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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ JANUARY 28, 2012

Brain Storm

Scientists seek cause of migraines' aches and auras

Mishmashed Monkeys

Soil Scientists Sling Mud

Pigeons Do the Math

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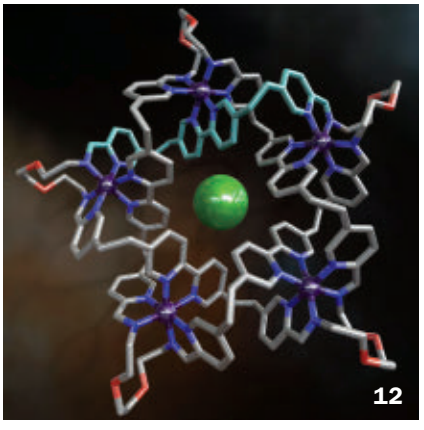

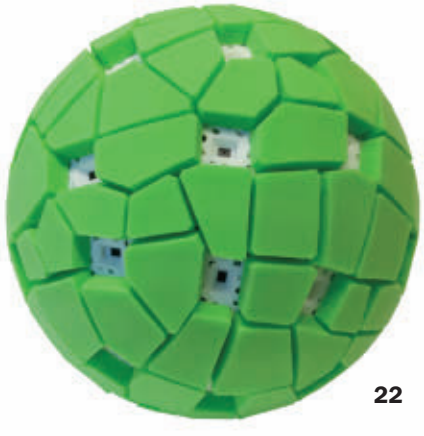

ScienceNews

In The News

Features

Departments

COVER Researchers find clues to migraines' origins with a little help from genetics.
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Science News (ISSN 0036-8423) is published biweekly, for $54.50 for 1 year or $98 for 2 years (international rate $80.50 for 1 year or $161 for 2 years) by Society for Science & the Public, 1719 N Street NW Washington, D.C. 20036.
Preferred periodicals postage paid at Washington, D.C., and an additional mailing office.
Subscription Department: PO Box 1205, Williamsport, PA 17703-1205. For new subscriptions and customer service, call 1-800-552-4412.
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FROM THE EDITOR

With scientific puzzles, all the pieces have to fit

In the 2002 remake of the film *The Time Machine*, the time traveler repeatedly fails in his efforts to go back in time to save his girlfriend's life. Only in a later trip to the future does someone explain to him that he can't save her because her death was the reason he invented the time machine to begin with. Saving her would have removed the motivation for building the time machine. With no time machine, she couldn't be saved, either.

Strangely, a similar paradox applies to the current claim that neutrinos can fly faster than light. As Devin Powell reports in this issue (Page 9), such superluminal speeds not only defy Einstein's special relativity, but they also contradict the law of conservation of energy. Neutrinos in this experiment are emitted in the decay of subatomic particles called pions; the pions possess far less energy than the amount required by the neutrinos to exceed light speed.

One possible response to such a limitation would be, So what? If special relativity is wrong, maybe conservation of energy is wrong, too. But here's the problem with that. Physicists figured out that the neutrino existed in the first place because something like it was needed to preserve the law of energy conservation. Initial studies of radioactive beta decay found that its products possessed less total energy than their precursors. If energy is truly conserved, some invisible particle must fly off with the energy needed to balance the books. Theory suggested such a solution would work nicely, and eventually the suspected particle was found. The neutrino's existence confirmed that energy conservation was correct.

So it would be pretty silly if neutrinos have now disconfirmed the reason for their own existence. Which is why most scientists dismiss the idea of faster-than-light neutrinos as simply an experimental mistake of some sort, whereas the mere hint of a sighting of the Higgs boson at the Large Hadron Collider has many physicists convinced that its discovery is imminent. That's because the Higgs fits into all the successful physics already known, while superluminal neutrinos fly in the face of well-established facts. Scientific truths are not isolated possibilities verified independently, but rather form a matrix of linked explanations identifying the regularities behind nature's apparent complexities. Outlier results like the superfast neutrinos have a negligible chance of ever making it into the textbooks. If it doesn't fit, you must omit.

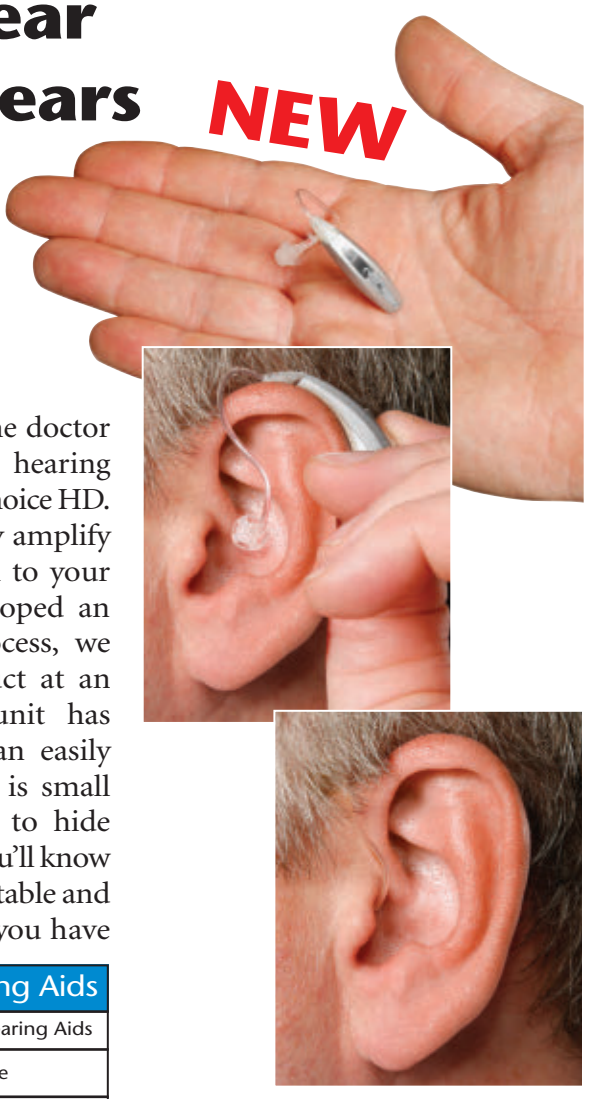
—Tom Siegfried, Editor in Chief

JIM WEBB

The invention of the year is great news for your ears

Perfect Choice HD™ is easy to use, hard to see and costs far less than hearing aids… it's like reading glasses for your ears™!

New Personal Sound Amplification Product is an affordable alternative



Over the years, technology has made the way we live easier, safer and more convenient. In many cases, it's even made many products more affordable… (remember how much the first VCRs used to cost?). Unfortunately, the cost of hearing aids never seemed to come down. Now, a new alternative has been invented… it's called Perfect Choice HD™.

"Reading glasses for your ears"

Perfect Choice HD is NOT a hearing aid. Hearing aids can only be sold by an audiologist. In order to get a hearing aid, you had to go to the doctor's office for a battery of tests and numerous fitting appointments. Once they had you tested and fitted, you would have to pay as much as $5000 for the product. Now, thanks to the efforts of the doctor who leads a renowned hearing institute, there is Perfect Choice HD. It's designed to accurately amplify sounds and deliver them to your ear. Because we've developed an efficient production process, we can make a great product at an affordable price. The unit has been designed to have an easily accessible battery, but it is small and lightweight enough to hide behind your ear… only you'll know you have it on. It's comfortable and won't make you feel like you have something stuck in your ear. It provides high quality audio so sounds and conversations will be easier to hear and understand.

Perfect Choice HD vs Traditional Hearing Aids

	Perfect Choice HD	Traditional Hearing Aids
Lightweight and Inconspicuous	YES	Some
Easy Toggle Switch Adjustment	YES	Few
Intelligent Setting Memory	YES	Few
Tests and Fittings Required	NO	Yes
Affordable	YES	as much as $5000
Friendly Return Policy	**YES**	**rarely**

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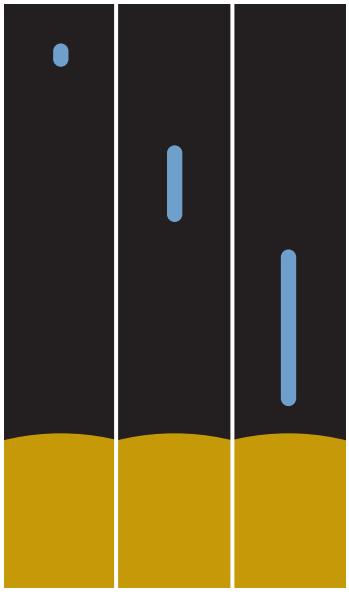

Say What?

Spaghettification ***\spuh-geht-tih-fuh-KEHY-shun*** ***n.*** The stretching that occurs as an object approaches a black hole or other superdense body. This "noodle effect," as it is also known, is caused by the same gravitational effect that generates tides on Earth. A massive body pulls harder on the side of an object nearest it, and in the case of a black hole this force stretches an incoming body into a long, thin strand (shown, left to right). "Spaghettification" was officially recognized by the American Heritage Dictionary in November. Physicists, though, have been fond of the term for decades.
—*Erika Engelhaupt*

Science Past | JANUARY 27, 1962

"SPACE WHISKERS" GROWN FOR NEW SPACE MATERIALS — Microscopically small "space whiskers" are being grown by scientists at Rocketdyne, a division of North American Aviation, Inc., Canoga Park, Calif., in search of methods of producing extremely strong new space materials. The fine filament-like crystals are being grown from many materials — lead, tin, copper, graphite, sapphire and even table salt. The tensile strength of the crystals reaches the level of millions of pounds because of the extraordinary perfection of their structure.... Some grow from a base like human whiskers, others grow by piling up atoms on the tip. Sapphire whiskers, seen on the front cover, are most desirable. They not only have great strength but they also have a high melting point and are resistant to oxygen.

The (-est)

Meet VFTS102, a star that spins so fast it's on the verge of being torn apart by its own centrifugal force. An international team of astronomers spotted the blue giant (shown, arrow) in the Large Magellanic Cloud. VFTS102 whirls at more than 1.8 million kilometers per hour, making it the fastest-rotating star ever discovered. The team suggests in *Astrophysical Journal Letters* that VFTS102 may once have had a binary buddy. When the companion went supernova, the explosion could have sent VFTS102 spinning into space alone. —*Allison Bohac*

Science Future

February 9
Learn about the science of wine and even stomp some grapes with your bare feet at the Durham, N.C., Museum of Life + Science. See bit.ly/syleOC

February 13
Enjoy an after-hours tour highlighting displays of love in exhibits at the American Museum of Natural History in New York City. Learn more at bit.ly/zRko4O

SN Online

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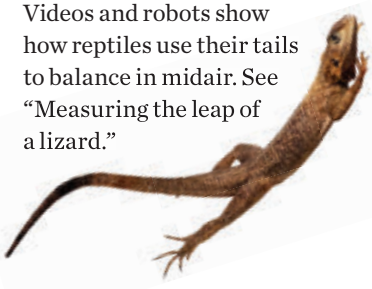
SCIENCE & SOCIETY
Plants, algae and fungi can now be named online and in English. Read "Botanists *et al* freed from Latin, paper."

LIFE
Videos and robots show how reptiles use their tails to balance in midair. See "Measuring the leap of a lizard."



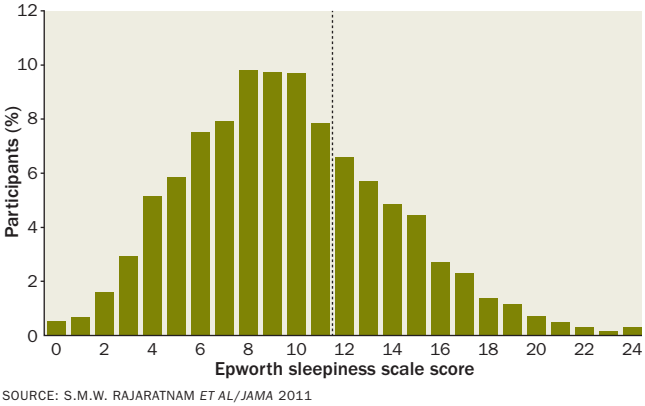
SCIENCE & THE PUBLIC BLOG
Climate-related natural disasters are on the rise. Learn more in "Insurance payouts point to climate change."

ATOM & COSMOS
Cassini images give a ringside view of Saturn's moons Titan and Dione. See "Saturn moons spied from the side."

Science Stats | TO PROTECT AND SNOOZE

A study of North American police officers finds many are dangerously sleepy. Forty percent had at least one sleep disorder, and 28 percent reported excessive sleepiness (scores to right of dashed line on chart). Twenty-six percent reported falling asleep while driving at least monthly.

Sleepiness scores of police officers with sleep disorders



SOURCE: S.M.W. RAJARATNAM *ET AL*/*JAMA* 2011

CLOCKWISE FROM TOP LEFT: T. DUBÉ; THOMAS LIBBY, EVAN CHANG-SIU, PAULINE JENNINGS, COURTESY OF POLYPEDAL LAB & CIBER/UC BERKELEY; M.-R. CIONI/VISTA MAGELLANIC CLOUD SURVEY/ESO

“Despite completely different brain organization and hundreds of millions of years of evolutionary divergence, pigeons and monkeys solve this problem in a similar way.” —ELIZABETH BRANNON, PAGE 11

In the News

STORY ONE

Antarctica is for crabs, Caribbean is for shrimp

Big differences seen among deep-sea vent communities

By Alexandra Witze

Each deep-sea hydrothermal vent has its own mix of animals. On the Southwest Indian Ridge, scaly-footed sea snails (left) can be found alongside yeti crabs (right).

BOTH: DAVID SHALE

Like the boroughs of New York City or the arrondissements of Paris, deep-sea communities turn out to have strong local flavor.

In the waters off Antarctica, piles of hairy crabs swarm by the thousand. In the middle of the Indian Ocean lives a motley collection of creatures never before seen together. And south of Cuba, at the world’s deepest vents, shrimp rule.

Thanks to a recent string of oceanographic expeditions, scientists are learning that there is no typical hydrothermal-vent ecosystem. Rather, each locale hosts its own eclectic residents, in patterns that may hint at how life spread through the ocean over geologic time.

“It allows us to move beyond the picture we’ve had so far, where you go to a new area and you find new and different species,” says Jon Copley, a marine ecologist at the National Oceanography Centre in Southampton, England. “Now we can say what are the relationships, the differences and similarities among all these places. That’s much more useful.”

The classic picture of a deep-sea vent ecosystem comes from the first glimpses researchers had of these otherworldly realms during the late 1970s. Explorers in deep sea submersibles like ALVIN saw giant tube worms, mussels and other creatures living off chemical energy provided by hydrothermal activity in the places where new seafloor is born.

But near Antarctica on the East Scotia Ridge, at the only hot-water vents known in the frigid Southern Ocean, tube worms and mussels are nowhere to be seen. A 2010 expedition found the seafloor crawling with a newfound species of yeti crab, a light-colored creature with long hairy arms and a furry chest. “It’s visually really quite astonishing,” says team leader Alex Rogers, a deep-sea biologist at the University of Oxford in England. “You have huge heaps of these crabs.”

Crabs usually die in polar waters because they can’t flush magnesium from their blood in the cold. But these animals survive by scrabbling over one another for the position closest to the 380° Celsius water pouring from the seafloor.

Along with the crabs, the researchers spotted smaller numbers of other creatures, including barnacles, limpets, snails and a predatory seven-armed starfish. The findings appear January 3 in *PLoS Biology*.

“There was a feeling that perhaps the Southern Ocean was a root of dispersal for hydrothermal faunas between other large oceans,” says Rogers. “So it was very surprising when it turned out to be a completely distinct vent community.” The extreme cold and seasonal swings in Antarctic waters may exclude animals such as mussels and shrimp, whose larvae need to feed at sea upon hatching, the scientists speculate.

Half a world away but just as puzzling are deep-sea vent animals along the Southwest Indian Ridge in the Indian Ocean. New seafloor crust is being born there at some of the slowest rates in the world, suggesting a relative lack of volcanic activity in the rocks below. But in 2007 a Chinese expedition discovered hydrothermal vents along the ridge at an average density of 2.5 vent fields every 100 kilometers.

“That number is big, about two to three times what scientists expected to

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find," says chief cruise scientist Chunhui Tao of the Second Institute of Oceanography in Hangzhou, China. Tao and his colleagues, who describe their survey in the January *Geology*, think that magma welling up locally may fuel the hydrothermal vents.

Last year, the International Seabed Authority granted China a permit to explore 1,000 kilometers of the Southwest Indian Ridge, including the active vents, for possible mining of metal deposits. Before that could happen, Rogers says, "there was a real feeling that we had to get in and document these vents."

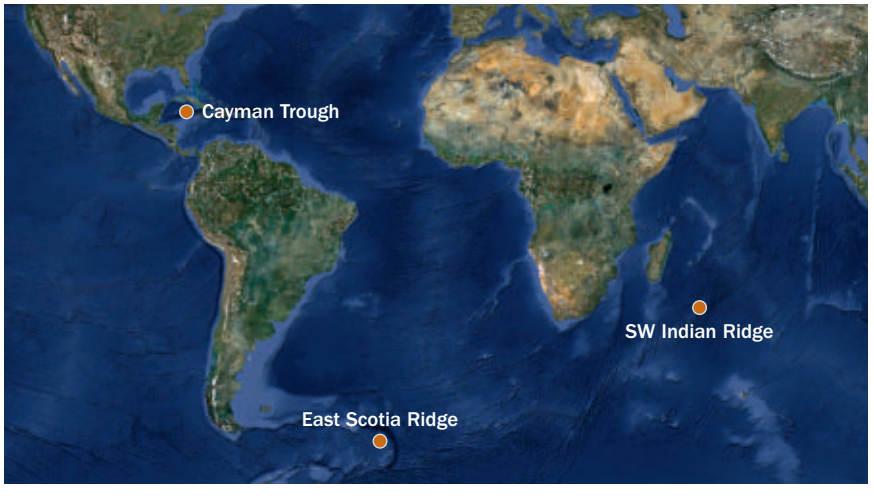
So last November and December, he, Copley and other biologists checked out a site called the Dragon Vent. In some ways, the animals there are similar to those near Antarctica, Copley says. There is a yeti crab, but probably not the same species as the Antarctic one and not present in such number. There are some shrimp, but not nearly as many as in the nearby central Indian Ocean. And there are a lot of scaly-footed snails, but not enough to take over the place. "Elsewhere you tend to find one species dominating," Copley says. "Here we've got at least four different types all jostling for it. It's quite a crossroads."

The idea of a deep-sea crossroads has inspired recent trips to a third place, the Cayman Trough in the Caribbean Sea. Volcanic activity has been going on there for 50 million years, Copley says; 3.1 million years ago, the Isthmus of Panama closed nearby, cutting off direct circulation between the Atlantic and Pacific oceans. Exploring the Cayman Trough, scientists reasoned, might tell them more about how deep-sea creatures once moved through this watery gateway.

A spring 2010 cruise to the vents yielded a surprise. The Cayman animals most closely resembled not those in the Pacific or at the closest known cold-water seeps 1,500 kilometers away in the Gulf of Mexico, but those at hot-water vents along the Mid-Atlantic Ridge — a full 4,000 kilometers away. At a hot-water vent 4,970 meters down, the dominant species was a new type of shrimp, the British scientists reported online January 10 in *Nature Communications*.

American researchers, led by the Woods Hole Oceanographic Institution, left Florida on a research cruise on January 6 to further explore the Cayman vent field.

"A single eight-week cruise can completely change our ideas about how these systems evolved and how species are distributed," says Rogers. "It really gives you some idea of the level of our knowledge of deep-water ecosystems." ■



Three widely separated deep-sea vent sites have distinct animal communities that may help researchers trace the spread of marine life over geologic time.

Back Story

MISSED OPPORTUNITY

In 1976, oceanographers exploring the seafloor near the Galápagos Islands were astonished to spot mussels, anemones and crabs living around deep-sea hot springs, totally isolated from ecosystems in shallower parts of the ocean. The vents' striking "black smoker" chimneys, like this one near New Zealand, quickly became icons of undersea exploration. But some scientists now say hydrothermal vents could have been discovered in Antarctic waters a decade earlier if scientists had realized what they were seeing. Library research recently unearthed a 1966 photograph, taken 2,377 meters deep along the Southern Ocean's East Scotia Ridge, that shows animals at what's now known to be an active hydrothermal vent. Oceanographers at the time "simply didn't recognize what they were investigating," says Alex Rogers, a marine biologist at the University of Oxford in England. "If they had, the course of scientific history would have taken a very different route."

The axe came down. The clay vessel shattered. And 1650-year-old coins spilled out.

Each coin over 1650 years old! No two are exactly alike.

In the spring of 1895, workmen on a wealthy British estate in Bishop's Wood, England dug into a wooded hillside behind a church. One of their pick axes suddenly shattered a large clay vessel—causing thousands of 1650-year-old ancient Roman bronze coins to spill out on the mossy ground. After carefully excavating the site, a trio of earthenware jars were uncovered—containing 17,550 Roman bronze coins struck from 307–361 A.D.

The mystery of why such a rich treasure trove of ancient coins would be buried in a sleepy British forest confounded the public. Scholars eventually confirmed that the treasure site appeared to be the treasury of a Roman Legion who had occupied Britain at that time. It was actually a common practice to bury military treasuries in those days. The large Roman army required a lot of money for supplies and soldiers' pay—and there were no banks. So just before entering into a battle, the entire hoard of coins would be buried in a secret place known only to a few members of the legion. Of course, if the army was defeated in battle, hidden hoards such as this one could languish forgotten for centuries. In the case of the Bishop's Wood treasure, most of the 1650-year-old coins were as perfectly preserved as the day they were buried.

The owner of the Bishop's Wood estate was a British Colonel. A personal friend of Prince Albert who owned racehorses and yachts, Col. Harry McCalmont considered this historic discovery as the perfect opportunity to give back to his beloved homeland. He donated 90% of the treasure to universities and museums throughout Britain—and as far away as Australia. But at the prodding of friends and family, the Colonel kept 1,661 of the finest coins in the treasure and they proudly remained in the family's care for the next 115 years.

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Body & Brain

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Staggered lessons may boost recall

Training at irregular intervals improves memory in sea snails

By Laura Sanders

Sea snails learn more effectively on an oddly timed series of training sessions rather than regularly spaced lessons, a new study finds. If the results extend to humans, they might suggest ways of improving students' study habits.

The work, published online December 25 in *Nature Neuroscience*, shows how a deep knowledge of biology and powerful computer models can lead to insights about the brain, says neuroscientist Eric Kandel of Columbia University, who won a Nobel Prize in 2000 for his work on sea snail memory.

When the rat-sized *Aplysia californica* receives an unpleasant shock, it retracts its gill and an appendage called a siphon. After numerous shocks, it will become sensitized, learning to retract the siphon and keep it in for a while.

Scientists normally expose sea snails to the signal at regular intervals over several hours to sensitize the animals. But Jack Byrne of the University of Texas Medical School at Houston and colleagues wondered whether there was a better way. "There's no real logic for why people use one protocol over another, other than it works," he says.

Kandel and others have worked out a lot of the biochemical details of how sea snails learn and form memories. When the creatures start to learn something, two major molecular cascades kick off in nerve cells. Genes jump into action, churning out proteins that then spur on other genes. One of these cascades happens quickly, and the other one is sluggish, but both need to deliver their products at the same time for a memory to stick.

> "The model spat out exactly what turned out to be right. It's just beautiful."
> LILA DAVACHI

Byrne and his team used this knowledge to make a mathematical model of how best to deliver this biochemical double-hit. The team asked the computer how to spread out five shocks over a period of several hours. Instead of evenly spacing the five at 20-minute intervals, the model suggested a completely different pattern: Give three doses 10 minutes apart, followed by a fourth dose five minutes later, wait half an hour, and then give a final dose.

When Byrne and his team tried this training protocol, it worked better than the standard 20-minutes-apart training doses. With the standard protocol, the sea snails forgot what they'd learned after five days. But on the enhanced protocol, the sea snails still remembered five days later.

"The model spat out exactly what turned out to be right," says neuroscientist Lila Davachi of New York University. "It's just beautiful."

Drug activates dormant gene

Chemotherapy agent may treat Angelman syndrome

By Tina Hesman Saey

By kick-starting a normally inactivated gene, chemotherapy drugs could help reverse a genetic disorder that causes severe developmental delays. The unexpected finding may also spark a new line of research on a type of gene silencing known as imprinting.

Angelman syndrome occurs in about one in 15,000 live births. It happens when the copy of a gene called *UBE3A* inherited from the mother goes missing or is damaged by a mutation. That's a problem because the copy of the gene inherited from the father is normally turned off in brain cells, making it unable to direct production of the UBE3A protein.

Genes in which one parent's copy is turned off are called imprinted genes. Until now, researchers knew of no way short of gene therapy to override the imprinting and restore gene activity.

Now, researchers from the University of North Carolina at Chapel Hill have discovered that a class of chemotherapy drugs can turn on the father's inactive copy of the gene in brain cells of mice. Neuroscientist Benjamin Philpot and his colleagues used brain cells from mice genetically engineered to make a fluorescent protein whenever the father's copy of *UBE3A* is active. The researchers tested more than 2,000 chemicals to see whether any could turn on the dad's copy of the gene.

Because most imprinted genes are tagged with chemicals either on the DNA or on associated proteins, the researchers expected to find that drugs affecting those chemical tags would restore *UBE3A* activity. Instead, drugs that inhibit the activity of DNA-unwinding proteins called topoisomerases did the trick. The team reports the finding online December 21 in *Nature*.

Researchers don't yet know whether the drugs can restore UBE3A protein production in human brain cells, or if turning the gene back on will reverse abnormalities in Angelman syndrome mice.

DNA-unwinding proteins have never been implicated in imprinting before, so the discovery is likely to generate lots of new research on how the proteins are involved in the process, says Yong-hui Jiang, a clinical geneticist and neurobiologist at the Duke University School of Medicine.

Atom & Cosmos

"The idea that a planet could survive while being immersed in a star is pretty spectacular." —ELIZA KEMPTON

Neutrino parents set speed limits

Faster-than-light flight would violate conservation laws

By Devin Powell

Physicists have found yet another reason to doubt recent reports of neutrinos traveling faster than light. The existence of such speedy particles would screw up not only Einstein's theory of special relativity, but also the laws of conservation of energy and momentum.

In September, the OPERA experiment reported clocking neutrinos traveling faster than the speed of light, arriving 60 nanoseconds early on their 730-kilometer journey between the European laboratory CERN, near Geneva, and the Gran Sasso National Laboratory in Italy. To try to explain the result, two new studies examined the particles that give birth to neutrinos. Both found that these particles, called pions, could not possibly have had enough energy to give rise to the faster-than-light, or superluminal, speeds indicated by OPERA.

"We give a clear constraint on the superluminality of neutrinos," says Xiaojun Bi, a particle astrophysicist at the Chinese Academy of Sciences' Institute of High Energy Physics in Beijing. His team reported its findings in the Dec. 9 *Physical Review Letters*.

If neutrinos can travel faster than light, they should get heavier as their energy increases. So there's a limit to how fast the particles can zip along, dictated by the energy of their unstable pion parents.

OPERA's pions, made at CERN, have on average 3.5 times as much energy as their neutrino progeny. That sets a neutrino speed limit that's lower than the speed measured by OPERA, physicist Ramanath Cowsik of Washington University in St. Louis and colleagues reported in the Dec. 16 *Physical Review Letters*. Bi suggests that OPERA's highest-energy neutrinos push this speed limit even lower.

Achieving the mind-boggling velocities measured by OPERA would have required pions with energies 20 times greater than their offspring, Cowsik's team calculates. At such energies, though, the lifetimes of pions would be six times longer, which has been ruled out by measurements from OPERA and other experiments.

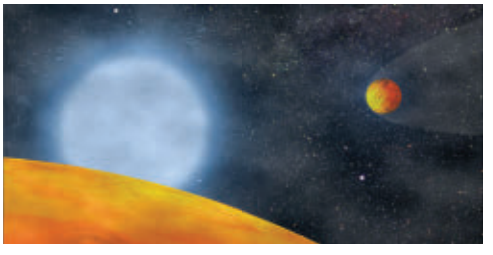
For Cowsik and other researchers, these problems and contradictions suggest that the laws of physics as currently understood are correct. But physicists will still be watching other neutrino experiments that can check OPERA's result, which may be clouded by some unknown source of error.

Toasty planets circle stellar heart

Once-giant orbs downsized when star ballooned to red giant

By Nadia Drake

One of the stars in the Kepler space telescope's crosshairs has apparently regurgitated the Earth-sized remains of two planets ingested when the star temporarily ballooned into a red giant. Now, the rocky survivors are whizzing around the star's small, pulsing heart, each completing its orbit in less than 10 hours.



S. CHARPINET

A dying star may have engulfed, downsized and then spit out two planets (orange) before collapsing into a rare type of subdwarf (blue).

At least, that's the interpretation offered by an international team that reports the oddball planetary system in the Dec. 22 *Nature*. While some astronomers are skeptical of the explanation, the story could explain how a rare type of star forms and foreshadow the fates of enormous planets engulfed by their hosts.

"The idea that a planet could survive while being immersed in a star is pretty spectacular," says Eliza Kempton, an astronomer at the University of California, Santa Cruz.

The star is a rare hot B subdwarf, and the two bodies — KOI 55.01 and 55.02 — are the purported cores of partially digested planets that were larger than Jupiter but are now smaller than Earth.

Normally, a star like the sun evolves into a red giant, then collapses into a white dwarf. But sometimes, the giant sheds its stellar skin before contracting, leaving behind a bright, beating heart — the hot B subdwarf. Scientists hypothesize that a companion star or planet might instigate the transformation.

To spy the tenacious travelers, scientists monitored enigmatic signals muddying the star's normal pulsations. Like bells, stars vibrate and ring at certain tones. This one, called KIC 05807616, had several subtle tones that couldn't be explained by the star alone, says study coauthor Stephane Charpinet of the University of Toulouse in France. He and the team ruled out other explanations before deciding that planets were the most likely culprits of the star's abnormal jingles.

But some scientists have doubts about the team's interpretation, pointing to a number of assumptions used to calculate the size and properties of the proposed planets. "I'm not convinced," says astronomer John Johnson of Caltech. "This doesn't have to be wrong, but I have my doubts."

Life

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Deep-sea glow serves as bait

Marine bacteria light up to hitch a ride somewhere else

By Alexandra Witze

Bioluminescent bacteria glow in the ocean for the same reason roadside eateries display neon signs: They want to attract hungry diners.

New laboratory experiments bolster the long-standing theory that marine bacteria light up to get themselves a free ride to other parts of the ocean in the digestive tracts of larger beasts, scientists from Israel and Germany report online December 27 in the *Proceedings of the National Academy of Sciences*.

"It's nice to see these ideas confirmed," says J. Woodland Hastings, a bioluminescence expert at Harvard University.

Many deep-sea creatures — including types of bacteria, fish and squid — are bioluminescent, meaning they generate light inside their bodies through chemical reactions. Different organisms glow for different reasons; the anglerfish, for instance, can light up a lure to attract prey, while some plankton glow when disturbed to attract predators of whatever is stirring them up.

Bioluminescent bacteria live throughout the ocean, and may have several reasons for their built-in glow. More than three decades ago, researchers suggested that one such reason could be to mark the presence of a floating food particle, so that a passing fish would see it and eat it. But no one had tracked this idea all the way to its logical conclusion — until now.

Margarita Zarubin, a graduate student at the Interuniversity Institute for Marine Sciences in Eilat, Israel, started with a type of luminescent bacterium, *Photobacterium leiognathi*, found 600 meters deep in the Red Sea. She put one bag of glowing bacteria at one end of a seawater tank, and at the other end she put another bag of bacteria that had a genetic change that kept the microbes dark. Shrimp and other small animals clustered around only the glowing bacteria.

Next she let brine shrimp swim in water with the luminescent bacteria; the shrimp themselves soon began to glow from their microbial dinner. "We could see the luminescence from inside their guts," says Zarubin, who did the work while at the University of Oldenburg in Germany and is now with the Hebrew University of Jerusalem.

Then she dropped both glowing and dark shrimp into a flume so they were swept past a hungry cardinalfish; the fish ate only the luminescent shrimp. Finally, the scientists tested the fish feces, and found that the bacteria passed unscathed through the fish guts. The whole process spreads the bacteria through the water faster than they could move otherwise, Zarubin says.

For their part, the shrimp must balance the benefit of eating a food particle that happens to glow against the drawback of becoming luminescent themselves, thus making themselves more vulnerable to predators. But in deep dark waters where food is scarce, Zarubin says, the advantage of getting a snack probably outweighs the disadvantage of potentially being eaten.

Early fossils don't look like animals

Hints of spores in deposits nix controversial classification

By Alexandra Witze

The oldest known "animal" fossils may have been living in the wrong kingdom. New images suggest that 570-million-year-old, many-celled blobs from China are not animal embryos as once thought, but some kind of spore-releasing cyst.

"They are not animals and they are not embryos," says Stefan Bengtson, a paleobiologist at the Swedish Museum of Natural History in Stockholm. The work, done with colleagues including Philip Donoghue of the University of Bristol in England, appears in the Dec. 23 *Science*.

The fossils come from the Doushantuo rock formation in southern China. Once thought to represent algae, the fossils were reclassified as animals in 1998 based on how their cells divided. Blobs caught in various stages of division showed that they split into two cells, then four, then eight and so on without the organism growing larger.

This 570-million-year-old fossil appears to be a spore-producing organism. Yellow represents cell nuclei.

SWEDISH MUSEUM OF NATURAL HISTORY

Scientists have debated ever since what this cell division really means, with some arguing that the fossils represent giant bacteria.

Bengtson's group used high-energy X-rays to probe 450 Doushantuo fossils. By tracing the blobs' growth into more advanced developmental stages than other scientists had, the team found that the fossils didn't start to develop new tissue types the way animals would. Instead, the cells kept dividing, creating more tiny cells that eventually lost their shape and got squeezed out as if being released as spores.

Finding the earliest animals may come down not to finding their physical remains but to spotting ways in which they changed their environments, Nicholas Butterfield of the University of Cambridge in England writes in a commentary accompanying the paper.

"They are not animals and they are not embryos." —STEFAN BENGTSON

Birds rival primates in number task

Trained on one-two-three, pigeons apply rule to bigger digits

By Susan Milius

Pigeons have matched primates in a test of learning an abstract concept similar to counting.

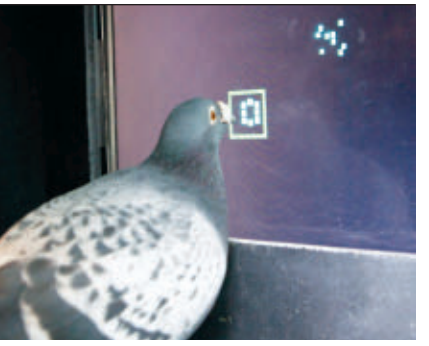
Trained on one-two-three, the pigeons then had to put pairs of numbers up to nine in order, says comparative psychologist Damian Scarf of the University of Otago in New Zealand. Pigeons rivaled rhesus monkeys tested earlier at the same task, Scarf and his colleagues report in the Dec. 23 *Science*.

The results "suggest that despite completely different brain organization and hundreds of millions of years of evolutionary divergence, pigeons and monkeys solve this problem in a similar way," says Elizabeth Brannon of Duke University, a coauthor of the original study of numerical order in monkeys.

Scarf used Brannon's numerical-order test, which baboons and lemurs as well as some monkeys have passed. Pigeons first saw computer screens displaying sets of three images, each with one, two or three shapes. Scarf rewarded birds for pecking in one-two-three order.

It took Scarf more than a year of sessions every day, workday and weekend, to get three pigeons' success rates up to 30 to 40 percent on ordering the three images. The way the exercise was set up, mere chance would have given the birds the correct answer only a bit more than 8 percent of the time, he says.

To test the birds, Scarf offered them pairs of shape clusters to peck. Birds had trained only up to three, but Scarf included all pairs possible with numbers one through nine. For the toughest challenge — when both numbers in a pair were unfamiliar from training — birds pecked the images in ascending numerical order about 74 percent of the time, matching the monkey score.



Pigeons rival rhesus monkeys at putting groups of shapes in numerical order. Here, a bird correctly pecks a cluster of eight squares before nine.

WILLIAM VAN DER VLIET

Molecules

6 billion | Types of knots known to be mathematically possible

Network predicts drug side effects

Might foresee adverse events before medications hit market

By Rachel Ehrenberg

Using a new mathematical approach, scientists have predicted drug side effects that typically aren't discovered until thousands of people have taken a medication. The technique is especially good at foreseeing side effects that show up after days or months of taking a drug, suggesting that a similar approach could help make drugs safer before they come to market and may even save lives.

Researchers started with a 2005 catalog of existing medications and their known side effects, such as heart attacks or sleeping problems. After linking drugs and their side effects into a network, the researchers instructed a computer to predict likely new connections between drugs and side effects. The program was able to predict 42 percent of the drug–side effect relationships that were later found in patients, the researchers report in the Dec. 21 *Science Translational Medicine*.

"Adverse drug events are very important and understudied," says Russ Altman, a biomedical informatics specialist at Stanford University who wasn't involved with the work. Before a drug ever gets to market it undergoes toxicology testing and clinical trials to establish that it is effective but not dangerous. These trials are often extensive enough to prove that the drug works, but not big enough to say anything meaningful about side effects, says Altman. So, many side effects aren't discovered until after the drug is on the market.

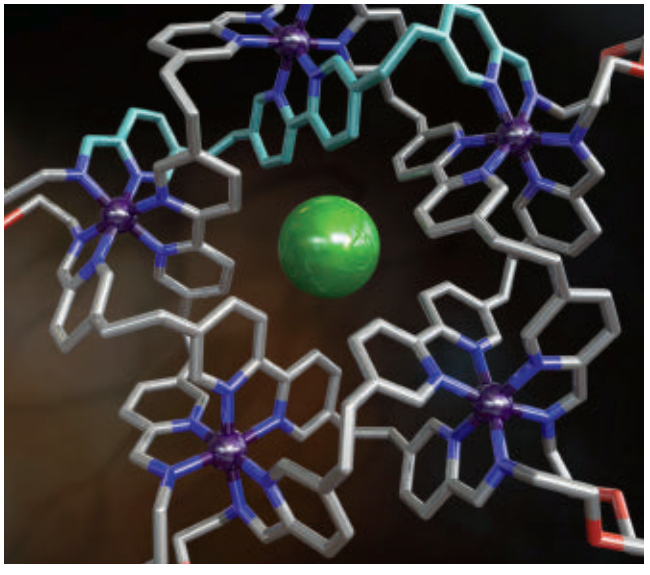
Drug side effects cause an estimated 770,000 injuries and deaths in the U.S. each year.

"You routinely find a whole bunch of annoying ones, and every now and then there's a showstopper," Altman says. An estimated 770,000 injuries and deaths in the U.S. each year are caused by drug side effects.

To clear some of the haze surrounding side effects, scientists from Harvard Medical School and Children's Hospital Boston created a network linking 809 medications to 852 side effects known as of 2005. The team also added information to the network on chemical properties, such as each drug's melting point and molecular weight, and where the drug does its stuff in the body. Using these data and relationships alone, the computer predicted side effects that were reported in later years, such as the seizure drug zonisamide causing suicidal thoughts in some people and the antibiotic norfloxacin's link to ruptured tendons. It also linked the controversial diabetes drug Avandia (rosiglitazone) to heart attacks, a connection that is supported by some research.

The additional chemical information, such as data describing molecular structure, didn't do much. The network diagram of the known relationships between drugs and side effects alone had more predictive power and fewer false positives than methods that added the additional information, the team reports.

"We were pleasantly surprised," says team member Ben Reis, who directs the predictive medicine group at Children's Hospital Boston. "The network encodes a lot of information from other worlds. Perhaps that's why it did so well."



ROBERT W. MCGREGOR

Molecule knots itself up

Chemists have tangled themselves a molecule whose 160 atoms loop over one another like a five-pointed star. The molecule's design, called a pentafoil, is the most complex knot that has been synthesized from chemical building blocks other than DNA. Knowing how to make it could lead to ways to make materials lighter, stronger or more flexible than before. "By knowing how to design types of knots, hopefully we can optimize these properties," says David Leigh, a chemist at the University of Edinburgh. He and his colleagues report the new knot in the January issue of *Nature Chemistry*. Leigh's team took negatively charged chloride ions and added ingredients such as positively charged iron ions and long chains of carbon and other atoms, then chemically programmed the whole thing to assemble itself. Five of the chains looped over one another and hooked up, along with five irons, with each chloride to create the pentafoil. —*Alexandra Witze*

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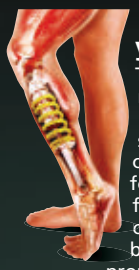

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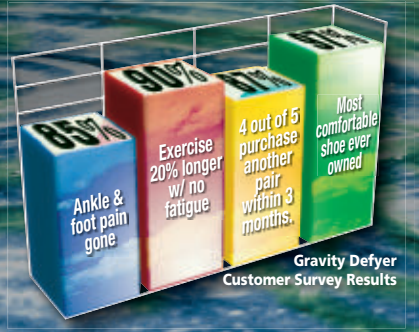

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Environment

"There's less wildfire in Africa than there has been in the last 4,000 to 40,000 years." —SALLY ARCHIBALD

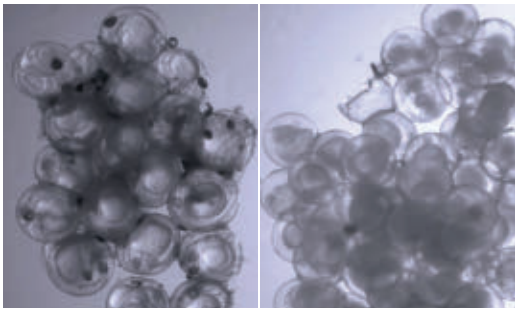
Sun-oil mix deadly for young herring

Fish embryos surprisingly vulnerable to 2007 SF Bay spill

By Susan Milius

A lethal combination of oil and sunlight proved unexpectedly toxic to herring embryos after a 2007 fuel spill in San Francisco Bay, virtually disintegrating the developing fish in the water.

Roughly 54,000 gallons of ship fuel spilled into the bay November 7, 2007, when the container ship *Cosco Busan* hit a tower supporting the San Francisco Bay Bridge. When herring spawned in the oiled waters in early 2008, researchers suspected the fish embryos would develop the heart troubles known from other spills, says environmental toxicologist Gary Cherr, director of the University of California, Davis' Bodega Marine Laboratory.



Healthy herring embryos (left) show pairs of eyespots in otherwise clear bodies. Embryos from water contaminated with bunker oil and exposed to sunlight are cloudy and torn, with no eyespots.

Swelling and malformed hearts did show up in herring embryos exposed to oil at depths greater than a meter. But embryos from shallower water were "liquefying before our eyes," Cherr says. Sunlight reaching embryos near the water's surface amplified the toxicity of something the eggs absorbed from the ship fuel, argue Cherr, John Incardona of the National Oceanic and Atmospheric Administration's Northwest Fisheries Science Center in Seattle and their colleagues. Their report on embryos in the bay appeared online December 27 in the *Proceedings of the National Academy of Sciences*. Results of lab tests have been scheduled to appear in *PLoS ONE*.

Chemists know from lab studies that oil's damaging effects can be intensified by light, a process known as phototoxicity. "The real question has been, is phototoxicity simply a laboratory artifact or is it important in the field?" says Mark Carls, a NOAA toxicologist and environmental chemist based at Auke Bay Laboratories in Juneau, Alaska. He says the new paper "clearly indicates that phototoxicity can happen in the real world."

In lab tests with zebra fish embryos in various oil-water brews, tissue breakdown started within minutes to an hour of exposure to sunlight. Yet embryos in the dark developed just the familiar slow doom of heart malformations, Incardona and his colleagues reported in 2010 in *Aquatic Toxicology*.

Incardona has yet to figure out which of the many bunker ingredients causes the embryo breakdown. Multiple suspects exist among a group of oil components called polycyclic aromatic compounds, which show up in affected embryos but hover elusively around current thresholds for detection, Incardona says.

Ancient savanna had more fires

Land-use practices control burning in African landscape

By Alexandra Witze

Africa, whose iconic savanna landscapes were shaped by fire, actually has fewer burns today than thousands of years ago, a new study suggests.

"There's less wildfire in Africa than there has been in the last 4,000 to 40,000 years," says Sally Archibald, an ecologist at the Council for Scientific and Industrial Research in Pretoria, South Africa, who led the team that did the research. The work appears online December 19 in the *Proceedings of the National Academy of Sciences*.

The new study is "the first to systematically analyze the different ways in which humans would have altered ancient fire regimes," says William Bond, an ecologist at the University of Cape Town in South Africa.

The scientists looked at satellite data on how often fires burn today, and archaeological data in the form of charcoal dug from across the continent. By simulating how fire spread both now and in the past, Archibald's team pieced together a picture of how fires changed as *Homo sapiens* appeared and spread across Africa.

Surprisingly, some factors — such as how often people lit fires — turned out to be not very important in dictating how fire spread. Far more significant, Archibald says, is how pastures or roads break up the countryside. Such landscape changes have kept fires from spreading as much as in the past.

How widely savanna fires spread in Africa depends on how people use the landscape, new work suggests.

FROM TOP: CAROL VINES, UC DAVIS BODEGA MARINE LABORATORY; LYNN TROLLOPE/SAVFIRE

Genes & Cells

$74 million | NIH funding of human embryonic stem cell research, 2007

$128 million | NIH funding of human embryonic stem cell research, 2012 (estimate)

Monkeys made from six embryos

Chimeras reveal prospects, limits of embryonic stem cells

By Tina Hesman Saey

For the first time, scientists have created primates whose cells carry one of several sets of genetic instructions instead of one consistent assemblage of DNA. The three rhesus monkeys are chimeras, each derived from conglomerates of cells from up to six genetically different embryos.

Researchers working with stem cells from mice and other animals use the creation of chimeras as the gold standard for showing that isolated embryonic stem cells have the power to generate any of the body's many cell types, a capability that could make them medically useful. The evidence that human and monkey stem cells are able to blossom into any cell type has been mostly circumstantial.

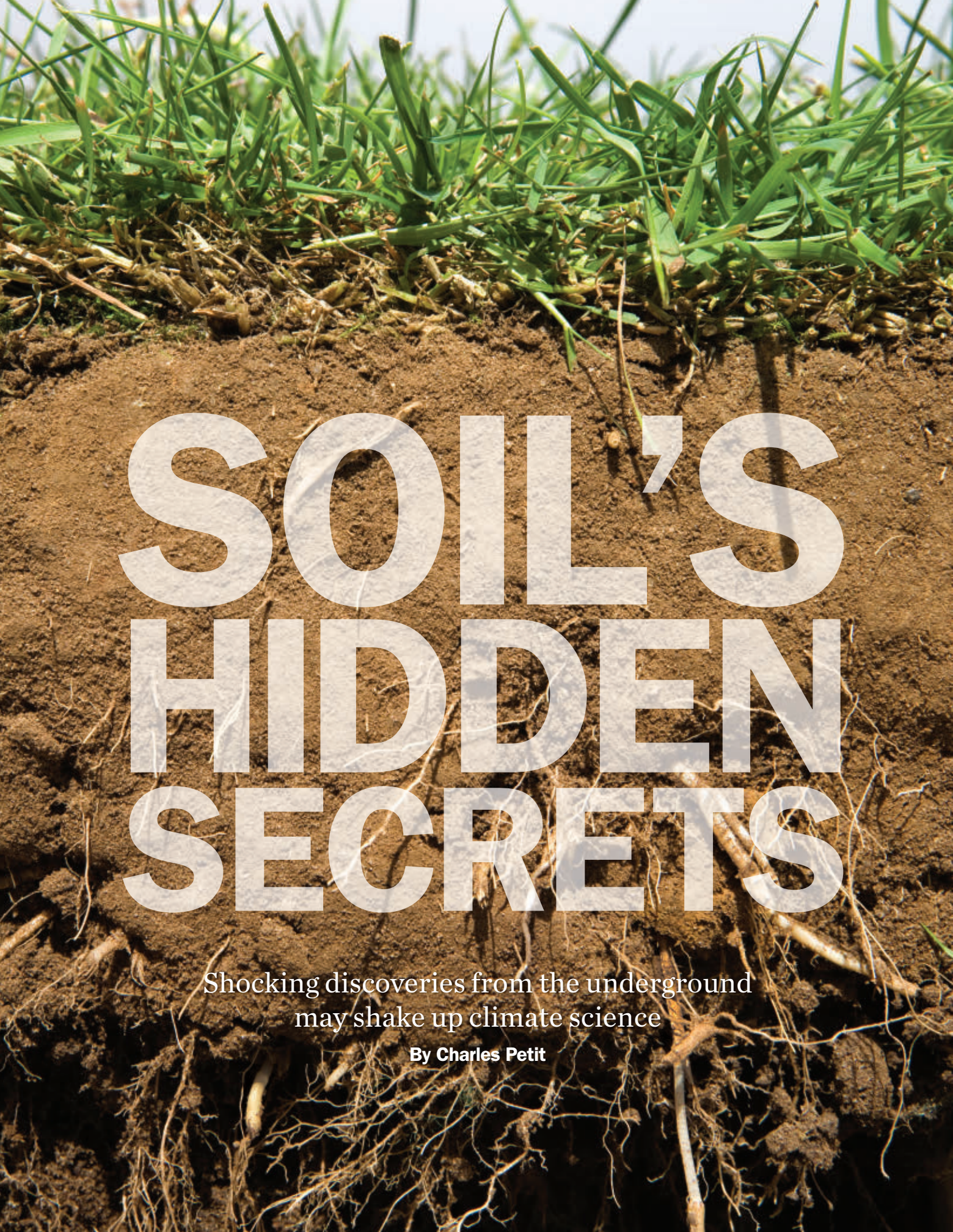
Baby rhesus monkeys Roku and Hex are chimeras, created by combining cells from up to six embryos.

"So far we just assume they are," says developmental and stem cell biologist Shoukhrat Mitalipov of the Oregon Health & Science University in Beaverton, who led the new study published online January 5 in *Cell*.

In the new experiments, Mitalipov and his crew found that neither embryonic stem cells that had been grown in the lab nor freshly harvested ones could incorporate themselves into a developing primate fetus. The results "may show that what we have now is not as potent as we think," Mitalipov says.

To create the chimeric animals, the researchers had to take a step backward from the stage of development when stem cells are normally harvested, fusing together up to six four-cell embryos.

The new work shows that it's unlikely scientists working with embryonic stem cells could inadvertently grow a human fetus in the lab, a concern among critics of stem cell research, says developmental biologist Gerald Schatten of the University of Pittsburgh School of Medicine. It also means stem cells are unlikely to create tumors or grow into the wrong type of cell once implanted in a patient.



SOIL'S HIDDEN SECRETS

Shocking discoveries from the underground may shake up climate science

By Charles Petit

Scientists around the world are closing in on some dirty truths about carbon emissions and climate change.

A cover-up is plainly involved; it's not about scandal but dirt itself. That means soil, the upper layer of earth typically a few feet but sometimes 10 feet or more thick, usually black or dark brown. Below is rock or other material that contains little of the organic matter, derived mainly from plants, that gives good farmland its fertility.

The last few decades have seen a string of discoveries that not only upset long-cherished theories about soil, but also could lead to ways of improving agriculture by altering factors that control soil quality, say to favor certain soil microbes over others.

Perhaps more important in the long run, the findings will bring a far deeper understanding of soil's response to climate change. This new understanding may include whether soil will speed up the pace of warming or slow it down as atmospheric concentrations of carbon dioxide and other carbon-rich greenhouse gases build up. Soil scientists don't question the urgency of dealing with fossil fuel emissions, but forecasting the course of global warming depends on understanding how the planet deals with carbon. Soil, for now, is a major wild card.

Soil organic material is about 60 percent carbon. Though highly fertile soils may contain only 1 to 3 percent organic material, a few kinds — in peat bogs or Arctic tundra — may be all compacted vegetation. In all, soil holds more than three times as much carbon as the amount found in aboveground vegetation or in the atmosphere. Carbon exists not only in living roots and myriad microbes, worms, fungi and other organisms that live on and near those plant parts, but also in accumulated material left behind by generations of plants that have come and gone.

If the bank of carbon held in the world's soils were to drop by just 0.3 percent, the release would equal a year's worth of fossil fuel emissions. But researchers need to answer many questions to learn whether and how the balance could tip. Why do some soil organics, such as rotting leaves near the surface and some several feet down, last only a season or two, while nearby there may be matter tens of thousands of years old or more? Microbes, most scientists agree, are key in decomposing such materials, but the factors that control the species at work, and why they may thrive in one spot and not another, are still mostly a mystery.

Recent research watching plants grow and soil carbon levels change in both natural and controlled settings outdoors — and in labs using advanced tools to scrutinize molecule by molecule the soil's minerals and organic debris — has led to a quiet revolution in soil science.

One old idea in particular is now in question, with the challenge culminating in a recent report in the journal *Nature*. Under fire is the belief that soil remains stubbornly soil, a large fraction of its organic materials resistant to decay because of the accumulation of large molecules called humic substances. One professional society devoted to the substances is in the odd position of hearing colleagues label as fiction its primary topic of study.

A new paradigm, that the persistence of soil organic matter is controlled by the surrounding microbial ecosystem, means that the huge store of carbon in soil may be less stable than has been thought. That also means, though, that manipulating conditions in the soil, particularly of forests managed for timber or paper or in agriculture, could improve the ground's ability to hold onto a larger share of the carbon cycling through.

"A major question is before us," says Margaret Torn, head of the climate and carbon sciences program at the Lawrence Berkeley National Laboratory in California. "How does our new molecular understanding tell us about how soil will respond to climate change?"

Breaking ground

Starting in the 1990s, scientists began to see one big assumption crumble. They had expected that just as the ocean absorbs much of the carbon that the burning of fossil fuels releases into the air, so should the soil store more carbon. Plants, invigorated by the fertilizing effect of carbon dioxide, would grow more roots and exude more proteins, sugars and other such organic compounds into the soil.

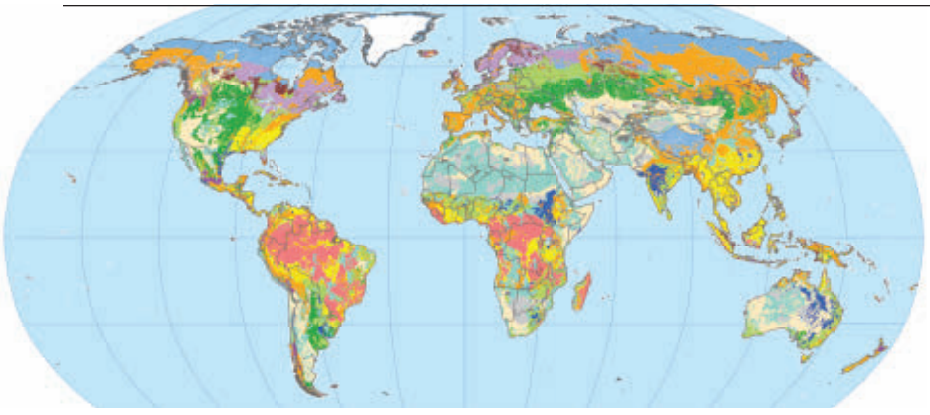
Instead, "we are recognizing more mechanisms of feedback," says Bruce Hungate of Northern Arizona University in Flagstaff. "And most of them tend to make climate change worse." While much of his time is spent on soil and nutrient dynamics in the southwestern United States, one project that Hungate joined in 1998 at the Kennedy Space Center in Florida sticks in his mind. It was in a stand of coastal scrub oak from which workers occasionally watched space shuttles roar toward orbit. He and researchers from several institutions, led by botanist Bert Drake of the Smithsonian Environmental Research Center in Edgewater, Md., mostly watched what happens to oaks in the air of the future.

The researchers built open-topped enclosures about 10 feet across around individual trees. Then they pumped in a continuous breeze of CO_2, raising the concentration around the foliage to about 700 parts per million, a level expected within 70 years or so. (For comparison, 2011 levels were at 389 ppm, up from 275 ppm before the 19th century's industrialization.)

Periodically, the researchers pulled out cores of dirt up to 10 feet long, by driving hollow steel pipes as big around as a soup can into the soil by hand with a heavy slide hammer that banged the core sections down. After 11 years, the team dug up the trees. The tests revealed that when CO_2 went up, the trees indeed grew more. But to the team's surprise, carbon in the soil fell — by as much as 15 percent near the surface.

In 2007, in the *Proceedings of the National Academy of Sciences*, the researchers reported that soil microbes and fungi got busier right along with the thriving trees. The scientists call the process "priming," but you might also call it serving appetizers. "Roots

OPPOSITE PAGE: BELTERZ/ISTOCKPHOTO



Different dirts Soils are divided into orders depending on their characteristics and the environment in which they form. While the moderately leached alfisols are common in forests, organic histosols are prevalent in peat bogs. Finding out what microbes reside in each soil type and how those organisms react when the ground warms is key to understanding soil's role in climate change.

naturally exude what the microbes regard as food, including sugars," Hungate says. "They do that even more when there is more CO_2. But what happens is that while the bugs eat the new material, they also start eating the other stuff that has built up. It is like if I served you a soda with lunch, you'd start eating the table, too." And when microbes eat organic matter, waste products include carbon dioxide and methane, which quickly make their way out of the soil and into the atmosphere.

Faced with a string of similar surprises and contradictions, in October 2009 the European Science Foundation rented a former Carthusian monastery in Switzerland founded more than 850 years ago and now called the Ittingen Charterhouse. Fifteen eminent soil researchers gathered there, calling themselves the Lake Constance Think Tank on Global Change and Feedback from Global Carbon Dynamics. "The Europeans really know how to host a workshop," says Torn, one of the think tank's leaders.

The participants spent three days reviewing literature and listening to one another's talks, much of them about new discoveries using advanced microscopes, high-energy X-ray beams and ion probes that sandblast soil at the atomic scale to reveal its molecular structures.

Afterward, the meeting's primary organizer, Michael Schmidt, took a sabbatical from the geography department at the University of Zurich to join Torn at Berkeley. The two were lead writers on a summary paper: "Persistence of soil organic matter as an ecosystem property," which appeared in the Oct. 6 *Nature*. "New insights gathered across disciplines ... have challenged several foundational principles of soil biogeochemistry and ecosystem models," the paper declared. In other words, a lot of what soil scientists thought they knew is just plain wrong. Among the conclusions:

- So-called humic soil substances, large compound molecules highly resistant to microbial assault and a focus of soil research for a century or more, are either rare or absent in detailed molecular and microscopic examination of soil. Previous studies have extracted small organic molecules from soil with acid and alkaline washes, while dark, resistant matter has been left behind. That dark matter was claimed as evidence of a distinct complex of interlinked molecules, the humic substances. But recent research has found no direct evidence for meaningful amounts of such distinct materials.
- Plant sugars, believed to be among the shortest-lived of organic materials released by plants in soil, can and do last for decades.
- Leaf and other surface litter, once believed to be the main way plant organic material gets into soil, is rapidly reduced to basic minerals by microbes before much of it can be incorporated deeply into the soil. Most of the fresh carbon enters soil deeper, released from living roots or left behind after roots themselves die.
- While traditional soil scientists, often serving the needs of farmers, paid most attention to the ground's top foot or so with the belief that that is the zone where organic material inputs and exhaustion are key, the actual carbon cycle extends much farther down. In the Florida scrub oak study, after 10 years' exposure of plants to boosted CO_2 levels, soil cores from more than two meters down had 5 percent of their carbon traceable to the added CO_2. At such depth much of the carbon is 10,000 to 20,000 years old. While the average age of the carbon still increased with depth, the movement of some of the carbon so deep, so fast, was a surprise, Hungate says.
- Burnt organic matter, often called biochar, remains mysterious in its mode of decomposition. But dating of old and new char, which can account for up to 40 percent of carbon in some grasslands and in boreal forests, shows that the material decomposes faster than remaining bulk organic matter — with 25 percent lost every century.

Humic heresy

Every one of the discoveries contributes to what will ultimately become a new view of how carbon in the atmosphere, the key to human-driven climate change, cycles through the soil. But the downgrading of humic substances is easily the most painful of the findings for some scientists to hear.

USDA, NRCS

Among attendees at the Lake Constance workshop was José A. González-Pérez of Seville, a member of Spain's Higher Council for Scientific Research. He is also a senior member of the International Humic Substances Society and was chairman of the 900-person group's 2010 meeting in the Canary Islands.

At the workshop, he had argued for recognition of humic substances as vital players in soil dynamics, stabilizing much of the carbon against decay and keeping it tucked underground. He resigned from the team after seeing the draft of the report Torn and Schmidt were putting together.

González-Pérez says it was hard but necessary to bow out, even though it meant "bye-bye to my *Nature* paper." He added in an e-mail: "Now my pain is double because presumably this paper will be highly cited due, in my opinion, to the outstanding and spectacular conclusions derived from a spurious use/review of the literature."

The society's chairman for samples collection, Paul R. Bloom of the University of Minnesota's Soil, Water and Climate Department in St. Paul, says "humification is real." For one thing, he says, humic substances are what make soil brown. While some of the old beliefs about their exact structure may need revision, and humic substances may not be "in as big pieces as we originally thought," the molecules remain distinctly different from what the roots originally put in the soil.

However, another soil science researcher, Claudia Czimczik of the University of California, Irvine, is satisfied: "I think the concept of humic substances to understand soil organic matter dynamics should have been declared dead a good decade ago.... The whole idea that molecules fuse together into giant humic molecules in soils does not make much sense energetically, and many of the proposed compounds haven't been detected in soils." She thinks humic substances specialists, in fact, may have manufactured the material themselves by the harsh chemicals they used to extract evidence for it.

Life below

While the debate over humic substances continues, there's a point of agreement: Soil science has a big job do to.

A closer look at soils and a greater breadth of data are needed to re-create scientific understanding from the ground up. Much of that dirty work will depend on figuring out what kinds of microbes are at work where. Few expect ever to have full lists of the myriad species in the soil; one gram of topsoil may contain a billion individual microbial cells encompassing tens of thousands to a million different species. Only a tiny fraction of those species have been cultured in labs or even named. But researchers hope at least to group the organisms by types that eat about the same things, multiply at the same rates and excrete the same gases and wastes.

Among the biggest unknowns is the future of Arctic soils, rich in organic material but also, for now, largely in a frozen state. More than 1.5 billion tons, an estimated half of all soil carbon, may be locked in the Arctic. As more of its permafrost melts, microbes conceivably may cause rapid decomposition.

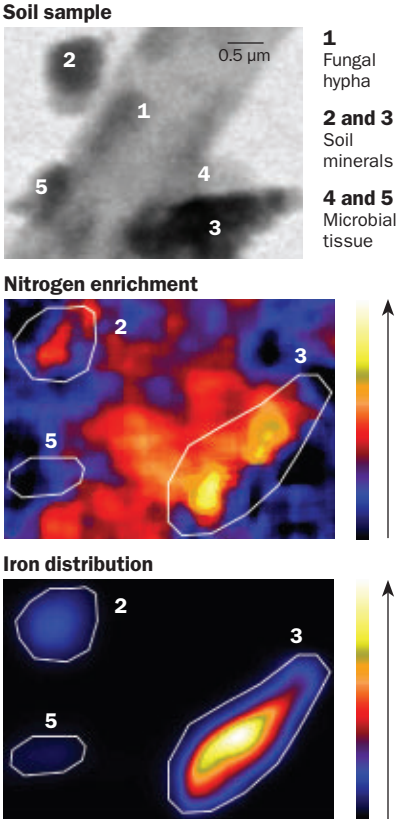
In *Nature* in December, a team of researchers at the Department of Energy's Joint Genome Institute in Walnut Creek, Calif., and colleagues reported one such microbe's draft genome — put together from DNA acquired from the semifrozen dirt in an Alaskan black spruce forest. The Alaskan microbe carries genes tuned to transform organic matter into methane, a finding that may one day help provide a vivid picture of what will happen as soil conditions change.

One person eager for such results is Inez Fung, director of the Institute of the Environment and a professor of atmospheric science at the University of California, Berkeley. For nearly 30 years she has worked on ways to account for how land and vegetation release or soak up carbon. She is part of the team continually refining a global circulation model maintained at the National Center for Atmospheric Research in Boulder, Colo. Such computer programs contain equations linking the behavior of plant cover, oceans, snow cover and numerous other factors as CO_2 in the air rises and the climate warms up.

"Soil is a big deal," Fung says. While she believes that the conclusions presented by the Lake Constance Think Tank are correct, she says scientists don't yet have the data needed to fully understand how soil's role will change as the Earth warms.

During a visit to her campus office, she pulled up a map on her computer showing the global distribution of soil types. It looked bewilderingly complex, covered in soil groups with names such as alfisols, common in forests, and histosols, found in peat bogs. But the map was a simple version; each group has

Soil inspection Teams are beginning to study soil in its natural environment without chemical alterations. In the sample below, a fungal hypha sits amid soil minerals and microbial tissues. Enriching fungal biomass with a nitrogen isotope revealed patterns of nitrogen enrichment and iron distribution suggesting that nitrogen from fungal cell walls is digested by microbes and preferentially deposited on iron oxide surfaces.



JENNIFER PETT-RIDGE, MARCO KEILUWEIT AND JEREMY BOUGOURE

Digging in

Sometimes the best way to understand how much carbon is in the soil and how it gets in and out of the atmosphere is to grab a shovel. Among those doing his part in the outdoors is Kurt Johnsen, a plant physiologist for the U.S. Department of Agriculture's Forest Service facilities at the Southern Research Station in Research Triangle Park, N.C.

His crews take trees down, weigh them, then dig up the roots and weigh them too (excavation shown at right).

The work, aimed at finding out how best to manage carbon in woodlands, including those at military reservations, is done under contract with the U.S. Department of Defense. The project managers include faculty at Auburn University and the University of Florida. Sometimes, the tools are those of timber cutters and construction workers: chain saws, backhoes and mattocks swung with a lot of sweat in the hot sun. Among the stranger devices is the air spade. It is a jackhammer with no jack but, rather, a stiff stream of compressed air to blow soil off roots as they are dug. "It'll take me and a crew of eight men all day to get one tree out," Johnsen says. The team digs down for only a few feet around most of a tree, but excavates six feet or more straight under to get the bulky, often forked taproots.

A single pine tree 60 feet tall and a foot or more wide at chest height can contain a metric ton of dry biomass, roughly half carbon. Most of the biomass is plain to see: The trunk, branches and leaves are made of organic matter. From a fourth to half of a tree's carbon-rich organic material, though, is out of sight in the roots.

Johnsen's research station is in the heart of loblolly and, increasingly lately, longleaf pine plantation country. America's Southeast, with its vast groves of these quick-growing trees — destined to be lumber or paper — is the most intensely managed forest area in the world. So it makes an ideal, controlled laboratory for studying how trees take carbon, as CO_2, from the air, grow roots and exude a lot of materials made from carbon from those

USDA FOREST SERVICE

roots, as well as for studying how fast the material gets recycled back into the air.

The project has cut down (and pulled up) close to 200 trees, freeing them from the loose soils of North Carolina's Sandhills region and the heavy clay in the upland Piedmont to the west. Researchers are trying to see whether they can gain clues to the underground mass from the form of the visible portion. Because that may prove futile, they are also comparing the pulled-up root mass to fuzzy underground measurements made beforehand with ground-penetrating radar — sometimes dragged on converted skateboards. The roots, full of water, stand out particularly well in dry soils.

The goal is to find whether nondestructive methods, once calibrated, could allow researchers to monitor underground carbon quickly, and without killing any trees, so as to track carbon buildup as forests grow.

The 52-year-old Johnsen recalls that when he was in school — undergraduate at the University of Vermont with a Ph.D. from the University of Georgia — "people figured it's in the vegetation where all the action is," as leaves fall and decompose into soil. "But it turns out a lot of the important questions and answers with the trees are belowground. Unfortunately, it's a pain to dig them up." — *Charles Petit*

multiple suborders such as, for alfisols, the cryalfs formed at high altitudes and in other cold regions or the aqualfs formed in warm, wet regions.

There are scores of such suborders. Each has its own place, its own slot or box, in Fung's computer program. But without data on what microbes are found where, and how they react to changing temperatures, she can't give life to the mathematics to predict the future global scenario.

Some microbes called methanogens, for instance, exude as waste the powerful greenhouse gas methane. Others, methanotrophs, consume it. "I need to know how the methanotrophs and methanogens compete," Fung said.

She hopes studies like the recent one by the Joint Genome Institute will start filling such details in. "There are people who can do DNA on a chip, can tell what species of microbe are in soil really fast," she said. "If they get data just on the 12 orders of soil that tells me what would be the differences in properties in the microbes, I would be very happy." She glanced again at her computer screen. "I have the soils mapped and have boxes in the model for them, you know. What do I put in the boxes?" ■

Explore more

- M.W.I. Schmidt *et al*. "Persistence of soil organic matter as an ecosystem property." *Nature*. October 6, 2011.
- For more on the different soil types from the University of Idaho, visit soils.cals.uidaho.edu/soilorders

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The Digital Camera REVOLUTION

Instead of imitating film counterparts, new technologies work with light in creative ways

By Rachel Ehrenberg

Take a grainy, blurred image of a formless face or an illegible license plate, and with a few keystrokes the picture sharpens and the killer is caught — if you're a crime-scene tech on TV. From Harrison Ford in *Blade Runner* to *CSI*, *Criminal Minds* and *NCIS*, the zoom-and-enhance maneuver has become such a staple of Hollywood dramas that it's mocked with video montages on YouTube.

In real life, of course, no amount of high-techery can disclose data not captured by a camera in the first place. But scientific advances are now gaining ground on fictional forensics. The field known as computational photography has exploded in the last decade, yielding powerful new cameras capable of tricks once seen only in the labs of make-believe.

For a long time camera makers and operators focused mostly on getting more pixels. But the "pixel war" is over, says Marc Levoy, a pioneer in computational photography at Stanford University. Today's manufacturers are looking beyond good resolution.

Low-cost computing and new algorithms, combined with fancy optics and sensors, are drastically changing how cameras re-create the world. Scientists have recently devised a camera that could spot a culprit by peeking around corners; another might divulge the identity of an attacker by collecting information reflected in a victim's eyes. Other developments, some of which are making their way into commercially available cameras and smartphones, won't necessarily help snag a bad guy but can turn anyone with a camera into a photographer extraordinaire.

Researchers are, for example, finding ways to clean up pictures so that smudges or window screens disappear. The addition of unconventional lenses means pictures can be refocused long after a shot is taken. And the "Frankencamera," recently developed at Stanford, is designed to be programmable, so that users can play around with the hardware and the computer code behind it. Such work may lead to previously impossible photos, researchers say — images that have yet to be imagined.

"The possibilities are not readily apparent at first," write MIT's Ramesh

FROM LEFT: CAMERA 2.0 PROJECT/STANFORD UNIVERSITY; COLUMBIA COMPUTER VISION LABORATORY; JONAS PFEIL/JONASPFEIL.DE/BALLCAMERA; PELICAN IMAGING; LYTRO

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1. A camera built from off-the-shelf parts, dubbed the Frankencamera, is programmable. The team that designed it has also released the code needed to manipulate the commercially available Nokia N900.

2. The BigShot camera comes as an educational kit. During assembly, kids will learn about optics, mechanics, electronics and the human eye. Researchers hope to have the kit on the market within two years.

3. A throwable, panoramic ball camera developed by researchers at Technische Universität in Berlin snaps a full spherical panorama. There's a design, but no word on investors—yet.

4. The Pelican camera, designed to fit inside a smartphone, has an array of 25 lenslets that capture a scene's entire light field. A release date hasn't been announced.

5. Lytro ($399 for 8GB, $499 for 16GB) allows the photographer to refocus at will after a shot has been taken.

Raskar and Jack Tumblin of Northwestern University in Evanston, Ill., in a comprehensive textbook on computational photography set to be published this year. "Like a long-caged animal in a zoo destroyed by a hurricane, those of us who grew up with film photography are still standing here in shocked astonishment at the changes."

Caught on camera

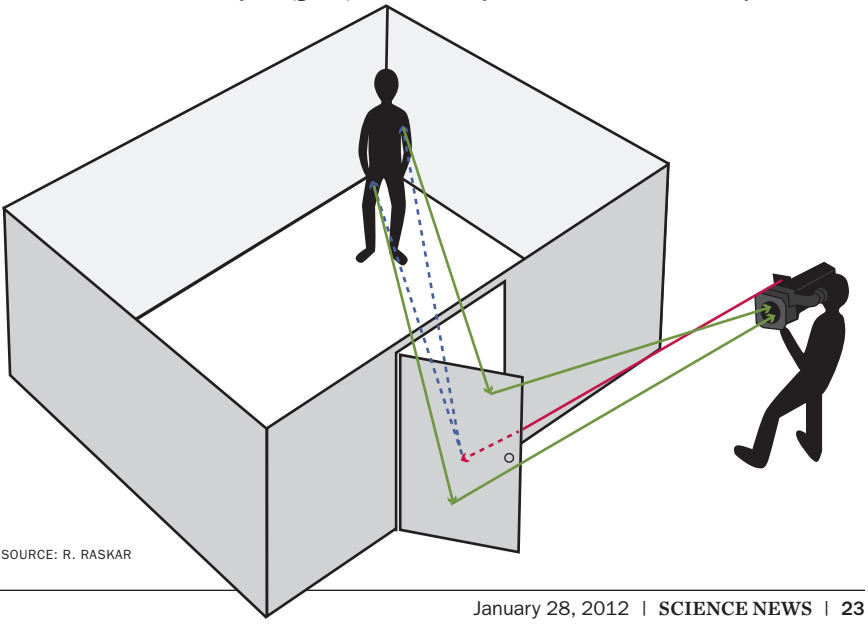
Until a few years ago, most digital cameras were basically film cameras, just with an electronic sensor doing the job of the film. These "filmlike" cameras use a lens to capture light from a 3-D scene, faithfully re-creating it as a 2-D image.

But in a digital camera, there's no need for that re-creation to be faithful. Digital cameras have a tiny computer that processes incoming optical information before it is stored on the memory card. That computer can transform the scene, measuring, manipulating and combining visual signals in fundamentally new ways. With the help of tricked-out optics—such as multiple lenses in different arrangements—photographers can not only perfect the traditional recording of their lives, but they can also manipulate those keepsake shots to get something strange and different.

Advances in math and optics are now developing hand in hand, says Shree Nayar, head of the Computer Vision Laboratory at Columbia University. "When you worry about both of them at the same time, you can do new and interesting things."

One new and interesting thing is the ability to look around corners, beyond the line of sight. Developed in 2009 by Raskar, MIT graduate student Ahmed Kirmani and colleagues at MIT and the University of California, Santa Cruz, a new camera with a titanium-sapphire laser for a flash shoots brilliant light in pulses lasting less than a trillionth of

Echo giveaway Researchers have recently designed a camera that can see around corners. Laser light leaving the camera (red) bounces off a door (blue) before hitting hidden objects. Echoes from the hidden objects (green) make their way back to the camera for analysis.



SOURCE: R. RASKAR

ADAPTED BY JANEL KILEY

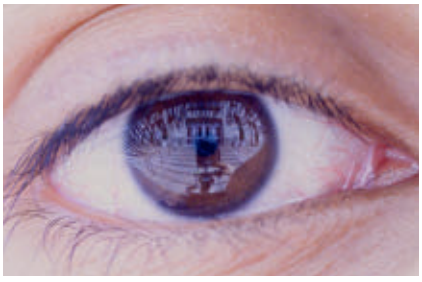
a second. After the light ricochets off objects, including those not visible to the photographer, the camera collects the returning "echoes." The camera then analyzes the photons that return and can estimate shapes blocked by a wall or other obstruction.

The technology might lead to devices that allow drivers to see around blind corners or surgeons to get a better view in tight places. It could also help first responders plan rescues in dangerous situations and crime fighters spot hidden foes.

Another technology that might aid real-world sleuths is the "world in an eye" imaging system, which can re-create a person's surroundings from information reflected in a single eye. Using a geometric model of the eye's cornea, Nayar and colleague Ko Nishino, now at Drexel University in Philadelphia, created a camera that detects where the cornea and the white of the eye meet. Computations then turn the cornea's reflection of a fish bowl–like image into a map of the environmental surroundings projected on the person's retina.

Using information on the tilt of the camera and the person's eye positioning, whatever the person is looking at can be pinpointed, making the technology useful for eye-tracking studies where researchers want to know what a participant is paying attention to. The technology (which is available as a software package from the Computer Vision Laboratory) is also helping people look into the past. One photographer has been assessing reflections in the eyes of old photographs, exposing a blurred scene reflected in the eye of an old man in an 1840 portrait.

Photo of a person's eye



Environmental map from the cornea

Retinal image

From an image of the eye, researchers at Columbia University can re-create exactly what a person is looking at.

COMPUTER VISION LABORATORY/COLUMBIA UNIV.

Picture perfect

If just capturing precious moments is more your style, many researchers, Nayar included, are exploring ways to enhance pictures taken for the more traditional purpose of archiving one's life. There are methods for getting around that annoying shutter delay that makes you miss your shot, for deblurring moving objects and even for erasing raindrops that obscure what a picture was meant to capture.

Such tricks are gradually making their way into commercial cameras, or being made available as downloadable apps for use with smartphones. One new camera dubbed Lytro, developed by Ren Ng for his dissertation at Stanford, can readjust the focus post-shoot, so a picture can clearly render what's nearby or far away.

Lytro's trick is it that it employs "radically different optics," says Stanford's Levoy, who worked on those optics with Ng.

In between the main lens and the sensor, Lytro has an array of tiny lenses called lenslets that capture an entire light field — the intensity, color and direction of every ray of incoming light (in this case, that's 11 million rays). Whereas a traditional camera captures some of the light leaving any one point in a scene and focuses it back together on a single pixel on a sensor, the lenslets distribute the light so it is recorded in separate pixels. This spread of information across pixels is encoded in the image, making refocusing later possible.

Lytro became commercially available last year, and another light-field camera may soon be available in smartphones. Last February Pelican Imaging announced a prototype for mobile devices that has an array of 25 lenslets. Like Lytro, Pelican promises images that can be refocused. But unlike Lytro's boxy shape, this version would fit in the slender confines of a cell phone.

Arrays of full cameras (not just the lenses) also allow for interesting manipulations. When packed close together, the cameras approximate a giant lens, which means much more light is available for manipulating. Photos can thus be created with a shallow depth of field so that the photo's subject is nice and crisp and the background is blurred, freeing the image from distracting clutter. A giant lens also means that a photographer can capture enough light from different angles to blur out foreground objects like foliage or venetian blinds, in effect looking around them. One of Stanford's large-camera arrays has 128 video cameras set up 2 inches apart. The arrangement is like having a camera with a 3-foot-wide aperture.

Tweaks to a camera's back end are also improving documentary potential. Image sensors have become much better at capturing light, so cameras can take many more pictures per second. A high frame rate combined with complex math means the camera can snap many versions of the same picture at

different exposures and then merge them for the best results or select the best of the single images, a trick known as high dynamic range imaging.

New cameras can also deal with shutter lag. When set in a particular mode, the camera begins taking a burst of photos and temporarily saves them. The photographer gets the typical shot (the one taken when the shutter is clicked) as well as a series of shots from before and after.

"It's something I've always wanted in a camera — for it to start taking pictures before something interesting happens," says Tumblin. "So when your daughter is blowing out her birthday candles, you have a sequence of shots, one right after the other."

Made to order

It's all well and good that camera manufacturers are getting around to incorporating such advances, Levoy says. But he has higher hopes — that consumer cameras will one day be programmable, giving users the power to get exactly what they want out of the device.

"I came out of computer graphics where anyone can play around," Levoy says. "The camera industry is not like that. It's very secretive."

While every digital camera has a computer inside, it's usually locked in a black box. You can't get in there and program it. Several hacking tools exist for liberating the code of particular cameras, but Levoy and his colleagues wanted to play around with settings without resorting to such measures. So Levoy and colleagues built the programmable Frankencamera.

Dealing with commercially available cameras "was just a painful experience," says Andrew Adams, who worked with Levoy and is now at MIT. "So after getting sufficiently frustrated at the programming that exists, we decided to make our own camera."

The Frankencamera started out as a clunky black thing built with off-the-shelf components (hence the "Franken"). But in the spirit of computer science, the camera is easy to program, running on Linux-based software. With a little effort, the camera can be made to, say, use gyroscope data to determine if it is moving when a picture is taken. If so, it can select the sharpest photo from a bunch that are taken, an application Adams calls "lucky imaging."

Nokia was interested enough in the Frankencamera to help researchers make their computer code compatible with the Nokia N900. The researchers began using the N900 in the classroom and have been shipping it around the world to other academics in the field of computational photography.

"The first assignment was to replace the autofocus algorithm," says Adams. "It was so cool; we gave them a week and they came up with better things than Nokia."

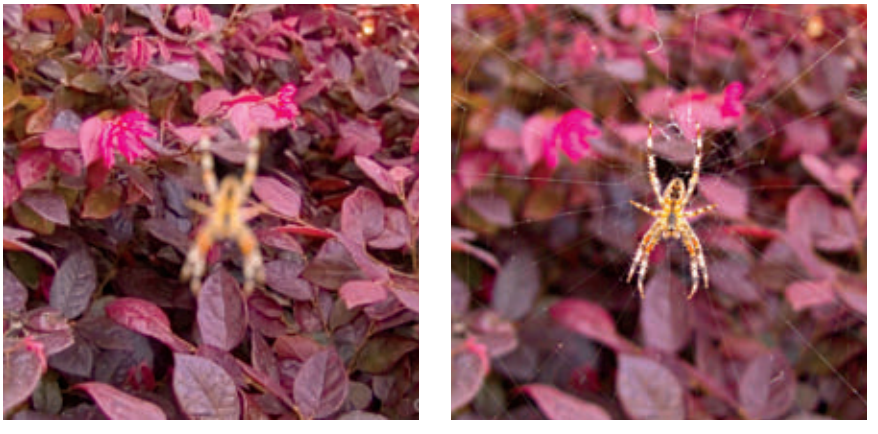
One student took several pictures over circular objects from above and programmed the camera to average the pictures together, yielding an image that normally could be captured only with a much larger lens, says Adams. Several other manipulations have been explored, such as panoramic stitching, high dynamic range imaging and flash/no-flash imaging, which combines shots taken with and without a flash to create a photograph that displays the best of both. The Frankencamera team released its code in 2010, so anyone can add these capabilities to the Nokia N900.

An app called SynthCam can make shots of buildings (Stanford quadrangle shown) look like miniature models.

The camera has also been set up for "rephotography," the retaking of a previously taken photo, historic or otherwise. The camera looks for distinguishing features in a scene, such as corners, and directs the photographer with arrows to align the camera precisely, creating a second version of the original picture but in a new season or new time in history.

With all the new souped-up cameras rolling out, the dangers of shaky hands or poor lighting are rapidly becoming concerns of the past. And the ability to make a picture bizarre, or shocking, is now available to anyone with the right smartphone and app. But once Frankencameras and similar build-your-own devices are in the hands of enough people, the creative possibilities balloon. You name it, programmers will find a way to do it.

"There's a catchphrase," Adams says: "Computation is the new optics." ■

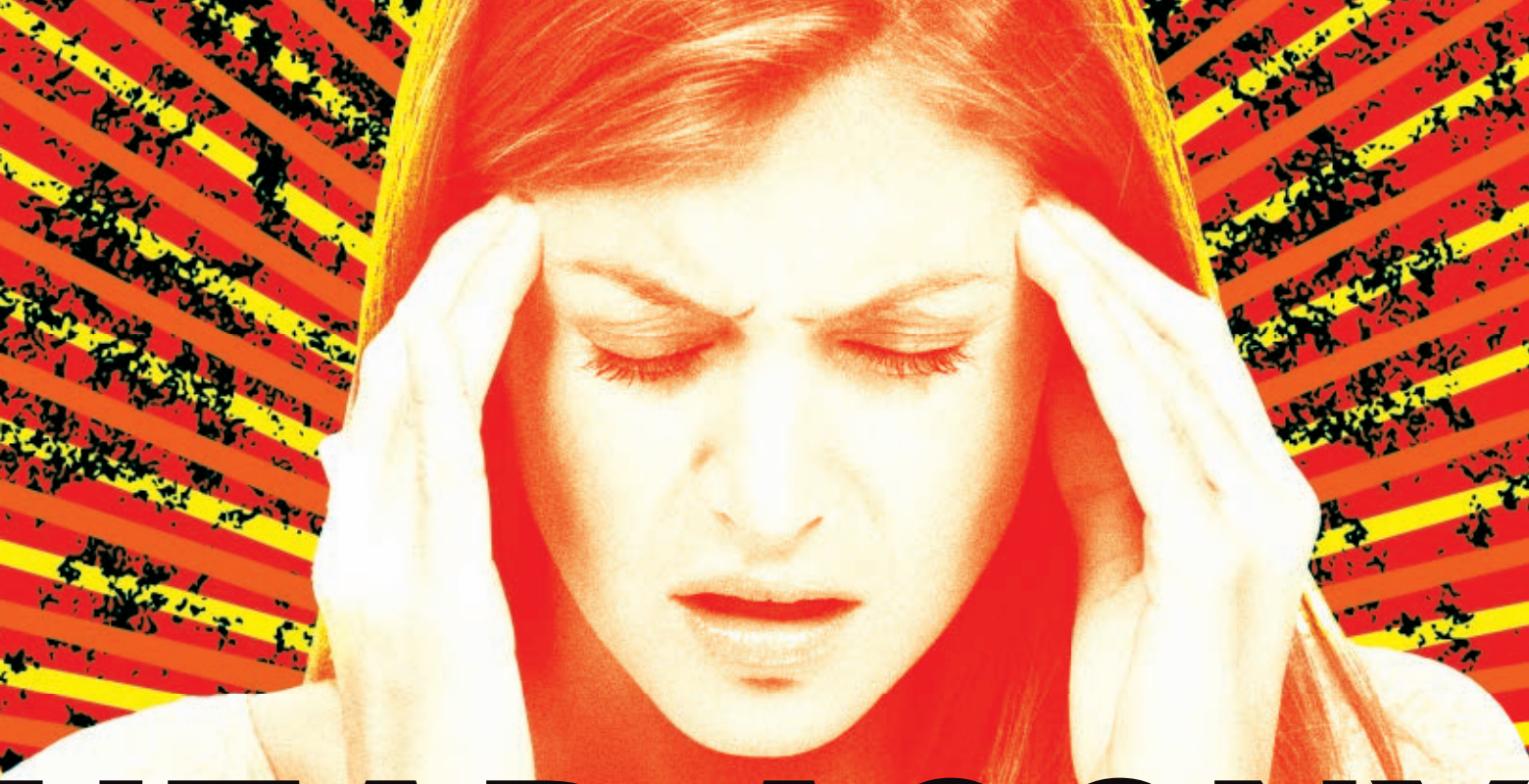


With the Lytro, a photo can be refocused after it is taken. A bit of adjusting shifts the focus of a shot from background leaves (left) to a spider and its web (right).

FROM TOP: M. LEVOY/STANFORD UNIV. COMPUTER GRAPHICS LAB; ERIC CHENG/LYTRO.COM

Explore more

- Columbia's Computer Vision Laboratory: www.cs.columbia.edu/CAVE



HEAD AGONY

Jumpy cells may underlie migraine's sensory storm

By Laura Beil

When Lewis Carroll sent Alice down the rabbit hole, she encountered a strange and twisted land with distortions of size and time. Some headache experts see something else — the possible ghosts of the author's migraines, which can leave victims temporarily blinded, nauseated, hallucinatory, numb, unable to concentrate or seeking shelter from painful stings of light and sound.

People with migraines travel between two worlds: one in which they are having a migraine and one in which they are not. "I'm very brave generally," Tweedledum tells Alice, "only today I happen to have a headache." But even after the headache is gone, migraine sufferers live with the dread of its return.

For more than a century, researchers have been trying to step through the looking glass to find clues to the mystery of migraines, with little success. Treatments that can prevent or end migraine attacks exist only because drugs for something else were found, often by accident, to quiet the migraine's neurological storm.

"All of the major things we use were not designed for migraine at all," says Peter Goadsby, a neurologist at the University of California, San Francisco. "It's not good enough that one of the commonest of medical problems has treatment developed by serendipity."

A major barrier to relief, it turns out, has been that migraines, which affect 36 million people in the United States, have no known cause. But researchers now think that they are, at least, looking for the culprits in the right places.

"For almost 100 years, people believed it was a vascular disease," says Rami Burstein, academic director of the Comprehensive Headache Center at Beth Israel Deaconess Medical Center in Boston. Blood vessels, it is now thought, are probably just aiding and abetting the crime. Instead, the perpetrators are nerves inside the brain itself, which misfire and set off a disastrous sequence of events. Making things more complicated, migraine sufferers may differ in their thresholds of susceptibility and sets of triggers. "Migraine is for the most part a genetic disease," Burstein says, "a problem with genes that regulate excitability of neurons in the cortex."

Study results announced last year point to three genes that may be linked to migraines. Along with other "migraine genes," the findings seem to paint a picture of brain cells that remain too jumpy when they are supposed to be settled down. With each new discovery, migraine sufferers are brought closer to the day when they might finally be able to escape the hell in their heads.

Stemming the tide

Migraine researchers spent a long time focusing on blood vessels, partly because the notion seemed to make sense: The

BACKGROUND: DONALD SAWVEL/SHUTTERSTOCK; WOMAN: YURI ARCURS/SHUTTERSTOCK

pain of a migraine throbs in sync with a person's heartbeat, and triptans — the first class of drugs approved specifically for migraines — constrict blood vessels in the brain. Research suggested that vessels in the head set off a domino of neurological reactions after abnormally contracting, then dilating. Ironically, some of the shift away from the blood vessel theory arose from the study of triptans themselves.

Sumatriptan, the first of the triptans, was introduced for clinical use in the early 1990s. "It was a real milestone in the headache world," Goadsby says. "But as people looked at sumatriptan, it became clear that it did more than just constrict blood vessels." The drug also affected nerves, raising the possibility of a different explanation for its effectiveness. More recent evidence has poked holes directly in the blood vessel theory: A study in 2008 in the journal *Brain* found that blood vessel size during much of the headache is normal (though a more recent study with better resolution is more supportive of at least some vascular role in a migraine attack).

Goadsby was drawn to study migraines largely because one part of the vascular theory never made sense to him. The pain often strikes only one side of the head, and it isn't necessarily the same side from episode to episode. "I never understood how something originating from the bloodstream would just affect one side of the head," he said.

So Goadsby decided to use medical imaging as a window into the brains of people having a migraine attack. His curiosity had mostly to do with the brain stem, which controls many basic body functions, such as digestion and circulation — some of the same systems known to go haywire during a migraine attack. It seemed logical to him that a migraine had to originate in some central area since, other than the headache itself, the symptoms don't tend to be lopsided.

"The brain stem has, in a small area, the ability to affect a large part of the brain," Goadsby says. In experiments he began publishing in 2005, he used PET scans to identify three locations in the brain stem (corresponding to three distinct structures) that show greater than normal activity during a migraine attack. These parts of the brain usually act as a damper on nerve signals, he says. But when the structures allow too much input to pass through, nerve signals pour into the rest of the brain without control, Goadsby hypothesizes. That's why normal sensations such as light, sound and even the pulsing of blood through the head become painful. He also believes that the malfunctioning of these areas of the brain stem give rise to one of the most peculiar aspects of a migraine — the aura.

Prevalence of migraines

6.5% American men

18.2% American women

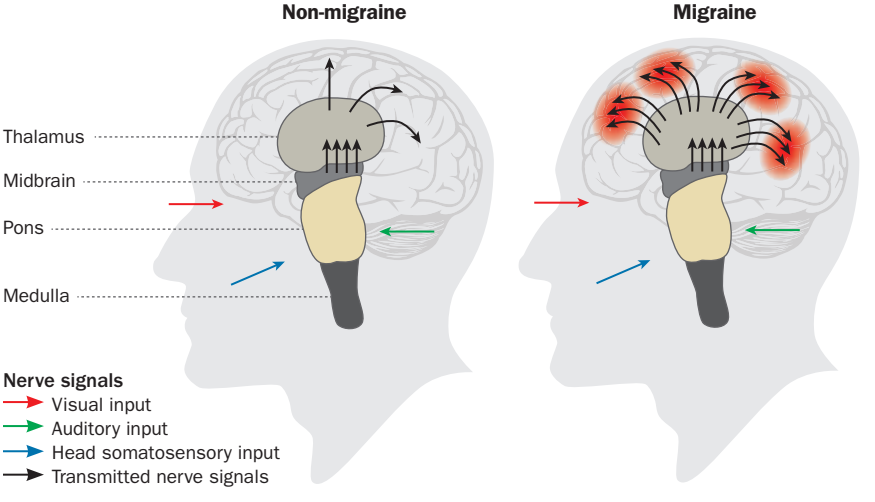
An aura is a sensory disturbance that occurs in about one in four people with migraines. It commonly begins as a flickering of bright lights, like the flashes of an ambulance, in the corner of the visual field and gradually intensifies as it works its way across the line of sight. Some patients experience tingling, nausea and slurred speech during the aura, as well as blind spots once it subsides. An aura vanishes within an hour, and is replaced by a detonation of pain in the head.

Unbearable lightness

The origin of the aura has long been a topic of research fascination. An explanation now gaining consensus emerged in the 1940s from Brazilian biologist Aristides Leão while he worked on his dissertation at Harvard Medical School. After performing experiments in rabbits, Leão noted a marked change in electrical activity that started in one group of cells and rippled across the cortex, the outer layer of the brain. The hyperexcited nerves fire, and then appear to recalibrate, going temporarily silent. Leão called the phenomenon "cortical spreading depression." Later researchers connected the phenomenon to a migraine aura, reasoning that the flickering light that patients see could occur as the cortical spreading depression crosses the visual center at the back of the brain.

The theory of cortical spreading depression was mostly confined to animal data, remaining at the margins of medical research for decades, until researchers could obtain brain scans of patients experiencing a migraine. One of the first of these images, published in 1994 in the *New England Journal of Medicine*, came about by chance. A young woman was in a scanner at UCLA for a study of cerebral blood flow when suddenly her migraine began. For about 15 minutes, researchers were able to document a wave of low

Filter flub Though no one agrees on what causes migraines, Peter Goadsby of the University of California, San Francisco believes the brain stem is to blame. Normally, this region filters sensory inputs before passing them along to the thalamus and outer brain regions. In migraine sufferers, nerve signals pour unfettered into the rest of the brain. SOURCE: T.W. HO *ET AL/NATURE REVIEWS NEUROLOGY* 2010



HEAD: SLOWGOGO/ISTOCKPHOTO; BRAIN: TAKITO/SHUTTERSTOCK

blood flow (which they believe corresponded to nerve cells going temporarily inactive) spreading across the woman's brain. A second study was led by Michael Moskowitz of Harvard Medical School. Moskowitz says that in the late 1990s he learned of an engineer who could induce his migraine auras with intense exercise. So Moskowitz and his team invited the man to campus, had him play basketball for 80 minutes and then whisked him off for an MRI.

In 2001 in the *Proceedings of the National Academy of Sciences*, Moskowitz's team published the first MRIs of an aura from start to finish. In addition to the engineer, the researchers also took brain images of two campus employees who entered the scanner shortly after their auras had begun. As predicted, the images showed a wave of overactive (then underactive) neurons creeping across the cortex. "It's not unlike what would happen if a stone were dropped in quiet pond," Moskowitz says. The data suggest that the blood flow changes in the brain — the ones that led researchers in the wrong direction for decades — are more likely caused by the aura, and not vice versa. Active neurons grow hungry for fuel.

There is little debate about whether cortical spreading depression is a component of a migraine, but one central question is where it comes from, as well as its exact relationship with the pain. Goadsby believes the aura and pain arise from the brain stem, but others, like Moskowitz, say the activity changes observed in the brain stem are a result of a migraine, not the cause.

"The evidence that this kind of an event is triggered in any precise region of the brain is overstated," Moskowitz says. Instead of having origins in the brain stem, he suggests, the cortical spreading depression can arise in any part of the brain, an idea consistent with animal studies.

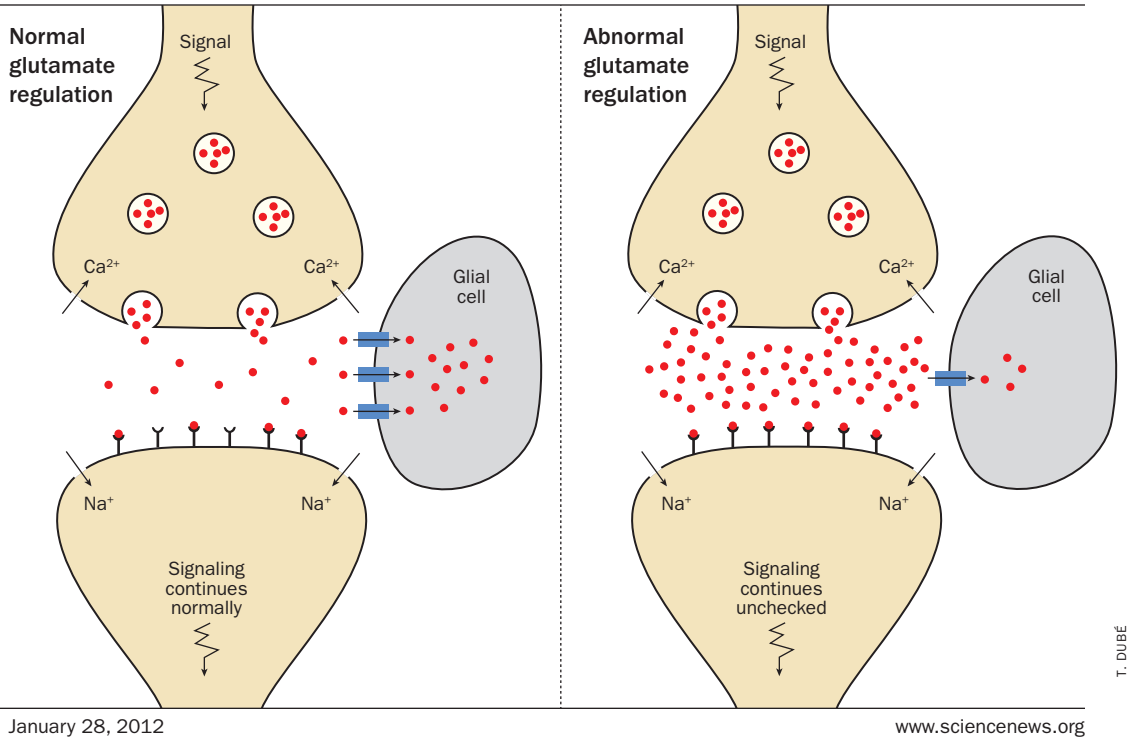
Moskowitz also does not agree that the changes that occur in the brain stem during a migraine open the floodgates on nerve signals, allowing normal sensations to become painful. Instead, he points to laboratory experiments supporting the idea that the cortical spreading depression itself is responsible for the pain. Most of the brain does not have the capacity to feel pain; only the nerve endings in the dura mater, the organ's tough outer covering, and related tissue are pain-sensitive. A headache happens because of the stimulation of these nerves, which fire as the wave of excitability makes its way across the cortex, Moskowitz believes. "Cortical spreading depression releases in a drastic way a group of chemicals that are normally sequestered in cells of the brain," he says. When those chemicals — such as potassium, hydrogen ions and the neurotransmitter glutamate — get dumped, they may activate the pain fibers on the brain's surface through a process that is still being worked out.

Skeptics of this idea point out that most people get migraines without an aura. Moskowitz's belief is that cortical spreading depression occurs but does not affect the brain's visual processing and thus remains undetected — a kind of hidden aura.

In truth, much about migraines is still unknown, says Burstein of Beth Israel. "Migraine is a complex disorder," he says, involving abnormalities in both the cortex and the brain stem. Where the pain comes from is still unclear, and perhaps the mechanisms behind chronic migraines (which occur more than 15 days a month) are different from those for less frequent ones. Migraines that strike regularly could originate from the cortex but over time could damage the cells of the brain stem. "This damage may reduce the ability of the brain stem to mitigate incoming signals," he says.

Genetic trouble

A nerve signal is passed from one cell to another at the synapse. As the signal approaches, ion channels open. An influx of ions triggers the release of a neurotransmitter, in this case glutamate. The glutamate stimulates receptors on the next nerve cell, causing ions to flow in and pass on the signal. One genetic variant linked to migraine may reduce the clearing of glutamate in the synapse by glial cells.



T. DUBÉ

And none of the research so far has clearly answered the biggest question: What's the first thing that goes wrong? The list of potential migraine triggers reads like a catalog of daily life experiences: hunger, flashing lights, alcohol, strong smells, chocolate, cheese, too little sleep, too much sleep, stress, relaxation after stress, menstrual cycle changes, weather changes, and on and on. (And there may be no triggers at all; the changes in the brain that lead to an attack could cause someone to crave chocolate or feel stressed, or undergo other physiological shifts.)

"We don't know why someone gets a migraine when they are exposed to a perfume in the elevator, when 10 other days they smelled the perfume and didn't get it," Burstein says. "Once it starts, we know a lot about it. What we don't know is why and how."

At the onset A host of factors can trigger a migraine among those who are susceptible, and the triggers often differ from person to person or from one situation to the next. Scientists don't yet know whether the triggers provide a clue to migraine's cause. SOURCE: UC BERKELEY

Trigger type	Examples
Dietary	Chocolate, cheese, alcohol, overripe avocados, beans and processed meats. Nutrasweet, MSG, yeast. Skipping meals.
Sleep	Changes in sleep patterns such as oversleeping or getting too little sleep.
Physical	Overexertion, eyestrain.
Hormonal	Changes in hormone levels such as those that occur during menopause, ovulation or while on birth control.
Environmental	Extreme heat or cold, bright lights, strong aromas, airplane travel.
Stress	Anxiety, shock and grief. An end to stressful times—such as the first day of a vacation or the weekend.

Tinderbox of nerves

While scientists debate the why and how of the trigger, genetic studies are getting at a separate question—who. Most researchers believe that genes contribute to a person's susceptibility to the triggers. The headaches seem to run in families, and the risk is higher if you have an immediate family member with migraines.

Most migraine sufferers probably possess a constellation of genes, each one of which contributes a little to the susceptibility. But there is one kind of migraine, called familial hemiplegic migraine, that appears to have an even stronger genetic component.

An international team of researchers studying this kind of migraine described the first "migraine gene" in the journal *Cell* in 1996. The discovery came after neurologist Michel Ferrari of Leiden University Medical Center in the Netherlands happened to see two patients on the same day with familial hemiplegic migraine. (They turned out to be both from the same region of the country and were obliquely related.)

Since then, researchers have discovered a handful of genes that may contribute. By understanding the role of these genes, scientists could gain clues to the mechanism behind a migraine. So far, all signs point to nerve activation.

"They confirm that migraine is a disease of hyperexcitability in the brain," says Ferrari.

Nerve cells work by transmitting electrical impulses. Normally, the inside of a nerve cell is negatively charged (thanks to a lot of negatively charged chlorine ions) and the outside is positive (from positively charged sodium, calcium and potassium ions). When a nerve cell releases a signaling molecule called a neurotransmitter, channels on the cell next door open up and allow positive ions to rush in. The cell briefly depolarizes—the inside loses its negative charge—and then returns back to its normal state.

Genes that have been linked to migraine all have some role in the firing of nerve cells and this positive-negative ion swap. The gene mutation described in 1996 affected the calcium ion channel. Another DNA variation, described in 2010 in *Nature Genetics*, inhibits a cell's ability to clear away the neurotransmitter glutamate after the nerve has fired, allowing it to accumulate. In June 2011, Ferrari and an international team of researchers described signs of three more rogue genes in *Nature Genetics*. These, too, are involved in the transmission of signals from cell to cell.

"The story seems to go in the same direction," Ferrari says. In a migraine-susceptible brain "it's easier to trigger neuronal activity."

The idea is also supported by a study published last January in the journal *Neurology*. Researchers exposed patients suffering a migraine attack to light—a normal stimulus that becomes excruciating during the headache. PET scans of the patients revealed that the light caused the nerves in the occipital cortex of the brain to fire. But when the patients were not experiencing an attack, the light did not have an effect on that part of the brain. Like a drought-stricken forest, the nerves may be easy to ignite, and easy to fuel once they do.

"The fact of the matter is there is plenty of evidence now that the brain of a migraine sufferer is never normal," says David Dodick, a neurologist at the Mayo Clinic in Scottsdale, Ariz., and president of the American Headache Society. It now appears that a migraine brain exists on edge, quick to set off a headache when the right combination of circumstances comes along. "Networks are active when normally they shouldn't be," Dodick says. "The threshold for generating an attack is always just below the surface." The rabbit hole is always near.

But maybe not forever. Soon migraine sufferers may, like Alice, be able to wake up from the nightmare inside their heads—something Alice's creator could never do. ■

Explore more

- Peer C. Tfelt-Hansen and Peter J. Koehler. "One hundred years of migraine research: Major clinical and scientific observations from 1910 to 2010." *Headache*, May 2011.

My Beautiful Genome

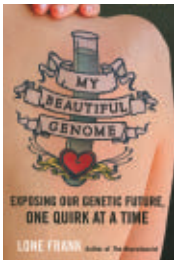
Lone Frank

Personal genomes, compendiums of a person's entire genetic makeup, are all the rage. Scientists have deciphered the genetic blueprints of thousands of people, with many more to come. And with the completion of these genetic instruction books, narratives about the genomic revolution have not been far behind.

Danish science writer Frank's offering is one of the most readable and fascinating of the bunch. Frank guides readers through various ways genetic information is being used. She explores her own genes, uncovering genetic quirks along the way. She ponders the use of genetic information to reveal ancestry and attempts to answer her own questions about why human beings are entranced by their biological origins.

Frank gives us a glimpse of her medical future as predicted by small variations in the composition of chemical letters within her genome. And yet this self-examination doesn't seem self-absorbed. Instead, she's a stand-in, a genetic everyman or everywoman, guiding readers through their own self-discovery.

Frank even takes up a male coworker's challenge to determine whether he and Frank would produce a genetically optimal child, or if she would be better matched with her boyfriend. Along the way she explores the world of DNA-based dating services and the debatable science on which they are based.



Despite the evidence that Frank presents suggesting that genes control everything from mental states to mate selection, she is careful to point out that "my genes are *not* fate but cards I've been dealt, and some of those cards give me a certain amount of latitude in playing the game of life." Well played, Ms. Frank.

—Tina Hesman Saey

Oneworld, 2011, 313 p., $15.95

Who's in Charge? Free Will and the Science of the Brain

Michael S. Gazzaniga

In his new book, Gazzaniga drags readers kicking and screaming to the brink of an existential meltdown, and then rescues them with a dramatic twist at the end.

Gazzaniga's opening salvo: You are not the boss of your brain. The illusion of control is a sweet lie that people — including neuroscientists — tell themselves. Gazzaniga, a neuroscientist himself, describes loads of studies, including some of his own, showing that people aren't always willful and purposeful agents in control. One of his best arguments: "Have you ever succeeded in telling your brain to shut up already and go to sleep?"

If natural laws and the ways of the brain can explain each and every behavior, it follows that free will is an illusion. But before you sprint out and buy a Porsche ("The universe made me do it!"), Gazzaniga calls out that very issue. Angsty hand-wringing about free will is meaningless, he argues. What really matter are social relationships. Just as it's uninformative to say that a person who is alone on a planet is the tallest, the concept of personal responsibility has no meaning if there are no other people to be responsible to.

No matter how much scientists learn about the brain, the results will never offer an escape clause releasing people from personal responsibility, he says.

For sensitive, introspective readers, the book may feel like an emotional roller coaster as it careens through brain science, morality and even law. But Gazzaniga is a funny, sympathetic and trusty guide, making the trip not just worthwhile, but fun. *— Laura Sanders*

Ecco, 2011, 272 p., $27.99

50 Popular Beliefs That People Think Are True

Guy P. Harrison

A journalist turns a skeptical eye on beliefs ranging from astrology to Atlantis, showing that scientific discovery can be just as fascinating as myth. *Prometheus, 2011, 458 p., $18*

Part Wild

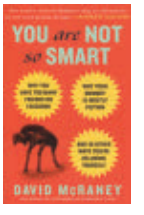
Ceiridwen Terrill

The cultural history and genetic story of dog domestication is told through the adventures of a wolf-husky hybrid adopted by a science writer. *Simon & Schuster, 2011, 274 p., $25*

Mushroom

Nicholas P. Money

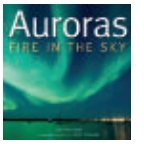
Mushroom lore and history mingle with science and medicine in a biologist's exploration of the fungal kingdom. *Oxford, 2011, 201 p., $24.95*



You Are Not So Smart

David McRaney

Forty-six of the brain's everyday fallacies and cognitive biases are highlighted in an expansion of the author's blog about the neuroscience of self-delusion. *Gotham Books, 2011, 300 p., $22.50*



Auroras

Dan Bortolotti

Striking images illuminate this exploration of one of nature's greatest light shows. *Firefly, 2011, 143 p., $29.95*

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The eyes have it

Just finished the latest issue of your spectacular magazine. I've been a reader for many years, but this is the first time I've felt compelled to write in. In the article about the tadpole ("Tiny voltage grows eyes in strange places," *SN: 12/31/11, p. 5*), the final sentence is a quote from Coffman: "The fact that a narrow range of voltage is enough to specify an eye is kind of amazing."

What might be even more amazing is if researchers find out the voltage level that prompts cells to initiate and grow malignant tumors. I hope someone will help me stir up some interest in this research idea.

Bob Wyrick, Portland, Ore.

Dreaming clearly

Laura Sanders' article "First brain image of a dream made" (*SN: 12/17/11, p. 10*) is most interesting; however, the definition of lucid dreaming is incomplete. Sanders writes, "Lucid dreaming is the rare ability to direct behaviors while in a deep sleep." Actually, lucid dreaming is defined as knowing we are dreaming while we are dreaming. After that epiphany occurs, some people can direct or control their dream behaviors but others cannot. Indeed, different factions differ as to the desirability of attempting lucid dream control. Perhaps this research will throw new light on this issue.

Margaret Jane Kephart, Boulder, Colo.

Computing 'junk' DNA

The conclusion that "junk DNA" is not trash ("Missing lincs," *SN: 12/17/11, p. 22*; "Turns out that 'junk DNA' wasn't just talking trash," *SN: 12/17/11, p. 2*) should have been obvious to computer programmers from the beginning. I have been using the following analogy ever since the junk DNA term entered the public literature: DNA strands are much like computer programs, which at the machine language level typically consist of long strings of "bytes," each consisting of eight "bits." Any given byte may be part of a computer instruction, part of a binary number or the encoding of an alphanumeric character (such as integers, punctuation marks or other characters).

If you try to read a program as if it were all alphanumeric characters, the result would be mostly gibberish. This "gibberish" is the programming that tells the computer hardware how to perform what it is intended to accomplish.

Very much like in DNA, some parts of the program are executed only once (at startup) and then turned off but not discarded. They may be turned on again if the program is "rebooted," very much like parts of the DNA in a new embryonic cell.

You see, programming was around long before the stored-program computer was invented by John von Neumann in 1945. (Sorry, John.)

Richard A. Brouse, Orland, Calif.

Counting trees for climate

The article "Columbus' arrival linked to CO_2 drop" (*SN: 11/5/11, p. 12*) theorizes that because the population was decimated by European diseases, the open ground that people would have created by burning for farming gradually filled in with trees. These additional trees absorbed great amounts of carbon dioxide, resulting in the Little Ice Age in Europe. If this theory holds true, then conversely the mass cutting down of trees in the last century would result in the Earth's surfaces becoming warmer. Has this been considered?

Jack Sarver, Pinckney, Mich.

Deforestation is considered to be an important contributor to climate change. In the 1990s, the mass clearing of trees in the tropics released about 1.5 billion metric tons of carbon into the atmosphere every year — about one-fifth of all greenhouse gas emissions caused by human beings. — Devin Powell

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

From the Archive

For the full 1935 article, visit
www.sciencenews.org/archive_heavy

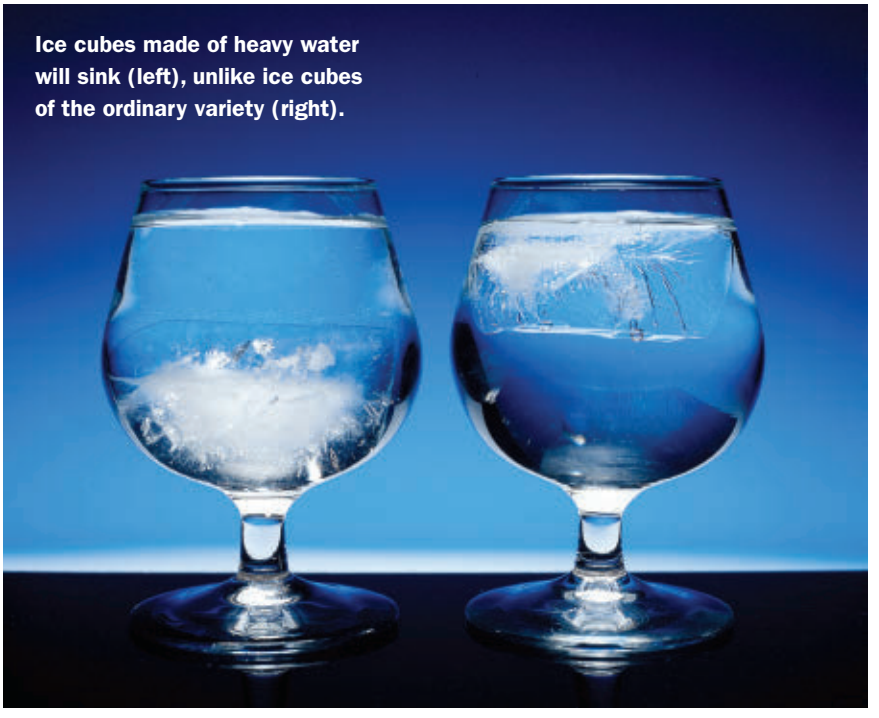
Pharmacologist drinks heavy water in experiment

Taking the risk of swallowing ten grams (about third of an ounce or teaspoonful) of "heavy water," Prof. Klaus Hansen, Oslo University pharmacologist, reported that he had apparently suffered no ill effects after five hours, sufficient to allow assimilation of deuterium-containing water.

Nevertheless he was attended by four doctors ready with stomach pumps, heart and respiratory stimulants for emergency use if they seemed to be needed.

In his first human test of the possible poisonousness of heavy water, discovered in America in 1931, Prof. Hansen intends to keep taking doses of the heavy water each day for two weeks until the daily dose is increased to a hundred grams of water of which 99 percent of the hydrogen is the heavy or double weight variety called deuterium to distinguish it from ordinary mass one hydrogen. If this plan is carried out he will then be taking three and one-third ounces of heavy water, a sizable drink.

Since the lowest production cost of heavy water declared probable is about $5 a gram, the drink already taken has a minimum value of about $50. The largest dose scheduled is worth at this rate about $500 and the whole experiment will use about $4000 worth of heavy water alone. The present U.S. market price of heavy water is $19 a gram.



Ice cubes made of heavy water will sink (left), unlike ice cubes of the ordinary variety (right).

PHOTO: CHARLES D. WINTERS/PHOTO RESEARCHERS, INC.; PAPER: PAPHIA/ISTOCKPHOTO

UPDATE

Self-experimenter didn't suffer

When Klaus Hansen swallowed heavy water in 1935, he joined a fellowship of researchers who have conducted (and continue to conduct) self-experiments in the name of science. Whether dismissed as zealots or praised for the depth of their devotion, several of these enthusiasts have made big marks on their fields over time.

Take Werner Forssmann, for example. In 1929 he inserted a catheter into his own arm and passed it into his heart, later sharing the 1956 Nobel Prize in medicine for his contributions to catheterization. Then there is physician Barry Marshall, who in 1984 swallowed *Helicobacter pylori* to try to prove that the bacteria cause ulcers. He got gastritis and a 2005 Nobel.

But while guts may bring glory, they don't always translate to a long life. The 18th century chemist Carl Wilhelm Scheele had a habit of tasting chemical compounds as part of his analyses, a behavior that may have led to heavy metal poisoning, contributing to his death at age 44.

As for Hansen, a report a year or so after the experiment found him in good health (and he lived past age 75). Just as heavy water's discoverer Harold Urey had suggested, the amount consumed was negligible compared with the quantity of regular water found throughout the body. Even Urey himself was known to have given heavy water a try, reporting that it tastes like the plain-old distilled variety. —*Elizabeth Quill*

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A. Fur and fashion, a report from the 1920s on the demand for pelts

B. Dividing light into three-inch pieces

C. Assigning blame for baldness, before the age of genetics

Chicago Doctor Invents Affordable Hearing Aid
Outperforms Many Higher Priced Hearing Aids

Reported by J. Page

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

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

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

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

- **Designed By A Board Certified Ear, Nose and Throat (ENT) Doctor**
- **Doctor-Recommended, Audiologist-Tested**
- **★★★★★-Rated, #1 Selling Hearing Aid on Amazon.com**
- **FDA-Registered**
- **Save Up To 90%**
- **Free Shipping Available**
- **Batteries Included! Comes Ready To Use**
- **100% Money Back Guarantee**

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

Inspiration from a surprising source

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

Affordable Hearing Aid With Superb Performance

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

Tested By Leading Doctors and Audiologists

The MDHearingAid PRO® has been rigorously tested by leading ENT physicians and audiologists who have unanimously agreed that the **sound quality and output in many cases exceeds more expensive hearing aids.**

DOCTORS AND PATIENTS AGREE: "BEST QUALITY SOUND" "LOWEST AFFORDABLE PRICE"

"I have been wearing hearing aids for over 25 years and these are the best behind-the-ear aids I have tried. ***Their sound quality rivals that of my $3,000 custom pair of Phonak Xtra digital ITE"***—Gerald Levy

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

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"Well, I finally did it. I finally decided to enter the digital age and get a cell phone. My kids have been bugging me, my book group made fun of me, and the last straw was when my car broke down, and I was stuck by the highway for an hour before someone stopped to help. But when I went to the cell phone store, I almost changed my mind. The phones are so small I can't see the numbers, much less push the right one. They all have cameras, computers and a "global-positioning" something or other that's supposed to spot me from space. Goodness, all I want to do is to be able to talk to my grandkids! The people at the store weren't much help. They couldn't understand why someone wouldn't want a phone the size of a postage stamp. And the rate plans! They were complicated, confusing, and expensive…and the contract lasted for two years! I'd almost given up until a friend told me about her new Jitterbug® phone. **Now, I have the convenience and safety of being able to stay in touch…with a phone I can actually use."**

Sometimes I think the people who designed this phone and the rate plans had me in mind. The phone fits easily into my pocket, and flips open to reach from my mouth to my ear. The display is large and backlit, so I can actually see who is calling. With a push of a button I can amplify the volume, and if I don't know a number, I can simply push "0" for a friendly, helpful operator that will look it up and even dial it for me. The Jitterbug also reduces background noise, making the sound loud and clear. There's even a dial tone, so I know the phone is ready to use.

Affordable plans that I can understand – and no contract to sign! Unlike other cell phones, Jitterbug has plans that make sense. Why should I pay for minutes I'm never going to use? And if I do talk more than I plan, I won't find myself with no minutes like my friend who has a prepaid phone. Best of all, there is no contract to sign – so I'm not locked in for years at a time or subject to termination fees. The U.S. Based customer service is second to none, and the phone gets service virtually anywhere in the country.

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