that contradict the metallic hydrogen claim, but they do not want to discuss their work in detail until it appears in peer-reviewed journals.

The Max Planck group, led by Mikhail Eremets, is involved in another high-pressure disagreement. In a paper appearing in *Science* in 2008, Eremets' team, along with colleagues from the University of Saskatchewan in Canada, reported that a mix of silicon and hydrogen became superconducting at high pressures. This compound, known as silane, is made of one silicon atom bonded with four hydrogen atoms. As an industrial compound, silane is used as a coating agent, a water repellent and in other applications. But mash it in a diamond anvil cell, and at around 960,000 atmospheres it starts allowing electrons to flow freely, the researchers reported.

Not so fast, other scientists said. One challenge with studying hydrogen is that at high enough pressures and temperatures, it starts reacting with just about everything around it — even elements that are usually chemically inert. Theorists led by Duck Young Kim, now at Carnegie, have reported that hydrogen may hook up with famously unreactive platinum at pressures around 210,000 atmospheres. At higher pressures, 700,000 atmospheres or above, this newborn platinum hydride may even start to superconduct, shuttling electrons without resistance, the scientists wrote in September in *Physical Review Letters*.

Such a mix of platinum and hydrogen could explain the superconductivity reported in silane, an international team argued in August in *Physical Review B*. The team's calculations suggest that platinum hydride could form as the silane breaks apart into silicon and hydrogen — and that hydrogen reacts with platinum electrodes used in the experiment. One particular crystal form of platinum hydride, the scientists say, could explain the superconductivity supposedly observed.

Eremets' team stands by its work, but the experience underscores how complicated high-pressure science can be.

### Core compression

Despite the difficulties involved in working under extreme conditions in the lab, it is still the only way to figure out what's happening in many places in the universe, including the ground under people's feet. For geologists, high-pressure experimentation is about as close as they will ever get to a journey to the center of the Earth. And the latest high-pressure studies show how many surprises still lurk there.

Iron, for instance, is the fourth most abundant element in the Earth's crust and makes up nearly all of the planet's core. Yet researchers have only now discovered an entirely new iron compound; it contains four atoms of iron and five of oxygen and exists only at high pressure.

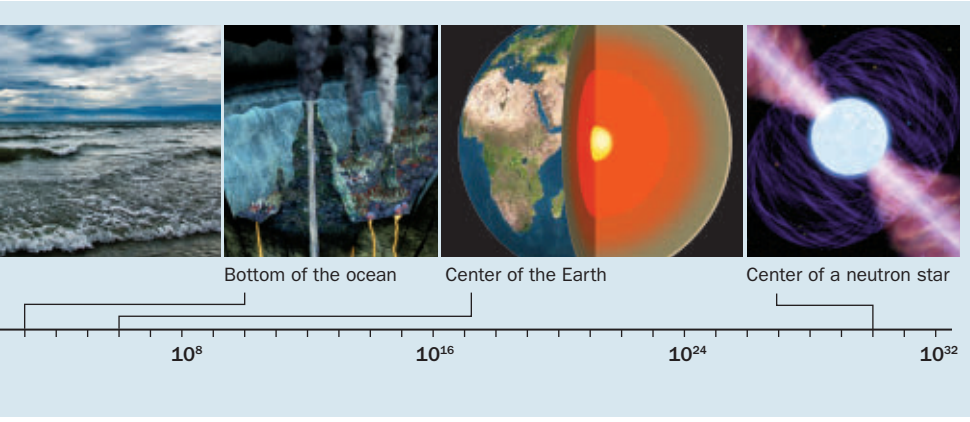
Barbara Lavina of the University of Nevada, Las Vegas and colleagues synthesized this compound in a diamond anvil cell by smooshing a different compound made of iron, carbon and oxygen. The compound began to break apart, and at about 100,000 atmospheres and 1,800 kelvins (1,500° Celsius) a new type of crystal appeared.

Other iron oxides are common in nature, but this was the first time this particular chemical combination had been seen. "It was thrilling for me just to write the formula $Fe_4O_5$," says Lavina, whose report appeared October 18 in the *Proceedings of the National Academy of Sciences*.

Understanding the details of how iron and oxygen atoms bond with one another may also reveal key properties of the Earth's innards, such as how heat flows within the planet. One mineral crucial to revealing these details is wüstite, or FeO. Independent teams at the University of Chicago and Osaka University in Japan recently squeezed wüstite and found that it conducts electricity at pressures and temperatures similar to those found in the planet's outer core and lower mantle, the layer just above the core.

Pockets rich in wüstite may exist at

TIMELINE, FROM LEFT: GERARD LODRIGUSS/PHOTO RESEARCHERS, INC.; MARK GARLICK/PHOTO RESEARCHERS, INC.; CERN/PHOTO RESEARCHERS, INC.; SCIENCE SOURCE; SURAWACH5/SHUTTERSTOCK; DORLING KINDERSLEY/GETTY IMAGES; NASA; CHRIS BUTLER/PHOTO RESEARCHERS, INC.




the core-mantle boundary, where the mineral may transfer heat from the core into more shallow depths, says Chicago's Rebecca Fischer. Metallic FeO could also help explain why oxygen dissolves in metal more readily at high pressures, such as in the planet's core, Fischer's team reports in an upcoming *Geophysical Research Letters*.

The world of high-pressure discovery also extends well beyond Earth — to other planets in the solar system, and on to other planetary systems. In particular, the cores of gas giant planets are "the least accessible but in many ways the most important objects in the solar system," says Hugh Wilson, a planetary chemist at the University of California, Berkeley. The very existence of the cores allowed Jupiter and Saturn to coalesce around them; the gravitational pull of the completed gas giants then helped dictate how the rest of the solar system grew.

**Here on Earth, scientists put on the pressure with a device called a diamond anvil cell.**

Yet scientists don't know much about how the giant planet cores formed. In principle, they were born as bits of rock and ice swirling around the newborn sun began to glom together, becoming big enough to start attracting hydrogen and helium gas to make up the rest of the planet. Today researchers don't agree on how big the cores are, much less the conditions that exist inside them.

One new idea, born from some high-pressure theoretical calculations involving hydrogen, even suggests that giant planet cores are slowly dissolving away. Over time, watery ice in Jupiter's core dissolves in the hydrogen-rich material swirling above so that the core shrinks, Wilson and Burkhard Militzer, also of Berkeley, write in an upcoming *Astrophysical Journal*. "What's going on inside Jupiter is more complicated and less homogeneous than had been taken into account in previous models," Wilson says.

The work may even shed light on planets in other solar systems, which astronomers have glimpsed only indirectly so far. Many known exoplanets are more massive than Jupiter, and so they are also hotter inside. Cores of these exoplanets would have started eroding away even faster than Jupiter's, Wilson says. As a result, elements may have leached from the core and become well-mixed in the gassy atmosphere. One day, if astronomers on Earth can get a detailed picture of an exoplanet's atmosphere from afar, they may need to account for such internal chemical mixing in order to properly understand what they're seeing.

## The squeeze machine

In perhaps the ultimate test of high-pressure science, researchers are gearing up to squeeze things at the world's most powerful laser machine. The three-football-field-long National Ignition Facility will focus 192 laser beams on a single tiny target. The eventual goal is to fuse the nuclei of hydrogen atoms, thus harnessing in the lab what the sun and billions of other stars do daily.

But for now, as NIF ramps up toward full power, other scientists are taking advantage of early, prefusion tests to see what happens to materials put in the path of the beams. "NIF is uniquely capable of trying to explore this realm of compression science," says Jon Eggert, a material scientist at the lab.

This spring, NIF scientists squished diamond in the facility's laser beams to pressures up to a crushing 50 million atmospheres — more than double the previous record set using a different compression technique by the OMEGA laser at the University of Rochester. So far, Eggert and his colleagues have seen stress patterns appear in diamond crystals that no one has seen before. The researchers have also put tantalum into the machine and spotted what may be a new transition between crystal forms at around 3.4 million atmospheres.

Later this year, the NIF team plans to squeeze materials at 100 million atmospheres. In theory, NIF could approach or exceed the pressure required to seriously disrupt the shell structure of atoms, called the atomic unit of pressure. That would come at around 300 million atmospheres, Eggert says, and would bring with it breakthrough insights into how matter behaves under such conditions. But it's still not clear, he says, whether the geometry of how the laser beams come together will allow the team to achieve the atomic unit of pressure.

No matter how high the NIF manages to go, Hemley says, it and the other experiments will continue to uncover new surprises. "Exploring these simple planetary materials under extreme conditions is really deepening our understanding of chemistry," he says. "A lot of what we thought we knew is wrong." ■

## Explore more

- Visit the National Ignition Facility website: lasers.llnl.gov

DIAMONDS: COURTESY OF VITALI PRAKAPENKA

### How To Think Like A Neandertal

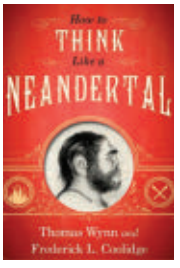
*Thomas Wynn and Frederick Coolidge*

A Neandertal raised in a human family would make a great fishing boat captain but a lousy police officer. He or she could call on extensive knowledge of local sea conditions and an ease in dealing with small crews, but an inability to read strangers' motives and recognize their lies would doom a Neandertal patrolling city streets.

So say psychologist Coolidge and archaeologist Wynn, who boldly transform studies of stones, bones and molecules into educated guesstimates about Neandertal thinking and personality.

In the authors' view, Neandertals lived in small groups and fashioned versatile stone tools, excelling at learning complex procedures and remembering task-relevant information but almost never innovating. They used spears to kill mammoths at close range, a dangerous pursuit that left behind few elders to pass on wisdom. Surrounded by family and friends, Neandertals probably spoke plainly and directly, cared about their own, had little imagination or sense of humor and took a stoic approach to life, the authors propose.

That put Neandertals at a disadvantage in competing with people for shrinking resources in Ice Age Europe around 30,000 years ago. Humans operated in large communities that fostered tool and weapon advances, complex social thinking and mental manipulation of information, Coolidge and Wynn argue. No evidence exists of violent encounters between Neandertals and people, but bloody conflicts must have occurred, the pair assert. Clever humans had invented gizmos to throw spears from a distance, so *Homo sapiens* won the evolutionary lottery.




These are controversial claims. Neandertals may or may not have been Stone Age stoics, but they overachieve at starting arguments among today's evolution researchers. *—Bruce Bower*
*Oxford Univ., 2012, 210 p., $24.99*

### The Art of Medicine: Over 2,000 Years of Images and Imagination

*Julie Anderson, Emm Barnes and Emma Shackleton*

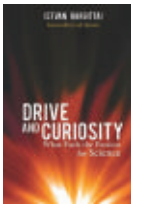
The images in this survey of medicine prove an eclectic mix of the curious, the grotesque and the breathtakingly beautiful. Covering a wide array of medically related topics — such as cholera, childbirth and charlatans — the book presents the most captivating pieces from pharmaceutical entrepreneur Sir Henry Wellcome's vast collection.


The equally engaging text reveals how Wellcome, a fascinating figure himself ("Born in a log cabin in Sioux Indian country ... Wellcome ended his days as a knight of the British Realm"), set about using his fortune to acquire an enormous museum of medical artifacts.

The book feels like a guided tour through that museum. In addition to drawings, paintings and photographs, the authors expertly display and explain sculptures, carvings and myriad other artifacts to provide a comprehensive visual history of the medical tradition across cultures.

Some of the first, crudely limned (and often laughably inaccurate) anatomical diagrams are contained here, as well as gorgeously rendered examples of modern high-powered microscopy. Annie Cavanagh and David McCarthy's picture of colored aspirin crystals taken from a scanning electron microscope looks like a blossoming flower, for example, a marked contrast to drab pills.

Of particular interest is the book's exploration of pseudoscientific practices, such as phrenology, astrology and alchemy, and their influence on the burgeoning medical traditions of many different societies. *—Nick Bascom*
*Univ. of Chicago, 2011, 256 p., $50*




### Drive and Curiosity

*Istvan Hargittai*

The stories of 15 leading scientists are examined for clues to what makes some scientists exceptional and what fuels discovery. *Prometheus Books, 2011, 338 p., $26*

### Bird on Fire

*Andrew Ross*

The prospects for sustainability look bleak for the city of Phoenix in this environmental analysis of the desert oasis. *Oxford Univ., 2011, 304 p., $27.95*

### Magical Mathematics

*Persi Diaconis and Ron Graham*

Learn the secrets behind card tricks, including step-by-step instructions for performing them, along with the mathematical ideas the tricks illustrate. *Princeton Univ., 2011, 244 p., $29.95*


### Neurogastronomy

*Gordon M. Shepherd*

A neuroscientist explores how the brain creates the sensation of flavor and discusses the effects of taste perception on healthy eating. *Columbia Univ., 2011, 267 p., $24.95*


### The Physics Book

*Clifford A. Pickover*

Ideas and subjects ranging from Maxwell's demon to the rings of Saturn are highlighted in short encyclopedia-style entries with attractive illustrations. *Sterling, 2011, 528 p., $29.95*

**How to Order** To order these books or others, visit www.sciencenews.org/bookshelf. A click on a book's title will transfer you to Amazon.com.

### Skaters slide

Regarding the article "Skateboarders rock at physics" (*SN: 12/3/11, p. 10*), the skateboarders' "intuitive" conclusion that the ball will roll faster down the blue ramp (which is longer but has two steeper sections compared with the shorter red ramp with a single shallower section) depends on the particular geometries chosen for the two ramps.

I've programmed the solution for a point particle sliding (so no rolling) without friction down the two ramps and find that for certain ratios of the heights and lengths of the various ramps, it can actually be faster to slide down the red (single) ramp. Intuition can only go so far in such problems.

A full examination of the problem requires analysis and calculation to aid intuition. Nowadays, this means using a computer to explore all the possibilities.

**Don Polvani,** Arnold, Md.

### Seldon crisis

Tom Siegfried's editorial about "econophysics" ("Perhaps physics can also solve economic puzzles," *SN: 11/5/11, p. 2*) makes it evident that the world needs a real Hari Seldon, the fictional person who mathematically described sociology in Isaac Asimov's *Foundation* trilogy.

**Mike James,** Ottawa, Canada

### Living on Venus

I enjoyed reading "Venus Unveiled" (*SN: 12/3/11, p. 26*). I have always felt that we have slighted Venus in our explorations. If there is one planet that has real promise for human habitation, it is Venus. Of course the current atmosphere is a problem. But I believe a bacteriological terraforming solution could be found that would modify that atmosphere to the point of usability.

We focus so much attention on Mars, but Mars has a much more fundamental problem — not enough mass. Even if you were to magically give Mars an Earthlike atmosphere today, it could not hold onto it. Venus, on the other hand, is 95 percent Earth's size and has 90 percent of Earth's surface gravity. This similarity to Earth makes Venus a much more attractive target for exploration and worth the effort to develop a solution for the atmosphere issue.

**Tom DuBois,** Glens Falls, N.Y.

### Correction

The feature "Space Eats" (*SN: 11/19/11, p. 20*) reported that crops grown in a 20-square-meter garden at Kennedy Space Center had surprisingly low yields. In fact, yields from crops such as wheat, lettuce and potato were quite high; they were lower in comparison with certain specialized plantings in smaller chambers.

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# From the Archive

For the full 1953 article, visit
**www.sciencenews.org/archive_oxytocin**

**Oxytocin is known to facilitate childbirth and breast-feeding, and has more recently been investigated for its role in maternal behavior.**

## Make pituitary hormone

Synthesis for the first time of a hormone from the pituitary, often called the body's master gland and famous source of the anti-arthritis ACTH, is announced by Dr. Vincent du Vigneaud and associates of Cornell University Medical College at the New York Hospital-Cornell Medical Center in New York.

Synthesis of a second hormone from this same gland has almost been accomplished, Dr. du Vigneaud also reports.

The first hormone is oxytocin, important in childbirth and lactation. The second is vasopressin, the blood pressure raising and antidiuretic hormone of the pituitary.

Oxytocin gets its name from the Greek word for "rapid birth." Its effect in causing contractions of the uterus make it important in childbirth, while it also influences release of milk in the mammary glands.

The achievement of the synthesis of oxytocin establishes the structure of this hormone and opens the door to many new investigations in biochemistry, pharmacology and physiology, which should lead to a better understanding of the function of this important principle, Dr. du Vigneaud pointed out. Such a synthesis may also provide an unlimited source of the oxytocic hormone for possible expansion of its use in clinical medicine, particularly in obstetrics, and in veterinary medicine, he said.

**UPDATE**

# Oxytocin goes from birthing drug to 'love hormone'

Oxytocin's synthesis in 1953 was recognized immediately as a monumental scientific advance. *Science News Letter* included the discovery among the 10 top stories of the year, alongside Watson and Crick's proposal for the double-helix structure of DNA, the successful climbing of Mt. Everest and the development of a vaccine against all three types of polio. Just two years later, Vincent du Vigneaud won the Nobel Prize in chemistry for this first synthesis of what's called a "polypeptide hormone."

In announcing the award, the Nobel committee acknowledged du Vigneaud's mastery of the chemistry needed to produce combinations of linked amino acid structures that play a fundamental part in life processes. The medical implications were huge: Drugs based on synthetic oxytocin would speed delivery time for women in labor, and the synthesis of other similar molecules promised a new era in hormone treatment.

What wasn't obvious in the 1950s was the role that oxytocin might play in behavior. In recent decades, researchers discovered that female virgin rats injected with the hormone mothered rat pups—building nests, licking the pups and attempting to nurse. Additional work has shown that oxytocin is important in pair bonding among prairie voles, as well as in forming social bonds and in developing trust among people.

Today oxytocin is more widely known as the "love hormone" than as a labor drug. And a recent review article suggests the substance may lead to yet more treatments, including for social phobias, autism, infertility and addiction. In untangling oxytocin's myriad effects, researchers are revealing that straightforward scientific achievements can give way to more nuanced investigations. —*Elizabeth Quill*

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A. The United States' first crackdown on asbestos
B. Quasars' long list of superlatives
C. Lamont-Doherty Geological Observatory's brittle map woes

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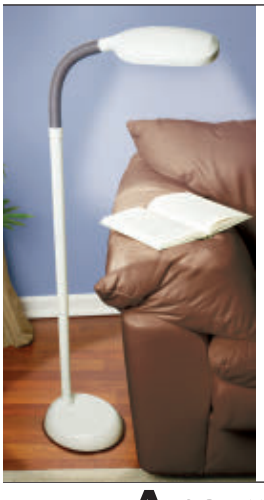

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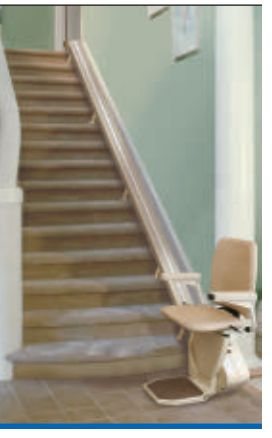

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