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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ OCTOBER 22, 2011

THE NEXT

Atomic Clock

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Virus Cleared in Chronic Fatigue

Neutrinos Caught Speeding — Appeals Pending

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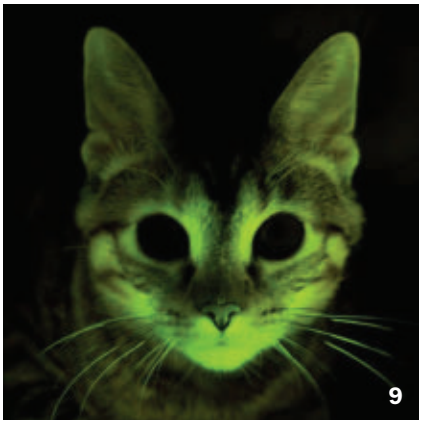

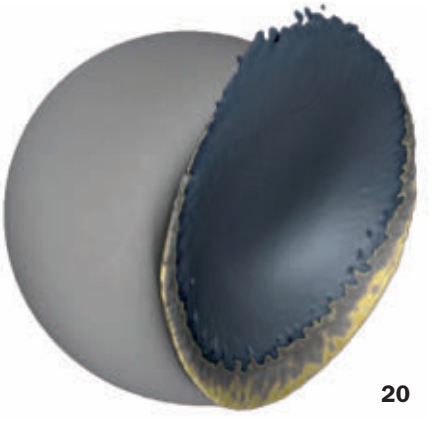

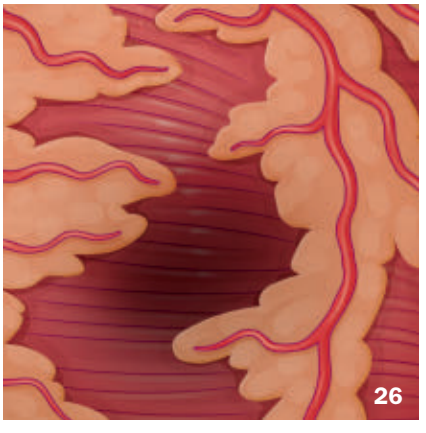

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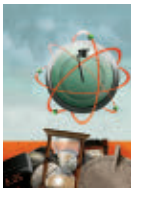

COVER Scientists seek supremely accurate atomic clocks to better explore the underpinnings of the physical world.
Michael Morgenstern

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FROM THE EDITOR

Don't stop presses yet for faster-than-light neutrinos

In the world of science journalism, rarely does any news evoke the desire to scream "Stop the presses!"

You'd need something really special to justify such a reaction. Like a 100-percent effective cure for cancer, or a message from an extraterrestrial, or an experiment clocking a subatomic particle exceeding the speed of light.

Well, as you might have heard, just such a shocking development was claimed in September, when researchers reported that neutrinos had traveled from CERN (near Geneva) to Italy's Gran Sasso underground laboratory in less time than the same trip would take for light in a vacuum.

At light speed, neutrinos would traverse the 730-kilometer distance in 2.44 milliseconds; after accounting for delays due to processing the signals, the researchers calculated that the neutrinos arrived 60 nanoseconds early. Einstein defied.

Unlike some previous claims for superluminal speeds, there are no obvious mistakes or misunderstandings in this report. The team's paper (available online at http://arxiv.org/abs/1109.4897) carefully assesses all the known sources of possible errors in the analysis. For one thing, the exact distance measured from source to detector might vary by as much as 20 centimeters, the team acknowledges. But a 20-centimeter error would adjust the travel time by less than a nanosecond, far too little to account for the 60-nanosecond difference observed. Other possible sources of error add up to 7 nanoseconds or so. Even adding another 7 for statistical uncertainties still doesn't substantially close the gap.

Nevertheless, few experts believe this result will hold up. Einstein's special relativity theory establishes the speed of light limit as a fundamental property of the relationship between space and time. And his theory has been tested so thoroughly, in so many ways, for so long, that the presence of some hidden flaw in this new experiment is much more likely than the need for a new theory of the universe.

Consequently, no presses were stopped. And only a small amount of space (see Page 18) was made available in this issue (you can read a longer version online at bit.ly/nxiRS3).

But who knows? Maybe the neutrinos know something about nature that Einstein didn't. We'll be watching. And if it turns out that an explanation does emerge for the neutrino results that confirms the refutation of relativity, it will get a lot more coverage. — *Tom Siegfried, Editor in Chief*

JIM WEBB

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Ever since the first humans built a fire in their dark cave, people have realized the importance of proper indoor lighting. But ever since Edison invented the light bulb, lighting technology has, unfortunately, remained relatively prehistoric.

Modern light fixtures do little to overcome problems associated with improper lighting. As more and more of us spend longer and longer hours in front of our computer monitor, these problems are compounded. And the effects of improper indoor lighting are not necessarily limited to a physical problem: the quantity and quality of light can also play a part in both our mood and work performance.

Studies show that sunshine can both lift your mood and enhance your energy levels. But as we all know, the sun does not always shine. Now, however, there's a solution to the problem–a way to bring the positive benefits associated with natural daylight indoors. The **Balanced Spectrum® floor lamp** will change not only the way you see, but also the way you feel about your living and work spaces. It brings the benefits of natural daylight indoors, simulating the full spectrum of daylight.

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Say What?

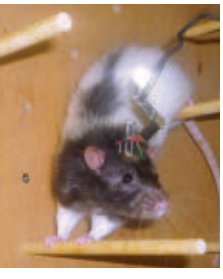
chorus waves ***\KOHR-uhs WAYVS*** ***n.*** A type of radio wave that appears in bursts inside Earth's magnetic field. Chorus waves get their name from their sound: When played through a speaker they sound like birds chirping. The waves accelerate electrons in Earth's radiation belts to high energies, and these electrons rain down on the atmosphere to create pulsating auroras that flash on and off. But the electrons can also damage satellite electronics. An international team of researchers reports online August 25 in *Space Weather* that a super solar outburst, bigger than one in 2003 that caused bright "Halloween Storm" auroras (shown), could inject electrons near Earth where chorus waves would pump them up. Radiation levels would increase for up to a decade and limit satellite lifetimes to less than a year. — *Camille M. Carlisle*

Science Past | FROM THE ISSUE OF OCTOBER 21, 1961

'ALARM CLOCK' BRINGS SNAKES TO SURFACE — A built-in "alarm clock" apparently helps a brightly-banded little desert snake come to the surface at night after he has buried himself to escape the day's heat.... It had been noted that these snakes, which remain buried in the sand most of the time, appear to come to surface virtually in unison over a wide area every night. It was thought that they followed a rising heat barrier in the sand which rises as the sand cools off each night. Laboratory studies ... have indicated that there may be a little more to it than this. The investigation has suggested that the snake has a biological alarm clock which "wakes" him up about 23 hours after his last emergence at the surface.

How Bizarre

Mammals' brains may navigate three dimensions with flat mental maps. Researchers in England and the United States hooked electrodes up to rats' brains and watched how neurons responded as the rats climbed vertical Peg-Boards and corkscrewlike paths. The scientists report in the Aug. 7 *Nature Neuroscience* that two types of brain cell "odometers" didn't record as much information during climbing as they did while the rats were walking on flat ground. It may be that Earthlings on land are bad at 3-D because they spend their lives surrounded by horizons, the researchers note. Humans floating in space also think with a horizontal reference, suggesting that internal flat maps are the norm. — *Camille M. Carlisle*



Science Future

October 31
Last day for artists to apply for a residency at the CERN particle physics lab near Geneva. Learn more at www.aec.at/prix/collide/

November 4
Chicago's Field Museum opens its "Restoring Earth" exhibit. See www.fieldmuseum.org

November 6
The National Museum of American History in Washington, D.C., explores MIT labs as hot spots of invention. See bit.ly/smitlab

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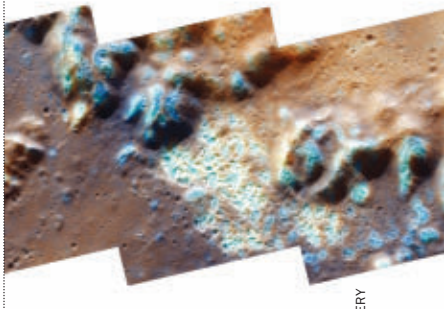
BODY & BRAIN
'Normal' B12 levels may not be enough for the brain. Read "B12 shortage linked to cognitive problems."

LIFE
A penguin can find its kin even in a sea of black and white. See "Penguins may sniff out relatives."

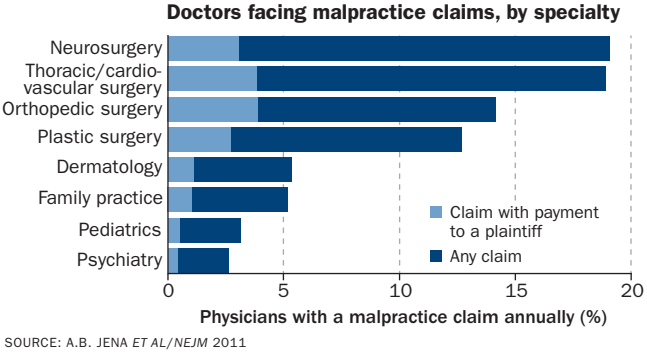
ATOM & COSMOS
A NASA probe has found bizarre landforms on the planet nearest the sun. Read more in "Messenger from Mercury."



HUMANS
A teenager's alcohol use is influenced by the friends of the teen's boyfriend or girlfriend. See "Teen daters pal up to the bottle."

Science Stats | WHO'S SUED

From 1991 through 2005, about 7 percent of doctors surveyed faced a claim each year, with 1.6 percent paying a plaintiff. Of all doctors, surgeons are the most often sued for malpractice.



SOURCE: A.B. JENA *ET AL*/*NEJM* 2011

CLOCKWISE FROM TOP LEFT: JAN PITMAN/AP PHOTO; NASA, JHU APL, CARNEGIE INST. OF WASHINGTON; KATE JEFFERY

“This will be a tremendous revolutionary finding if it is true.”
—CHANG KEE JUNG, PAGE 18

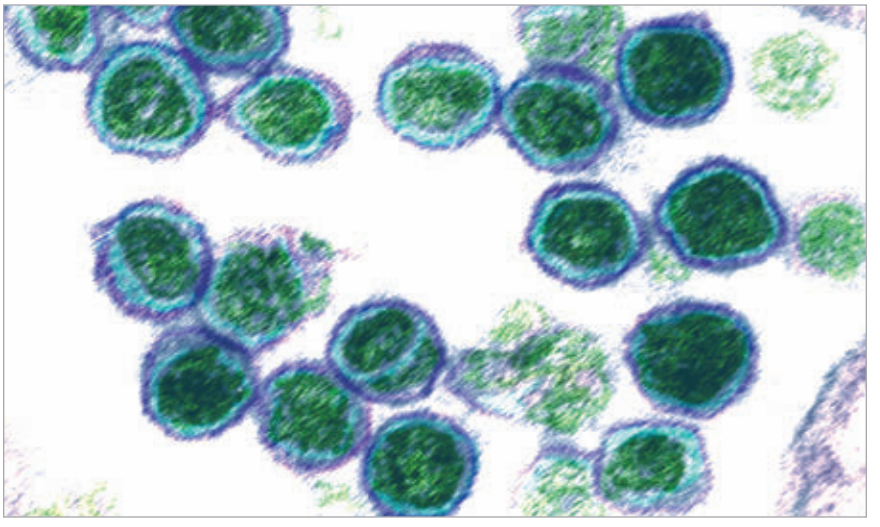
In the News

STORY ONE

Study debunks chronic fatigue's virus connection

New analyses indicate that XMRV was a lab contaminant

By Laura Sanders



DR. GOPAL MURTI/VISUALS UNLIMITED, INC.

Research linking chronic fatigue syndrome to a virus family that can cause cancer in mice (XMRV relative XMLV is shown) has been refuted by a nine-lab study.

A meticulous study has failed to confirm recent research linking chronic fatigue syndrome to a family of viruses that can cause cancer in mice. Nine laboratories—including the two that previously identified a connection—could not reliably detect the virus XMRV or any of its relatives in blood cells from patients with the mysterious and controversial condition, researchers report online September 22 in *Science*.

In another blow, one of the labs that contributed to the original study retracted its key result because some of the samples used in the research were found to be contaminated with genetically engineered XMRV DNA. The partial retraction also appears online September 22 in *Science*.

Together, the new data largely exonerate the virus as a cause of chronic fatigue syndrome—a disorder with a constellation of symptoms, no known cause and no effective treatment.

“The data certainly contradict the original findings,” says infectious disease specialist Michael Busch of the University of California, San Francisco and the Blood Systems Research Institute in San Francisco, who coordinated the new nine-lab study. “To me, it demonstrates that these labs have serious problems with false positive results and that those earlier data are not credible.”

For some researchers, the end to the XMRV saga can't come soon enough. “The whole scientific world pretty much knows this whole thing is hocus-pocus,” says Robert Gallo, director of the Institute of Human Virology at the University of Maryland School of Medicine in Baltimore. “Basically, it's not real.”

In 2009, researchers reported in *Science* that two-thirds of blood samples from people with chronic fatigue tested positive for the mouse leukemia virus XMRV, compared with only 3.7 percent of samples from healthy controls.

In addition to hinting at the cause of chronic fatigue syndrome, the finding also raised serious concerns about the safety of the blood supply. If the virus infected a substantial fraction of the population, it could turn out to be widespread in donated blood.

Busch set up the nine-lab study to assess the potential threat to the blood supply. In the study, scientists studied blood samples from 15 healthy people and 14 people with chronic fatigue syndrome who had previously been found to harbor the virus. The samples were blinded and mailed out to the nine laboratories, where the blood was put through a battery of tests to find the virus.

Seven of the labs found not a whiff of the virus in any of the specimens. The groups that had previously published the virus-syndrome link did turn up some positive samples. But both of these groups reported inconsistent test results on the same samples. More important, these two groups found that the virus didn't show up any more often in samples from people with chronic fatigue syndrome than in samples from healthy participants.

“Their positives are scattered randomly between cases and controls,

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leaving you with the inescapable conclusion that this is a fairly high level of false positives," says John Coffin of Tufts University School of Medicine, who is a coauthor on the new paper. He says that the idea that the virus is tied to chronic fatigue syndrome is "fading fast."

The partial retraction resulted from a reanalysis of DNA sequences from blood samples of people with chronic fatigue syndrome and people without the condition. Robert Silverman and Jaydip Das Gupta, two Cleveland Clinic Foundation researchers who were both involved in the original study, reanalyzed seven samples that had tested positive for the virus in the original report. Just as before, tests were positive for the viral DNA. But the viral DNA wasn't ensconced in the cells' DNA, as the researchers had initially assumed. Instead, the evidence for the presence of the virus came from a piece of artificially introduced DNA called a plasmid that was unmistakably lab-engineered.

"The whole scientific world pretty much knows this whole thing is hocus-pocus."

ROBERT GALLO

It's not clear how or when the contamination occurred. "The contaminated samples originated outside of the Cleveland Clinic," a statement from the Cleveland Clinic says.

Also unclear is how the original work found such a high percentage of samples with the virus in the chronic fatigue samples and such a low percentage in the healthy samples. A high rate of random false positives caused by a contaminant should have been the same for both groups. Instead, it appears that the chronic fatigue samples were preferentially affected.

"There is no way of knowing how the plasmid got into those particular samples," says Judy Mikovits, a coauthor on the original and the new papers and, until recently, research director at the Whittemore Peterson Institute for Neuro-Immune Disease at the University of Nevada, Reno. The retraction "does not invalidate the numbers found," she says, though the two-thirds finding may be called into question. But even considering the contamination problem, Mikovits says that the team still has evidence of viral infection in chronic fatigue patients.

Mikovits cites several reasons that the recent multilab project may not have detected the XMRV virus: Virus loads may fluctuate over time in chronic fatigue patients, the virus could hide out in tissues other than blood and the amount of virus present may be too low to detect. What's more, she suggests, other viruses similar to XMRV may be to blame.

Mikovits plans to pursue the question, but it will be somewhere other than the Whittemore Peterson Institute. One week after the new XMRV data were published, the institute fired her for reasons unrelated to the new findings, Mikovits says. "I have several opportunities to take my grants to institutions where my research can be fully supported," she says.

Ian Lipkin, a virologist at Columbia University who was not involved in the studies, says that the case is not closed yet. He is leading another large collaborative effort to test for the presence of retroviruses, including XMRV, among different populations of people with and without chronic fatigue syndrome.

"We don't want to have to revisit this, and there's a risk of that," Lipkin says. He and his colleagues expect results by the end of 2011. "I don't know what we're going to find," he says. "I have no horse in this race." ■

Back Story | A THEORY'S BIRTH AND DEATH

October 23, 2009 XMRV turns up in two-thirds of blood samples from people with chronic fatigue syndrome, researchers report in *Science*.

May 31, 2011 At least 10 independent studies have failed to find XMRV in patients with chronic fatigue syndrome. Two online publications in *Science* cast still more doubt: One traces XMRV's origins to a lab-engineered mashup between two mouse viruses in the 1990s. The other finds no evidence of XMRV in 61 people with chronic fatigue syndrome. *Science* publishes an "Expression of Concern" about the 2009 study.

End of 2011 Another large-scale study of retroviruses in chronic fatigue syndrome patients, using a new group of subjects, is slated to conclude.

2010 — 2011

August 23, 2010 Another group reports online in the *Proceedings of the National Academy of Sciences* that it has found high rates of viruses related to XMRV in people with chronic fatigue. Other scientists try to replicate the findings, without success.

September 22, 2011 Seven of nine labs fail to find virus in samples from chronic fatigue syndrome patients, researchers report in *Science*. The two others are the same labs that had previously found a link, but their hits are not clustered in patients with chronic fatigue. The authors of the 2009 *Science* paper retract a key result after it is shown to have been due to contamination.

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Twin peaks reveal what lies beneath

Pacific island chemistry hints at variations in plume source

By Alexandra Witze

Hawaii's scenic volcanoes come in two chemical flavors, and now scientists think the igneous peaks on other Pacific island chains do, too.

Two parallel lines of volcanoes stretch from the Big Island of Hawaii in the southeast to Molokai in the northwest. Volcanoes on the Samoan and Marquesas islands are similarly paired. A new study finds that in all three chains one row of volcanoes is richer than the other in versions of elements such as lead and neodymium.

"This might be a common feature for all the Pacific hot spots," says Shichun Huang, a geochemist at Harvard and lead author of a paper appearing online September 18 in *Nature Geoscience*.

If so, these island chains may tap similar sources deep in Earth's mantle. Molten rock rises toward the surface in two chemically distinct streams, one stream feeding each row of volcanoes.

Geologists think Hawaii, Samoa and the Marquesas each formed as a plate of Earth's crust moved across a "hot spot," the top of a plume carrying molten material from the planet's deep interior. Like a welding torch passing across a piece of metal, the hot spot punched out island after island as the plate moved over it.

Recent studies have shown that the hot spots are more complex than once thought, says isotope geochemist Dominique Weis of the University of British Columbia. The plume rising below Hawaii, for instance, feeds individual streams of chemically distinct magmas into Mauna Loa and Mauna Kea, volcanoes on the Big Island.

By analyzing published data on lava samples, Huang and his colleagues have now shown that this chemical difference also exists in Samoa and the Marquesas.

The plumes feeding these island chains (as well as Hawaii's) apparently tap a single massive reservoir that underlies much of the central and southern Pacific. This reservoir contains chemical signatures of ancient surface rock that plowed into the interior eons ago through plate tectonics. As a plume rises, it carries part of this material with it.

Studies suggest that the molten rock forming the volcanoes on Hawaii and other Pacific island chains derives from a geochemically varied source.

The new work shows how surface volcanoes can be linked to deep sources of magma, says geochemist Albrecht Hofmann of the Max Planck Institute for Chemistry in Mainz, Germany. A few other scientists have questioned the existence of mantle plumes, but the new work "strongly suggests that at least these particular hot spots are actually mantle plumes that ascend from the lowermost mantle," Hofmann says. ■

Nature's crystal palace

Mexico's Cueva de los Cristales, or Cave of Crystals, may look like Superman's Fortress of Solitude. But unlike its comic book counterpart, this cave's assortment of supersized crystals took a lot longer than a few minutes to grow.

Under a laboratory microscope, pieces of these gypsum crystals immersed in mineral-rich water elongated a mere billionth of a meter per day—the slowest ever measured in a crystal—a team of scientists in Spain and Japan reports in the Sept. 20 *Proceedings of the National Academy of Sciences*. Depending on temperature, the crystals could have reached their modern-day lengths, up to 11 meters, in 100,000 to 1 million years.

To nurture such growth, cave temperatures must have ranged from about 50° to 58° Celsius, the team reports. While no fortress, this balmy lair—with its icelike decor—might have made a nice sauna for the Man of Steel. —*Devin Powell*

FROM TOP: AZ68/ISTOCKPHOTO; CARSTEN PETER/NATIONAL GEOGRAPHIC/GETTY IMAGES

Genes & Cells

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Cats engineered to resist disease

Genetic tweak may foster immunity to HIV-like virus

By Tina Hesman Saey

A new breed of glowing green kitties may represent a first step in creating cats that are resistant to feline AIDS, possibly giving clues about fighting HIV infections in people.

The kittens are engineered with a gene that makes an antiviral protein that scientists hope will combat feline immunodeficiency virus, or FIV. (Another inserted gene makes the cats glow under fluorescent light so scientists can readily confirm the procedure's success.) Researchers at the Mayo Clinic College of Medicine in Rochester, Minn., and Yamaguchi University in Japan report the accomplishment online September 11 in *Nature Methods*.

TgCat3 (for transgenic cat 3) carries genes for green fluorescent protein, which makes her glow under fluorescent light, and also for an antiviral protein.

MAYO CLINIC

HIV has killed millions of people worldwide and infects millions more; FIV is causing a similar worldwide epidemic within the feline population, says study leader Eric Poeschla, a molecular virologist at the Mayo Clinic.

Part of the reason cats fall prey to the virus is their lack of a key immune protein called TRIM5alpha, which helps fight viruses even before the rest of the immune system knows an infection is under way, Poeschla says. He and his colleagues decided to do "an evolutionary experiment" to see if inserting this antiviral protein would protect cats from FIV.

The researchers injected eggs from ovaries left over after spaying procedures with viruses containing genes for a rhesus monkey version of the antiviral protein and a green fluorescent protein. The viruses inserted the genes into the eggs' DNA. After fertilizing the eggs, the researchers transplanted the resulting embryos into the wombs of feline surrogate mothers. In the end, three transgenic kittens — meaning kittens carrying foreign genes — survived past birth: two males and one female. Because the cats carry the foreign genes in every cell, including eggs and sperm, the animals have been able to pass the genes on to their own kittens.

Poeschla and his colleagues don't know yet whether the monkey gene will protect the cats from getting FIV: The team needs to do more genetic experiments and breed the cats to get enough animals to test immunity to the virus. If the experiments are successful, the cats could be the first of a new breed immune to the virus. The researchers also hope studying the cats will show how TRIM5alpha and related proteins work, something that could be important for protecting humans from HIV.

These cats are the first to carry two foreign genes, says Martha Gomez, a reproductive biologist at the Audubon Center for Research of Endangered Species in New Orleans, who was part of a team that created fluorescent cats using cloning.

It remains to be seen whether the newly created cats will be able to pass along any protection their foreign genes might confer for more than one generation. Unpublished data from Gomez and her colleagues suggest that foreign genes are shut off before reaching a second generation of kittens. That could limit the usefulness of the technique for making multiple generations of transgenic cats. ■

NEWS BRIEFS

Heart light

Stanford University researchers have created human heart cells that beat in response to light. The team genetically engineered embryonic stem cells to contain the light-activated protein channelrhodopsin-2, then grew the stem cells into beating heart cells in lab dishes. The heart cells naturally beat to their own rhythm until researchers turned on a flash of blue light. Then the cells became tuned to the rhythm of the flashing light, the team reports in the Sept. 21 *Biophysical Journal*. Controlling cells with flashes of light may help researchers better understand how hearts beat, and could lead to light-based pacemakers.
—Tina Hesman Saey

Anti-aging proteins are no font of longevity

Sirtuins, proteins once touted as the answer to fighting aging, aren't all they were cracked up to be. Previous research had shown that making more of a sirtuin called sir-2.1 could lengthen the lives of roundworms and fruit flies. But the life-extending properties observed in those experiments were probably due to genetic variations unrelated to sirtuins, report researchers at University College London and an international team of collaborators in the Sept. 22 *Nature*. Mohan Viswanathan and Leonard Guarente, both of MIT, also show in the same issue that the role of sirtuins in increasing life span was overstated in reports of earlier experiments. Guarente's lab was the first to discover a link between sirtuins and longevity.
—Tina Hesman Saey

Molecules

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

Explosive goes boom, not too soon

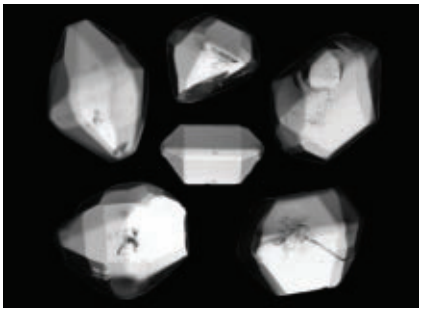
Mixing with TNT makes powerful substance relatively stable

By Rachel Ehrenberg

Look out, Road Runner: There's a new explosive for Wile E. Coyote's arsenal. By reining in a supersensitive explosive with good old-fashioned TNT, chemists have created a new compound that can be stored safely and then quickly converted to a superexplosive form.

The new "cocrystal" comprises a zigzagging chain of the explosive CL-20 and TNT that, after heating, reverts to a form of CL-20 that detonates more readily than either explosive alone, researchers report online August 25 in *Angewandte Chemie International Edition*.

"You want an explosive to deliver a lot of destructive energy," says Thomas Klapötke of the Ludwig Maximilians University of Munich, an expert in energetic materials. And it should explode fairly easily. "But then it often becomes more dangerous to handle," Klapötke says.



By combining two explosives, TNT and CL-20, scientists have created a new crystal (pictured) that's very explosive yet relatively safe to transport.

Seeking a magical mix of stability and explosive power that would also provide a good bang for the buck, materials chemist Adam Matzger and his University of Michigan colleague Onas Bolton experimented with CL-20, a relatively new material developed by the U.S. Navy.

"CL-20 has wonderful power, but it's a little sensitive — it tends to go off easily," says Matzger. "If you're on a ship transporting munitions you don't want a little hit to set everything off."

So the researchers put CL-20 in a solvent with Wile E.'s old standby, TNT. Mixed together, the two substances form a solid crystal that is much less sensitive than CL-20, the researchers report. They tested the material using a detonation yardstick known as a drop test, which is just what it sounds like: The researchers repeatedly dropped a weight on the new material from different heights to find the distance that causes it to explode 50 percent of the time.

Drop testing with a 2,940-gram weight showed that this height for the new crystal is 99 centimeters. That's more than twice the height for CL-20 alone, suggesting that the new material might be transported relatively safely.

Then, when it's time to blow something up, handlers would heat the new crystal to 136° Celsius to create a supersensitive version of CL-20. The substances separate, yielding pure TNT and CL-20 that's peppered with structural defects that make it even more touchy, with a drop height of 41 centimeters.

Science gets details on DEET

Repellent appears to deter insects by confusing them

By Rachel Ehrenberg

The insect repellent DEET doesn't actually repel insects — it confuses them. New research suggests that DEET gums up sniffing machinery, sabotaging an insect's sense of smell.

Nerve cells that send odor-related signals to the brain respond differently to DEET if it's sniffed alone or with other scents, experiments with fruit flies reveal. DEET's effects also vary depending on what variety of smell-receiving machinery catches the scent, and whether it's a whopping dose or just a whiff, researchers report online September 21 in *Nature*.

"The effects of DEET are not straightforward," says neuroscientist Maurizio Pellegrino of the University of California, Berkeley, a member of the research team. "We think it confuses the odor coding — the insect doesn't know exactly what it is smelling."

While DEET has protected people for decades from loathsome mosquitoes, ticks and chiggers, it hasn't been clear how it does its stuff. Some evidence suggests that the compound, technically N,N-diethyl-meta-toluamide, hits a specific cellular baseball mitt, an odor receiver that catches repellent scents, triggering a "get-the-heck-out-of-here" signal.

But the new work suggests that DEET isn't repulsive or frightening to bugs. It's baffling, blinding them to the delicious scent of human.

Fruit flies have much of the same sniffing machinery as mosquitoes and are more convenient experimental subjects. The flies have more than 60 cellular mitts, or receptor molecules, for catching scents. When the mixtures of molecules that make up odors drift by, the mitts snatch particular molecules, causing nerves to fire and send an odor message to the fly's brain.

When the researchers exposed flies to DEET both alone and combined with other scents, the nerves didn't fire in a consistent pattern. Changing up the concentration of DEET altered the nerve firing as well. The results suggest that DEET corrupts the odor signal, perhaps by contorting parts of the sniffing machinery so that wafting molecules other than DEET are misinterpreted.

O. BOLTON AND A. MATZGER/*ANGEWANDTE CHEMIE INTERNATIONAL EDITION* 2011

Life

"We're watching a clock in the process of being broken." —NICHOLAS S. FOULKES

Cave fish follows its own rhythm

Odd biological clock counts a 47-hour day, cues to grub

By Tina Hesman Saey

A species of fish that has lived in caves for millions of years has lost its eyes—and may be losing inner clocks that set body rhythms to daily light-and-dark cycles.

A fish that swims in limestone caverns under the Somalian desert has something to tell scientists about keeping time. Despite living in permanent darkness, this blind cave dweller still has its own quirky sense of rhythm.

The Somalian cave fish (*Phreatichthys andruzzii*) has an inner timekeeper set by food rather than sunlight that ticks out a roughly 47-hour day, scientists from Italy, Germany and Spain report online September 6 in *PLoS Biology*.

This odd biological clock may teach scientists more about the molecular pathways that govern such clocks, why clocks are important to organisms and how living things adapt when their clocks are no longer tied to cycles set by the rising and setting of the sun.

The daily clocks of most animals, plants and some kinds of bacteria follow an approximately 24-hour cycle and are reset largely by sunlight. These circadian clocks help govern sleeping, waking and feeding times, the rise and fall of blood pressure and other daily rhythms.

Over up to 2.6 million years, Somalian cave fish have adapted to life in the dark. The fish's eyes, scales and coloring have disappeared, and its clock has been altered, say coauthors Nicholas S. Foulkes of the Karlsruhe Institute of Technology in Germany and Cristiano Bertolucci of the University of Ferrara in Italy.

In lab tests, the cave fish didn't respond to 12-hour light-and-dark cycles that set circadian clocks in closely related zebra fish. But after scientists replaced two faulty light-sensing proteins in cave fish cells with ones from zebra fish, the cave fish's clock responded to the light-dark cycles, indicating that core components of the fish's biological clock still work.

"We're watching a clock in the process of being broken," says Foulkes. In another million years or so, the cave fish may lose other important clock parts, he says.

But other researchers see a different scenario. "I think one of the remarkable things is how intact the clock still is," says Jennifer Liang, a developmental biologist at the University of Minnesota Duluth. The clock may be shifting to other environmental cues, she says.

Indeed, the cave fish and zebra fish clocks could both be set by feeding times. And although temperature is steady in the cave fish's subterranean home, raising the temperature sped up the cave fish clock and lower temperatures slowed it in the lab. Most organisms' clocks are insulated from temperature changes.

Cave fish may have gradually lost the unneeded insulating capacity along with the light sensors, says Robert Lucas of the University of Manchester in England.

FROM TOP: SAULO BAMBI; C. TRACY

Frogs make do with dew

During northern Australia's dry season, green tree frogs can pull a drink out of thin air. Even on chilly nights, green tree frogs (*Litoria caerulea*, left) turn up outside their cozy tree cavities. New experiments show that water condenses on the frogs when they hop back inside from the cold, Christopher Tracy of the University of Melbourne in Australia and colleagues report in the October *American Naturalist*. "They can get a little bit of water, and that little bit of water might be very important," Tracy says. Frogs air-cooled to below 15° Celsius accumulated 0.03 percent to 0.54 percent of their body mass in condensation. The strategy is a trade-off for the animals, however, because leaving a humid refuge for the dry, cold night air increases water loss through the skin. Using a computer simulation, the team calculated that a frog would benefit if it stayed outside only for the half an hour or so needed to chill itself to the temperature of the night air. —*Susan Milius*

Science & Society

For longer stories on the Nobel Prizes, visit **www.sciencenews.org/Nobels2011**

Surf-zone study wins top prize for young scientist

Awards announced for first Broadcom MASTERS contest

By Devin Powell

Daniel Feeny (center), shown with SSP's Elizabeth Marincola (left) and Broadcom CEO Scott McGregor, earned first place in the Broadcom MASTERS competition.

A typical 14-year-old goes to the beach to play in the waves. But Daniel Feeny went to a beach near Pescadero, Calif., to study them. Using a homemade rig of springs and balls, he showed that the force of the waves close to shore doesn't dictate the diversity of marine life.

"I discovered that nature doesn't work that way; it's not that simple," says Feeny, now 15, who ran his experiment as an eighth-grader at Woodside Elementary School. "Many variables ... can affect diversity, like the terrain and drying out."

For his own research and his performance in team-based contests, Feeny won first place in the inaugural Broadcom Math, Applied Science, Technology and Engineering for Rising Stars, or MASTERS, program. Winners and finalists in this national competition for sixth-, seventh- and eighth-graders were honored October 4 at a gala at the Carnegie Institution for Science in Washington, D.C.

"It's all about getting more kids to touch science and to have a hands-on experience with science," says Scott McGregor, chief executive officer of Broadcom Corp. and president of the Broadcom Foundation, which sponsors the competition. Feeny's prize, a $25,000 education award, was funded by the Samueli Foundation, a private nonprofit organization based in Corona del Mar, Calif., begun by Broadcom's cofounder Henry Samueli.

In its first year, the competition received 1,476 entries from students in 45 states, Puerto Rico and Washington. Each student had been nominated by a local science fair affiliated with Society for Science & the Public, the nonprofit organization that administers the Broadcom MASTERS program and publishes *Science News*. Thirty finalists came to Washington to present their research projects and compete in contests testing aptitude in science, technology, engineering and math.

"We want to reinforce a scientific mind-set in students whether or not they end up going into science," says Elizabeth Marincola, president of SSP and publisher of *Science News*.

The team of scientists and engineers that judged the students awarded second place and $10,000 to Benjamin Hylak, 14, of West Grove, Penn. Inspired by a visit to his grandmother in a nursing home, he built and programmed a robot that can be operated remotely over the Internet for people who live far from their relatives.

"We've all run out of time in our culture, and I was seeing a lot of people staring at walls," says Hylak, who made the robot out of a Roomba robotic vacuum, a trash can and a total of $500 in parts.

Third place and a $5,000 award went to I-Chun Lin, 14, of Plano, Texas, who tested new ways to improve the efficiency of solar cells using natural dyes from raspberries and blackberries.

Other finalists earned a combined $20,000 in prizes in individual disciplines. Samantha Rowland, 14, of Tipp City, Ohio, tested whether some colors of decorative lights cause more Christmas tree needles to fall off than other colors, earning the award in the Science category. Robert Heckman, a 14-year-old snorkeler from Kailua, Hawaii, won in Technology for investigating why tumors form on corals. For her tests of whether rising salt concentrations have an impact on mud snails, Katherine Landoni, 14, of Sequim, Wash., placed first in Engineering. The Math award recipient, 14-year-old Crystal Poole of San Diego, drew on her experience frosting cakes with her grandmother to show that adding cornstarch helps prevent icing from melting.

Two students chosen for Rising Stars awards will travel to Pittsburgh in May to observe the Intel International Science and Engineering Fair, a competition organized by SSP. Carolyn Jons, 13, of Eden Prairie, Minn., showed that bubbles can improve the insulation provided by a liquid. Chad Campbell, 12, of Hampstead, N.C., developed a way to test for antibiotics in meat samples from local supermarkets.

Finalists' schools will receive $1,000 and teachers will get a $125 Walmart gift card, provided by Elmer's Products Inc., the classroom sponsor.

ROBIN BARRETT

Shocking discoveries dominate the 2011 Nobel science prizes

Awards recognize findings that went against the grain

The 2011 Nobel Prizes have recognized three very different scientific advances that had at least one thing in common: They shocked researchers in their fields by overturning fundamental notions of how the world works.

On October 5, the chemistry prize went to a scientist who essentially lost his job over his discovery, only to be vindicated when his work was later validated. Dan Shechtman, now at the Technion–Israel Institute of Technology in Haifa, was working in a U.S. federal lab in 1982 when he concluded that crystal structures — lattices of identical, repeated arrangements of atoms in countless solid materials — don't necessarily have to be identical or repeated. Some materials arrange themselves in quasicrystals, similar arrangements of atoms that vary slightly over space. None of Shechtman's colleagues believed him at first, and he moved to a different lab. Three decades later, quasicrystals are found in surgical blades and may be useful as heat insulators in engines and electronic devices.

"He stuck to his guns, and with time researchers found that this unique crystal structure was actually right," says American Chemical Society president Nancy Jackson, a chemical engineer at Sandia National Laboratories in Albuquerque.

The 2011 physics Nobel went to three researchers who turned cosmology on its head. Work by astronomer Edwin Hubble in the 1920s showed that the universe is expanding: Until the end of the 20th century, that expansion was thought to be gradually decelerating under the force of gravity. But in 1998, astrophysicists showed that the expansion of the universe is actually speeding up, as if some undetected source of energy were pushing spacetime itself apart. Today that mysterious phenomenon, dark energy, is one of the hottest topics in theoretical physics.

The winners of the physics prize — Saul Perlmutter of Lawrence Berkeley National Laboratory in California, Brian Schmidt of the Australian National University in Weston Creek and Adam Riess of Johns Hopkins University and the Space Telescope Science Institute in Baltimore — documented the universe's acceleration by studying stellar explosions known as type 1a supernovas. The astrophysicists found that light from more distant supernovas looked dimmer than would be expected if the universe's expansion is steady or decelerating.

"It was with a fair bit of trepidation that we ended up telling our group, and eventually telling the world, that we had this crazy result," Schmidt told the Nobel committee during the public announcement of the prize on October 4.

At the same time that Schmidt and his colleagues were studying supernovas, Jules Hoffmann of the Molecular and Cellular Biology Institute in Strasbourg, France, was studying a fruit fly gene known as *Toll* that helps guide the assembly of the insect's body. He found that when mutated, the gene not only disfigures fruit fly larvae but also makes them vulnerable to fungal infections. Further research showed that in mammals, a *Toll*-like gene and the protein it encodes are fundamental to "innate immunity," the body's initial response to infection. One of the researchers who did that work, Bruce Beutler of the University of Texas Southwestern Medical Center at Dallas, shared half of the 2011 Nobel in medicine or physiology with Hoffmann.

The other half of the medicine prize went to Ralph Steinman of Rockefeller University in New York City. Steinman discovered dendritic cells, which are activated by the innate immune response and recruit a second, more specialized wave of cellular defenses against invaders.

Steinman died on September 30, three days before the winners of the Nobel medicine prize were announced. Though Nobel rules forbid awarding the honors posthumously, the committee that grants the prizes has decided that Steinman's selection will stand. — *Nathan Seppa, Devin Powell, Rachel Ehrenberg*

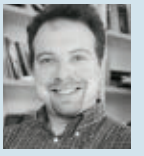
2011 NOBEL LAUREATES

Bruce A. Beutler
Physiology or Medicine
For discoveries concerning the activation of innate immunity

Jules A. Hoffmann
Physiology or Medicine
For discoveries concerning the activation of innate immunity

Ralph M. Steinman
Physiology or Medicine
For discovery of the dendritic cell and its role in adaptive immunity

Saul Perlmutter
Physics
For the discovery of the accelerating expansion of the universe



Adam G. Riess
Physics
For the discovery of the accelerating expansion of the universe

Brian P. Schmidt
Physics
For the discovery of the accelerating expansion of the universe

Dan Shechtman
Chemistry
For the discovery of quasicrystals

FROM TOP: COURTESY OF THE SCRIPPS RESEARCH INSTITUTE; BALZAN PRIZE; ZACH VEILLEUX/ROCKEFELLER UNIV.; ROY KALTSCHMIDT, LAWRENCE BERKELEY NATIONAL LABORATORY; HOMEWOOD PHOTOGRAPHY; BELINDA PRATTEN; TECHNION-ISRAEL INSTITUTE OF TECHNOLOGY

Humans

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Fossil finds give new details on ancient relative

Species proposed to have given rise to first humans

By Bruce Bower

Newly described fossils provide the closest look yet at an anatomically quirky, 2-million-year-old member of the human evolutionary family. Discoverers of the ancient bones suspect they come from a species that served as an evolutionary bridge from relatively apelike ancestors to the *Homo* genus, which includes modern people.

Four papers published in the Sept. 9 *Science* describe a mosaic of humanlike and apelike skeletal traits on *Australopithecus sediba*, a species found at South Africa's Malapa cave site. Dates for newly exposed cave sediments, presented in a fifth paper in the same issue of *Science*, indicate that *A. sediba* lived there 1.977 million years ago, give or take several thousand years.

An international team led by anthropologist Lee Berger of the University of the Witwatersrand in Johannesburg views the new findings as consistent with its previous suggestion that *A. sediba* fossils at Malapa represent late-surviving members of a hominid line that gave rise to *Homo*.

Bumps and furrows in a nearly 2-million-year-old *A. sediba* skull show similarities with modern humans, researchers say.

That proposal is controversial. Some researchers doubt that *A. sediba* set the stage for the *Homo* genus. Others regard the Malapa fossils either as an early *Homo* species or as late-surviving members of *Australopithecus africanus*, a dead-end hominid species that lived from about 3 million to 2.4 million years ago in South Africa.

"There's still not enough evidence to place *A. sediba* squarely at the root of the *Homo* genus," remarks anthropologist Brian Richmond of George Washington University in Washington, D.C. Several *Homo* fossils date to more than 2 million years ago, suggesting that *A. sediba* evolved too late to serve as a transition, Richmond says.

A. sediba — represented in the new studies by fossils from a young male and an adult female — possessed traits typical of both *Australopithecus* and *Homo* species, Berger's team contends.

A virtual, 3-D reconstruction of bumps and furrows on the *A. sediba* male's brain surface allowed Witwatersrand anthropologist Kristian Carlson and his colleagues to peer through rock and into the male's skull to measure impressions made by his brain on surrounding bone.

Surface landmarks of *A. sediba*'s brain look humanlike, though the ancient hominid's brain is small even by *A. africanus* standards, Carlson says. Markers of frontal-brain expansion in *A. sediba* align it closely with modern humans.

Reorganization of the frontal brain, not a larger overall brain as is often argued, characterized the transition from *Australopithecus* to *Homo*, Carlson theorizes.

It's not clear that *A. sediba*'s frontal brain was more humanlike than that of *A. africanus*, says anthropologist Dean Falk of Florida State University in Tallahassee, who was not involved in the research. *A. sediba*'s reconstructed brain surface includes a frontal landmark found in apes but not people, Falk says.

The fossil right hand of an adult *A. sediba* female may hint at tree climbing as well as a precision grip.

Both *A. sediba* individuals, and especially the female, possessed bowl-shaped, humanlike hip bones, an unexpected trait for hominids with such small brains, says Witwatersrand anthropologist Job Kibii. This anatomical combination challenges the long-standing idea that wide pelvic openings in the *Homo* genus evolved in response to brain expansion, allowing females to give birth to babies with relatively big heads, Kibii contends.

Pelvic widening in *A. sediba* may have evolved in response to an increasing emphasis on walking, he suggests.

Foot, ankle and lower-leg bones from both Malapa individuals underscore that *A. sediba* walked upright, although more stiffly than modern humans and without abandoning tree climbing, says Witwatersrand anthropologist Bernhard Zipfel.

A nearly complete right hand from the female *A. sediba* skeleton shows key humanlike features, says anthropologist Tracy Kivell of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. Shortened fingers and a long thumb, as well as evidence of powerful grasping muscles, indicate that *A. sediba* was capable of making and using stone tools, Kivell says.

In Kivell's opinion, *A. sediba*'s hand and wrist were more humanlike than those of the 1.75 million-year-old *Homo habilis*, which means "handy man." Stone tools found in 1960 among some handy man remains in East Africa — including parts of a left hand — cemented his reputation as a toolmaker. Researchers have unearthed no stone tools at Malapa.

FROM TOP: BRETT ELOFF, COURTESY L. BERGER/U. OF WITWATERSRAND; PETER SCHMID, COURTESY L. BERGER/U. OF WITWATERSRAND

When one face looks like a crowd

Multiple photos of a stranger's mug ID'd as different people

By Bruce Bower

For an instant "identity crisis," just peruse some photographs of a stranger's face. In many instances, people view different mug shots of the same unfamiliar person as entirely different individuals, say psychologist Rob Jenkins of the University of Glasgow in Scotland and his colleagues.

Yet photos of a celebrity or other recognizable person retain a uniform identity despite changes in lighting, facial expression and other factors across images, the scientists report online September 3 in *Cognition*.

"There are real problems with photo IDs," says psychologist Richard Russell of Gettysburg College in Pennsylvania. Previous research has found that volunteers often can't match the face of a stranger standing in front of them to that person's image on an ID card. Other evidence suggests that digitally combining several photos of the same person taken under different conditions improves performance on this matching task.

Jenkins' new study underscores a deep, poorly understood divide between familiar and unfamiliar face recognition, says psychologist Bradley Duchaine of Dartmouth College. Russell theorizes that face familiarity partly requires learning to recognize an individual's physical properties that stay constant under different conditions.

Jenkins and his colleagues gave 20 British college students a shuffled deck of 40 photos. Twenty different images of each of two Dutch celebrities appeared on the cards. Volunteers had never seen the foreign celebrities.

When asked to sort photos by identity, participants created anywhere from three to 16 piles. Students most often discerned nine individuals in the two women's photos.

Dutch volunteers usually sorted photos of the two women, whom they recognized, into two piles.

Another experiment found that, among British students shown a dozen face photos of each of 40 familiar British celebrities, some images were considered much better physical likenesses than others. A greater number of face photos of particularly well-known celebrities were rated as good likenesses, supporting the idea that familiarity with someone's face breeds tolerance to facial variability.

Body & Brain

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Brain may subvert efforts to diet

In obese, hunger signals can persist even after a meal

By Janet Raloff

In obese people, even when the brain knows the body isn't hungry, it responds to food as if it were, new brain-scan data show. That means that when obese people try to shed weight, they may find themselves on the losing side of a battle with neural centers that unconsciously encourage eating.

For instance, in normal-weight people a neural reward system that reinforces positive feelings associated with food turns off when levels of the blood sugar glucose return to normal after a meal — a signal that the body's need for calories has been sated. But in obese people, that reward center in the central brain turns on at the sight of high-calorie food even when blood sugar levels are normal.

"The regulatory role of glucose was missing in the obese," says Elissa Epel of the University of California, San Francisco, an obesity researcher not involved with the new study. She says the data might "explain the drive to eat that some obese people feel despite how much they've eaten."

For the study, nine lean and five obese adult volunteers viewed pictures of foods such as ice cream, french fries, cauliflower or a salad while undergoing brain scans. Throughout the procedure, researchers asked the recruits to rate their hunger and how much they wanted a particular item.

Volunteers arrived for their brain scans several hours after eating, and the researchers used insulin pumps to establish volunteers' blood sugar levels at either normal background values (roughly 90 milligrams per deciliter), or at the "mild" end of low (around 70 milligrams per deciliter). That low value can occur briefly in some people during the day, especially in people with diabetes or metabolic conditions that precede diabetes, notes Yale endocrinologist Robert Sherwin, a coauthor of the new study.

All volunteers reported wanting food, especially high-calorie fare, when blood glucose was low, Sherwin's team reports online September 19 in the *Journal of Clinical Investigation*. Brain scans showed that parts of the brain that control reason and willpower, such as the prefrontal cortex, were relatively inactive when blood glucose was low, while regions that foster eating and offer positive reinforcement turned on. For lean people, the opposite trend emerged when blood glucose was normal.

The surprise, Sherwin says, was that the part of the brain that allows people to consciously exert willpower over food intake largely turns off in obese people. Such changes "may perpetuate obesity."

Though small, this study was so well designed and controlled that it "lets us see some clean results in a relatively small cohort," says obesity scientist Dianne Lattemann of the Veterans Affairs Puget Sound Health Care System in Seattle. The research team's ability to discern differences in the desire for foods by body weight — and based on a not-too-dramatic drop in blood sugar — "is extremely interesting," she adds. The results pull together trends seen in animals and findings reported in more limited human trials.

If that's a TV, this is the den

To the brain, a scene may be just the sum of its objects

By Laura Sanders

To one part of the brain, a bathroom equals tub plus toilet. In mental terms, certain scenes are sums of their objects, researchers report online September 4 in *Nature Neuroscience*. The results help explain how people quickly and accurately recognize complicated scenes such as playgrounds and traffic intersections.

Much of what is known about vision comes from studies of how people see simple objects in isolation, such as a line floating on a white screen, says Dirk Bernhardt-Walther of Ohio State University. The new work, in contrast, deals with messy, real-world scenes. "It's an awesome study," he says.

A number of brain systems help tell people where they are, each relying on different information. When the outlines of a place offer little info, the brain homes in on specific objects. "A bathroom and a kitchen may have similar three-dimensional shapes ... but the objects will tell you a big difference," says study coauthor Sean MacEvoy of Boston College.

MacEvoy and Russell Epstein of the University of Pennsylvania measured the brain activity of 28 people viewing one of four scenes: a bathroom, kitchen, street intersection or playground. Participants also saw isolated objects associated with each scene, allowing the researchers to record the neural signature of each object. Combined, the signatures of single objects closely matched the responses to entire scenes in a part of the brain called the lateral occipital cortex, or LOC, the researchers found. The average LOC response to a stove and a fridge, for example, matched the response to an entire kitchen.

For scenes with few objects, the brain may rely on a different system that takes a more holistic view. "If you put a sofa in the desert, you create a huge conflict of what you're looking at, whether it's a desert or a living room," says Marius Peelen of the University of Trento in Rovereto, Italy. Studies of what happens when people view such images may illuminate how the systems work together, he says.

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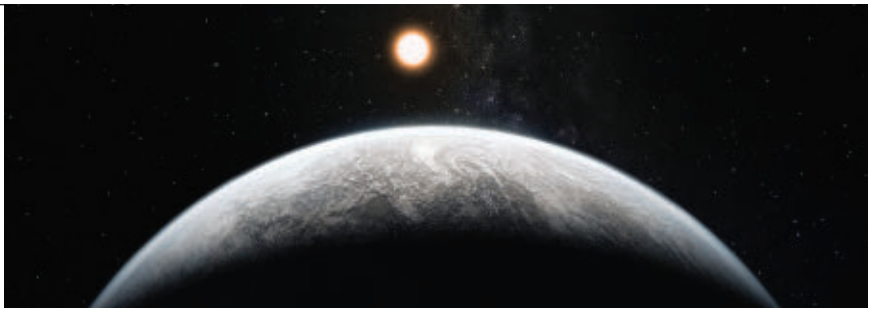
Planet hunt finds lots of little ones

Odds improve for detecting a plethora of Earthlike orbs

By Nadia Drake



The super-Earth HD 85512b (illustrated here) is one of more than 50 newly discovered exoplanets announced September 12 by the Swiss-led HARPS team.

Planet hunters have unlocked a treasure chest of alien worlds: more than 50 planets, at least 16 not much bigger than Earth, including one small, sparkling nugget: a 3.6-Earth-mass planet parked just inside its star's life-friendly zone.

"We can say that most of the stars have planets, and most of them have low-mass planets," says astronomer Francesco Pepe, a member of the Geneva Observatory's HARPS team that presented the new finds September 12 during the Extreme Solar Systems conference in Moran, Wyo.

HARPS finds distant worlds by focusing on wobbly stars pulled in different directions by orbiting bodies, causing a Doppler shift in the color of the starlight. The update brings the team's eight-year discovery total to more than 150 planets.

A paper to appear in *Astronomy & Astrophysics* presents the team's description of its planetary population and suggests that more than 50 percent of sunlike stars sport a planet. The latest planet dump suggests that roughly 70 to 80 percent of low-mass planets — with masses between Earth's and Neptune's — might live in multiplanet neighborhoods.

"We can see that most stars have planetary systems, probably like our own," says astronomer Debra Fischer of Yale University. "This paper is a home run hit for the Geneva team."

The new collection suggests that lighter planets are more common in extrasolar systems than heavier Jupiter-like ones. Astronomers predict Earth-sized planets will be yet more common.

Surveys haven't detected any such planets yet but are getting close. HARPS previously bagged a planet with 1.9 Earth masses; the newly discovered planet HD 85512b, which lives in the habitable zone around its star, is only 3.6 Earth masses. As searches continue, finding Earthlike planets in life-friendly orbits looms.

"The floodgates are about to open," Fischer says.

Hints of a flaw in special relativity

Neutrinos exceed speed of light, but physicists stay skeptical

By Devin Powell

An experiment with neutrinos has called into question Einstein's theory of special relativity. Physicists working on Italy's OPERA experiment say they have clocked the neutrinos traveling faster than the speed of light.

Few experts believe that this result will ultimately hold up. But according to the OPERA team's calculations, there's only a one in a billion chance that the finding is a statistical fluke, the team announced on September 23 at the European physics laboratory CERN near Geneva.

"This will be a tremendous revolutionary finding if it is true," says Chang Kee Jung, a particle physicist at Stony Brook University in New York. But he says he'd bet his house that it isn't.

OPERA's neutrinos were born from protons smashed into a chunk of graphite at CERN. They then traveled underground to Italy's Gran Sasso National Laboratory beneath the Apennines Mountains. A detector spotted the arrival of a small fraction of the particles — about 16,000 in total between 2009 and 2011.

Thanks to GPS devices, the distance of this trip, about 730 kilometers, is known to within 20 centimeters.

Light traveling in a vacuum would have made this trip in 2.44 milliseconds. The neutrinos shaved about 60 nanoseconds off that time, according to atomic clocks at either end synchronized by a satellite.

Still, the team may have missed some unknown uncertainties built into their equipment, says Kevin McFarland, a particle physicist at the University of Rochester in New York.

"It's just odd," he says. "Everybody's bias in responding to this is going to be that this is some sort of systematic uncertainty that they didn't figure out."

This isn't the first report of superluminal neutrinos. In 2007 the MINOS experiment turned up hints of neutrinos traveling impossibly fast between Fermilab, in Batavia, Ill., and a mine in Minnesota. But the uncertainties in those measurements were large.

MINOS will soon upgrade its equipment with new atomic clocks, says Fermilab physicist Rob Plunkett. The upgraded experiment will start in 2013 and last for a year or so.

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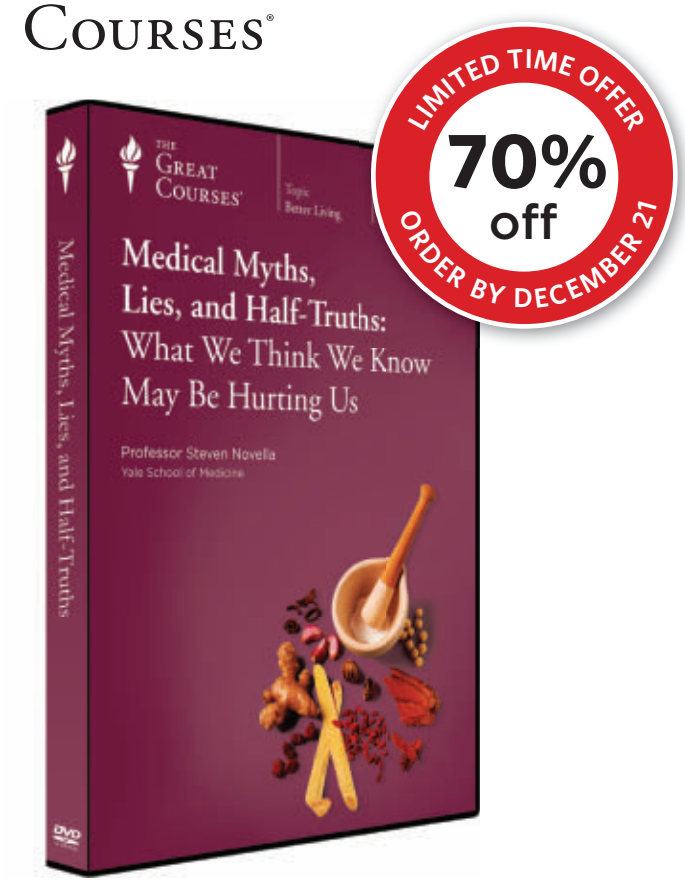

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A shadowed past

Understanding of moon's earliest days gets even murkier

By Nadia Drake

Suspended in the sky, the moon has stared unblinking at the Earth for billions of years. But new work suggests the placid sphere's two faces may belie a violent childhood — one that involved the death of a small celestial companion. The moon may also be lying about when it was born, by millions of years.

Together, the studies, published in August in *Nature*, lend a somewhat shady character to this perennial source of both fear and inspiration. With the Lunar Reconnaissance Orbiter already keeping a close eye on the moon (*SN Online: 9/18/09*) and the recently launched twin GRAIL spacecraft (*SN Online: 9/20/11*) tasked with mapping its interior, scientists hope to uncover more clues to the satellite's past.

Not since the Apollo era has Earth's nearest neighbor attracted such attention and resources.

"There's definitely a resurgence in lunar science," says planetary scientist Robin Canup of the Southwest Research Institute in Boulder, Colo. "The moon will always be a singularly important object in many ways. It's our moon. Its history is tied to us. It's not just proximity; it's what we think of as a shared history of origin."

Most scientists believe that the shared history dates to just over 4.5 billion years ago, when the Earth and a Mars-sized object collided. The resulting impact blasted molten debris into space, where it formed a disk around the planet. Eventually, the fiery material coalesced and became the early moon — a big ball of crackling rock and the host of a global magma ocean. As that ocean solidified and cooled, it differentiated into the lunar crust and mantle, forming the rocks later plucked from the surface by those legendary space cowboys, the Apollo astronauts.

But when planetary geologist Lars Borg recently investigated one of these moon rocks in a mass spectrometer, the ingredients hinted at a revision to the classic tale.

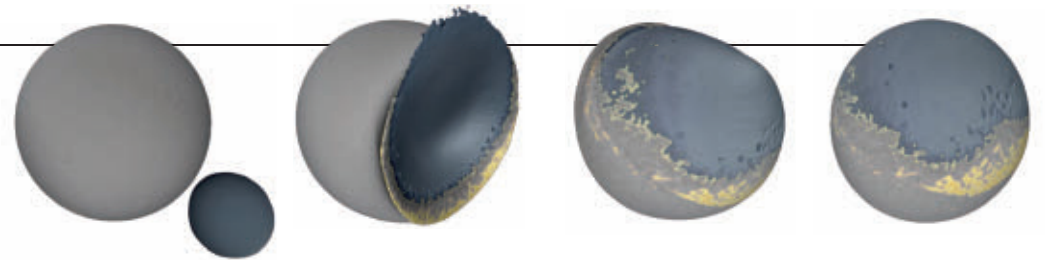
New lunar years

Borg, of the Lawrence Livermore National Laboratory in California, and his colleagues set out to determine the rock's age by comparing levels of different isotopes, versions of an element differing in the number of neutrons in their atomic nuclei.

The rock would reveal when minerals floated atop the lunar magma ocean and solidified into crust, marking the moon's formation. After looking at the levels of decaying lead and neodymium isotopes, though, Borg's team found that this particular rock was much younger than expected, and not just by a bit. It

Much of the moon's history remains unclear, including why the nearside (right, in this north pole view) is so different from the farside.

NASA, JPL, USGS



Splat in the sky A smaller companion moonlet may have long ago smacked into Earth's current moon (as shown at right), a recent study suggests. That splat would have blanketed the moon's farside with debris, explaining its thicker crust.

M. JUTZI AND E. ASPHAUG/*NATURE* 2011

was only 4.36 billion years old, about 150 million years younger than theory would suggest.

The result, published in the Aug. 18 *Nature*, is surprising, but it's hard to argue with. Scientists agree that the team's methods were solid, the analyses careful.

"Everybody's question, including our own, is 'What does this mean?' " Borg says.

One possibility is that the moon cooled slowly. "But that gets to be problematic, because there's good evidence that cooling happened rapidly," Borg says. Another option is that the rock came from a regional magma sea or some other process, rather than the global magma ocean believed to be the source of such rocks.

Linda Elkins-Tanton, a planetary scientist at the Carnegie Institution for Science in Washington, D.C., who studies magma oceans, says she's not yet ready to rewrite the global magma ocean story. "I would be very cautious about changing our understanding of lunar solidification based on one age," she says.

She suggests that scientists go back and redate older moon rocks — including some as old as 4.45 billion years — using the improved analysis.

Clive Neal of the University of Notre Dame in Indiana agrees. "I don't think you can throw the baby out with the bathwater here. Go back and look at some of the samples with older ages.... Do the same careful work that Borg *et al* did."

Redating these samples could reveal that the moon is in fact younger than previously thought — a third explanation for the age of Borg's rock — though scientists aren't ready to support such a conclusion yet.

Companion moonlet

For now, the mystery of the moon's age remains unsolved, joining another lingering puzzle regarding the satellite's past: why the hemispheres are so different. The nearside is smoother, with large volcanic basins. The farside is mountainous and cratered, with elevations exceeding 8 kilometers.

Planetary scientist Erik Asphaug of the University of California, Santa Cruz and Martin Jutzi of the University of Bern in Switzerland have a new explanation for this disparity. The moon might not have always been a companionless, lonely crescent, they suggested in the Aug. 4 *Nature*. Once, it might have had a friend sharing its orbit, a smaller moonlet that adorned Earth's skies with another shifting face for tens of millions of years. But, in this team's story, that friendship had a sad ending.

One day, in a slow-motion collision, the moonlet smacked into the moon's farside. Because the splat happened slowly, it didn't produce a crater. Instead, the moonlet pancaked, covering the moon's backside with rocks.

The extra material deposited on the lunar backside would explain the asymmetrical thickness of the lunar crust, which varies by as much as 50 kilometers between the hemispheres. Such a smack could have also pushed a residual magma ocean and subsurface metallic layer to the moon's nearside, explaining the elemental composition beneath that portion of the satellite's skin.

"I'm pretty cautious about running head over heels about a hypothesis," Asphaug says, "but of the models I've put together involving collisions, this one has the most pieces that go click."

Canup likes the new idea. "It's definitely out of the box compared to the prior explanations," she says, referring to existing theories that link internal lunar processes to the moon's two different faces. She has produced several simulations of the original moon-forming giant impact — which Asphaug and Jutzi based their work on — and her models have included short-lived smaller moons.

Since they are littler, these moonlets would solidify more quickly and be made of rocks with older ages than the moon's.

Borg says he would expect some small fraction of the moonlet's shattered remains to litter the nearside. Perhaps some of them were even swiped by the Apollo astronauts, explaining the range of ages now measured from moon rocks.

"One interpretation is that this age range really reflects the older ages from the backside mixing with younger ages on the nearside," Borg says. But he thinks it is more likely that the older ages on some of the rocks are unreliable.

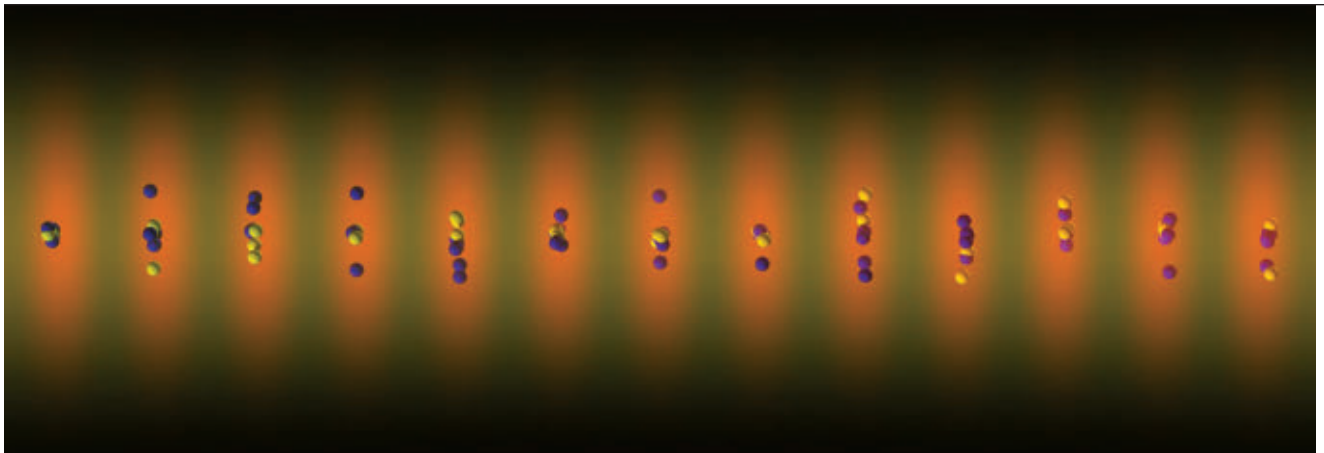
By mapping the moon's gravity field, the GRAIL mission might uncover new clues about the moon's interior structure, such as how thick the crust is and whether a global magma ocean ever existed. But the best way to address the new hypotheses presented by Borg's and Asphaug's teams is to collect more moon rocks, including from the farside highlands.

Such rocks are more than souvenirs brought back from Earth's companion, and they'll do more than help scientists unlock the mysteries of the moon. The extraterrestrial chunks may also hold clues to how terrestrial bodies form, including the watery sphere people call home.

"Once every couple of months, we get out the telescope, we get out the kids, and we look up at the moon in the backyard. And I explain how it might be relevant for the ground they're standing on," Borg says. "We look at the Apollo landing site. I'm just left with a sense of awe." ■

Explore more

- NASA Lunar Science Institute: lunarscience.nasa.gov/



The ULTIMATE Clock

Keeping precise time on the universe's scale

By Charles Petit

Time is an ancient and contrary mystery. Augustine of Hippo, writing his *Confessions* in a North African monastery, asked "Who can even in thought comprehend it, so as to utter a word about it? But what in discourse do we mention more familiarly and knowingly, than time?"

More than 16 centuries later, many scholars share the feeling, if not the prospect of sainthood. "We don't even know what time is. But we can measure it really, really well," says Chris Oates, a physicist at the National Institute of Standards and Technology's Boulder, Colo., campus.

His team operates a ytterbium optical lattice clock, one of the latest types of souped-up atomic timepieces. To track the passing seconds, such clocks rely on the fixed frequencies of photons absorbed and emitted by atoms' electrons as they change energy levels. Recently, scientists have found ways to make these quantum counters even better, by switching from a reliance on microwave frequencies to the faster-paced optical regime and introducing a system of checks that relies on multiple atoms in levitated grids. In a remarkable recent development, the central atomic metronomes are protected from distortion by a method so powerful that physicists formally call it magic.

Oates is a member of a worldwide cadre working with such devices at the frontier of clockmaking. His team's clock loses time at a rate of about one second every few hundred million years.

In what's called an "optical lattice clock," thousands of atoms are held in wells made of laser light. Oscillations of the atoms' electrons keep the time.

Speedy metrology

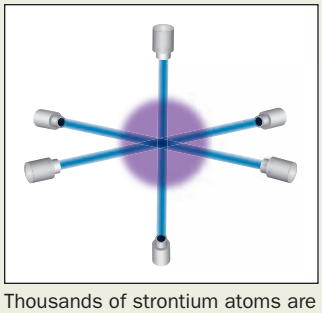
Such accuracy is why time is not just one dimension among several but a foundation for defining other fundamental units. The meter's definition has been defined with increasing accuracy by such things as one ten-millionth the distance on a circular arc from the equator to the North Pole, and by a precision-made "prototype meter" bar of metal alloy kept in Paris. In 1983 the meter officially became the distance light will travel in a vacuum in 1/299,792,458 of a second. The better the stopwatch, the

FROM TOP: NIST; PAUL CLEMENTS

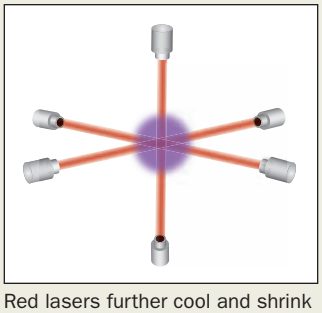
A laser jubilee

From the outside, a lattice clock appears to be a dizzying array of lasers, but (as shown in one type of strontium clock at right) each laser has a role in reading the time from atomic oscillations.

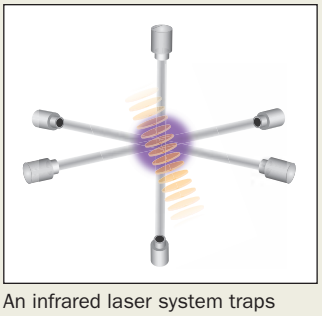
SOURCE: NIST



Thousands of strontium atoms are cooled by a system of blue lasers.



Red lasers further cool and shrink the cloud of atoms.



An infrared laser system traps the atoms, locking them into pancake-shaped wells.

better such definitions can be applied.

The metrology of time is not holding still. In the April-June issue of *Reviews of Modern Physics*, experimental physicist Hidetoshi Katori of the University of Tokyo and theorist Andrei Derevianko of the University of Nevada, Reno declared dramatic ambitions for a record-breaking atomic clock based on emissions from mercury atoms.

"If someone built such a clock at the Big Bang and if such a timepiece survived the 14 billion years, then the clock would be off by no more than a mere second," they note in the paper. That is actually conservative. The goal formally is to lose or gain no more than one out of every billion billion seconds. That is one second in about 32 billion years, and is 10 to 100 times better than any existing clocks.

In scientific shorthand, the proposed mercury clock would reach a fractional uncertainty of at most one part in 10^{18} — it would run for 1,000,000,000,000,000,000 seconds before being one second awry.

Already, atomic clocks have come a long way. While experimental clocks are moving ahead, a device called the NIST-F1 is the official U.S. timekeeper. It's accurate to a few parts in 10^{16}. It occupies a large first floor room in Building One at NIST's Boulder campus. The dominant feature is a shiny steel vacuum chamber 8 feet high. Inside is a laser-controlled fountain of cesium atoms chilled to near absolute zero. The atoms rise in clumps about as large as a man's thumb and, responding to gravity, fall back through a cavity in a tunable microwave generator.

Oscillations within the cesium atoms are akin to the to-and-fro of the balance wheel in an old wristwatch, but it is the microwave generator that communicates with the outside world. Just as the ticking of a watch arises from the escapement mechanism connected to the gears and hands, oscillations within the cavity are recorded electronically.

By itself, the microwave generator would drift off time. So with each passage of the atoms, the generator checks to be sure its pulsations exactly match the signal from a chosen energy transition in the atoms' electron clouds — an electromagnetic wave that beats 9,192,631,770 times a second.

NIST is now working on a successor, called F2. With an improved cooling system and superior way of moving the atoms through the microwave chamber, it will be about four times better and will beat out the current record for a long-term timekeeper, a clock in the United Kingdom that is accurate to about two parts in 10^{16}.

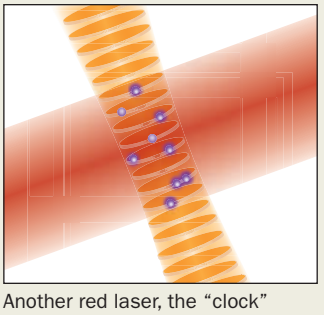
Such astonishing accuracy is no mere intellectual exercise. Recent advances in timekeeping have brought practical payoffs in the design of better global positioning systems that triangulate locations on Earth by measuring distance via radio-signal travel time, as measured by satellite-borne atomic clocks. Further progress should lead to instruments able, from the slowing or speeding of time's passage due to shifts in gravity, to improve maps of the planet's interior and to find mineral deposits or detect the movements of deep magma. Pure research on Earth and in space may gauge to almost unimaginable exactness the stability (or drift) of supposed constants of physics that not only affect nuclear decay, but also, some astronomers say, may have worked differently in distant eras.

Ticking gears

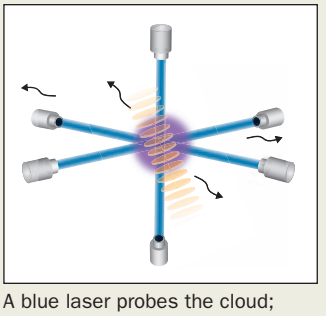
By historic standards, clock progress is now frenzied.

People have long kept track of time by monitoring processes that change measurably in a steady way. Early peoples monitored the seasons by the motion of the sun and moon. An 11th century Chinese water clock, its gears driven by a steady stream, might lose or gain 10 minutes a day — an accuracy of about a part in 100. Large, stable swinging pendulums in the 1600s were good to a few seconds a day. Eighteenth century navigation clocks that were the pride of the British Navy weren't much better. They lost or gained a minute or less per month, an accuracy of about one in 10,000, but they did it while tossing about in ships at sea. Quartz clocks and watches, paced by electrically stimulated crystals vibrating at about 32,768 times per second, were developed in the late 1920s. They keep time to within a second per day, better than a part in 10^5.

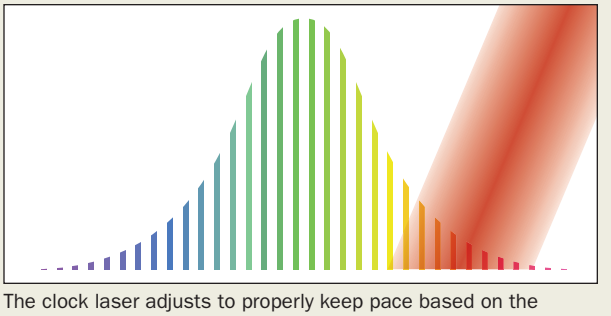
Then along came atomic clocks, following the beat of quantum mechanics, the laws that govern the energies of electrons bound to nuclei. Every 10 years since the first one debuted in 1949, based on oscillations in the ammonia molecule, the accuracy has increased by about 10 times. Recently, things have gone even faster.



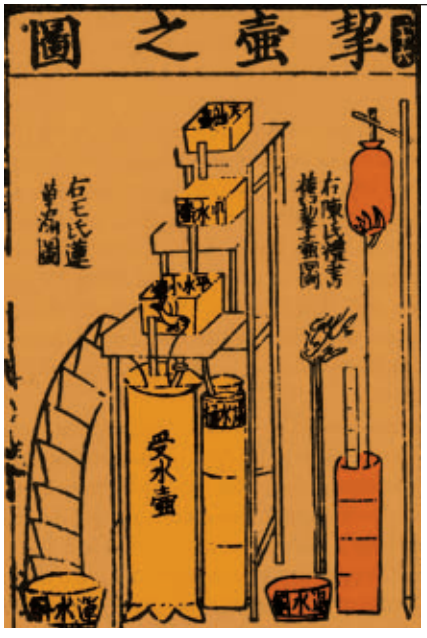
Another red laser, the "clock" laser, bathes the atoms, causing many of them to become excited.



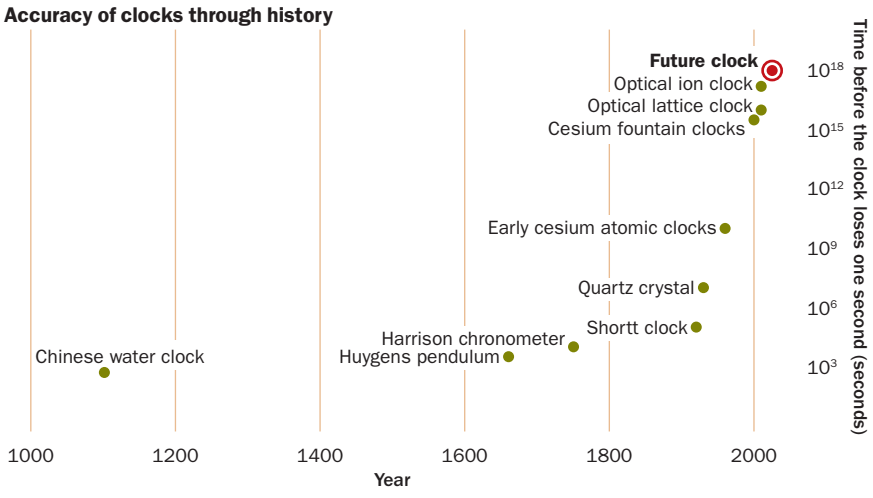
A blue laser probes the cloud; emitted light reveals how many atoms became excited.



The clock laser adjusts to properly keep pace based on the atoms' excitations. Light from the clock laser is passed through a "frequency comb," allowing the light's ticks to be read.



Time over time Timekeeping's accuracy improved dramatically during the last millennium. A Chinese water clock (oldest printed illustration shown at left) could lose around 10 minutes a day. Within five years, scientists hope to have an atomic clock that loses less than one second over the universe's lifetime. SOURCES: S.A. DIDDAMS *ET AL*/*SCIENCE*, C. OATES



While devices like the NIST-F1 use atomic signals of microwave frequency with billions of cycles per second, newer clocks, including Oates', rely on light waves beating a million times faster. The new approach "is like having a ruler with more divisions," says Tom O'Brian, NIST's chief of the divisions of Time and Frequency and of Quantum Physics. "The pace of improvement is skyrocketing."

A further development, the lattice clock, has been imagined only in the last decade, with rapid progress in the last five years. For now, related devices called single ion optical clocks, which key in on solitary electrically charged atoms such as aluminum, are the most accurate. However, lattice clocks' use of many atoms simultaneously, with a strong combined signal, appears to give these clocks the ultimate edge.

Katori says his team in Tokyo hopes to have the first clock with one part in 10^{18} accuracy working within five years. A look at how the record-setting mercury clock would work reveals the basics of all contemporary neutral-atom lattice clocks.

At a glance, the proposed clock is a bewildering laser beam jubilee — but there is underlying order.

The action starts with a system of cooling lasers that bathe a thin vapor of mercury atoms in what is called "optical molasses" to slow their motion. Temperatures hit a few millionths of a degree above absolute zero, a coolness at which each atom drifts roughly at the walking speed of ants. But even at that slow speed, the motion causes a slight blur in the atoms' collective optical signals.

The cooling lasers propel the chilled atoms gently into a zone where another laser system's beams cross one another. The interacting light waves, sometimes doubled up by mirror systems, form a tiny three-dimensional array of shimmering energy fields.

This is the lattice. Its standing waves rise and fall but do not propagate. When the fields' energies are diagrammed, they take on a pattern that looks a bit like the hollows in egg cartons. These nodes trap and hold the atoms — ideally one atom per energy well — in perfectly aligned ranks. The entire array of atoms is levitated in a tiny near-vacuum about 100 micrometers across, roughly the thickness of a page in a glossy magazine like this one. Most important, the trapping lasers whose beams produce the lattice will be set to a "magic frequency" — a recent breakthrough in the field — to grip the atoms in place while not distorting the shapes of their electron clouds.

All that is preamble to the key step. A clock laser will, a bit faster than once per second, illuminate the atoms, adjusting itself as needed to match the frequency at which they most easily absorb and emit light. Lasers may be popularly considered the essence of precision optics and purity of color. But at the esoteric edge of the timekeeper's craft, they are too wobbly to keep time by themselves. Thus the clock laser's orderly light waves are paced by the atomic metronome — just as a drill sergeant keeps troops in precise cadence.

Just one more big step: reading the clock. Though this clock relies on visible light, optical waves flicker far too fast, nearly a million billion times per second, for electronic circuits to count one by one. So, the clock laser is keyed in turn to yet another recent invention, what's called an optical comb laser. It is many thousands of lasers in one. Its multiple wavelengths, when plotted, look like the teeth of a comb, stretching across a vast frequency range. Optical combs were a big reason another scientist at NIST, John Hall, shared a Nobel Prize in 2005.

The comb's function is akin to a transmission's gears. By synchronizing one of the optical teeth with the clock laser, atomic clockmakers force the other teeth to become equally stable. That way one of those in the microwave domain can be selected to deliver a countable beat, a million times slower.

FROM LEFT: NEW YORK PUBLIC LIBRARY/PHOTO RESEARCHERS, INC; PAUL CLEMENTS

Now, a pause to ponder magic. By the 1990s it was clear that laser lattices would allow a probe laser to gaze at a throng of trapped atoms long enough to get a better reading on their signal than is possible with a fountain clock such as the F1. The lattice would also prevent collisions among the atoms, a key source of distortion in microwave fountain clocks. However, lattices come with a price. Their oscillating electromagnetic fields typically and severely distort atomic energy levels. One can easily guess how badly a violin would go off tune if someone squeezed its belly and twisted its scroll just as the violinist was striving for a delicate note.

In 2001, Katori and colleagues began publishing proposals that there might be a cure. Perhaps there could be certain frequencies of trapping fields that would displace the boundaries of one key energy transition by exactly the same degree. Katori's insight, bolstered by calculations by Derevianko and others, offered a way to grab that violin roughly yet leave one selected note unwavering.

In conversations with Katori, Nobelist Hall said such frequencies sounded like magic. Some journal editors initially resisted when formal papers referred to magic. But the name stuck.

Magic frequencies give lattice clocks accuracy a billion-fold better than they would otherwise manage. "That is nine orders of magnitude," Derevianko says. "That is magic happening."

Katori calls it "a gift from nature."

With magic frequencies soon discovered for several atoms suitable to trapping in lattices, physicists now had an army of atoms, says Jun Ye of JILA, an institute that NIST and the University of Colorado operate jointly. "A million-man army is better than a one-man army."

Ye's group operates a strontium-based lattice clock. In 2007 he interlinked, via optical fiber, his clock with a calcium-based lattice clock in Oates' lab at NIST. The two researchers were able to cross-check the time to an accuracy of one in 10^{16}, an exercise proving that such clocks can be interlinked over electronic and optical circuits.

Beyond the tock

Such advances are the latest step in humankind's ancient drive to measure how long it takes things to happen, whether for a season to pass or an automobile equipped with GPS navigation to drive 10 feet as monitored by the changed time for a radio signal to reach and return from two distant satellites whose locations are known. A one in 10^{18} clock would allow location to a matter of inches — on Mars using satellite transceivers at Earth.

The European Space Agency aims to make the International Space Station a platform for fundamental discovery with lattice clocks. That agency, along with the French space agency, has already begun a mission called ACES, or Atomic Clock Ensemble in Space. Its aim is to install on the space station a laser-cooled cesium microwave clock, with accuracy of about one in 10^{16}.

The current best long-term timekeeper is the United Kingdom's atomic clock. It loses or gains less than a second every 138 million years.

U.K. NATIONAL PHYSICAL LABORATORY

Linking to ground clocks based on different atoms and atomic transitions in a worldwide network, the timekeeper will probe fundamental laws of physics to high accuracy, says Luigi Cacciapuoti of ESA's astrophysics and fundamental physics division. Under scrutiny will be such esoterica as the constancy of the speed of light in all directions, and Einstein's equivalence principle declaring that gravity and acceleration have the same effects on time and physical processes. With shuttles retired, the first such clock could be delivered by a Japanese or other automated transfer vehicle as early as 2014.

Stephan Schiller of Heinrich-Heine-Universität in Düsseldorf, Germany, and colleagues, in a program called Space Optical Clocks, hope to put aboard the station around 2020 an optical lattice clock 10 times as accurate. They look forward to comparing the relativistic effect of Earth's gravitational field on time with that of the sun. Some theories suggest that Earth, with its iron core and other heavy, neutron-rich matter, may very slightly affect time's passage differently than the neutron-poor hydrogen that dominates the sun.

Can timekeeping possibly continue a tenfold improvement every decade? There are many orders of magnitude before timekeeping would reach the smallest increment allowed by known physics — called the Planck time, 10^{-43} seconds. To even approach it seems out of reach.

As for boosting precision relatively modestly by bringing today's atomic lattice clocks into ultraviolet or even X-ray domains, several technical hurdles stand in the way.

While atomic clocks depend on the activity of electrons in an atom's outer boundaries, there may be other processes to tap — nuclear processes. Within an atom's nucleus, neutrons and protons jostle and change energy according to quantum mechanics, too. Calculations suggest, for instance, that in the nucleus of the isotope thorium-229 is a transition that should emit ultraviolet rays. If that signal can be confirmed, and stimulated, a laser frequency comb might lock on to it and produce a lower frequency beat that could be fed into an electronic counter.

"This is a very important development, as the nuclei are very well isolated from external perturbations," says Derevianko. It may open a path "toward the ultimate clock."

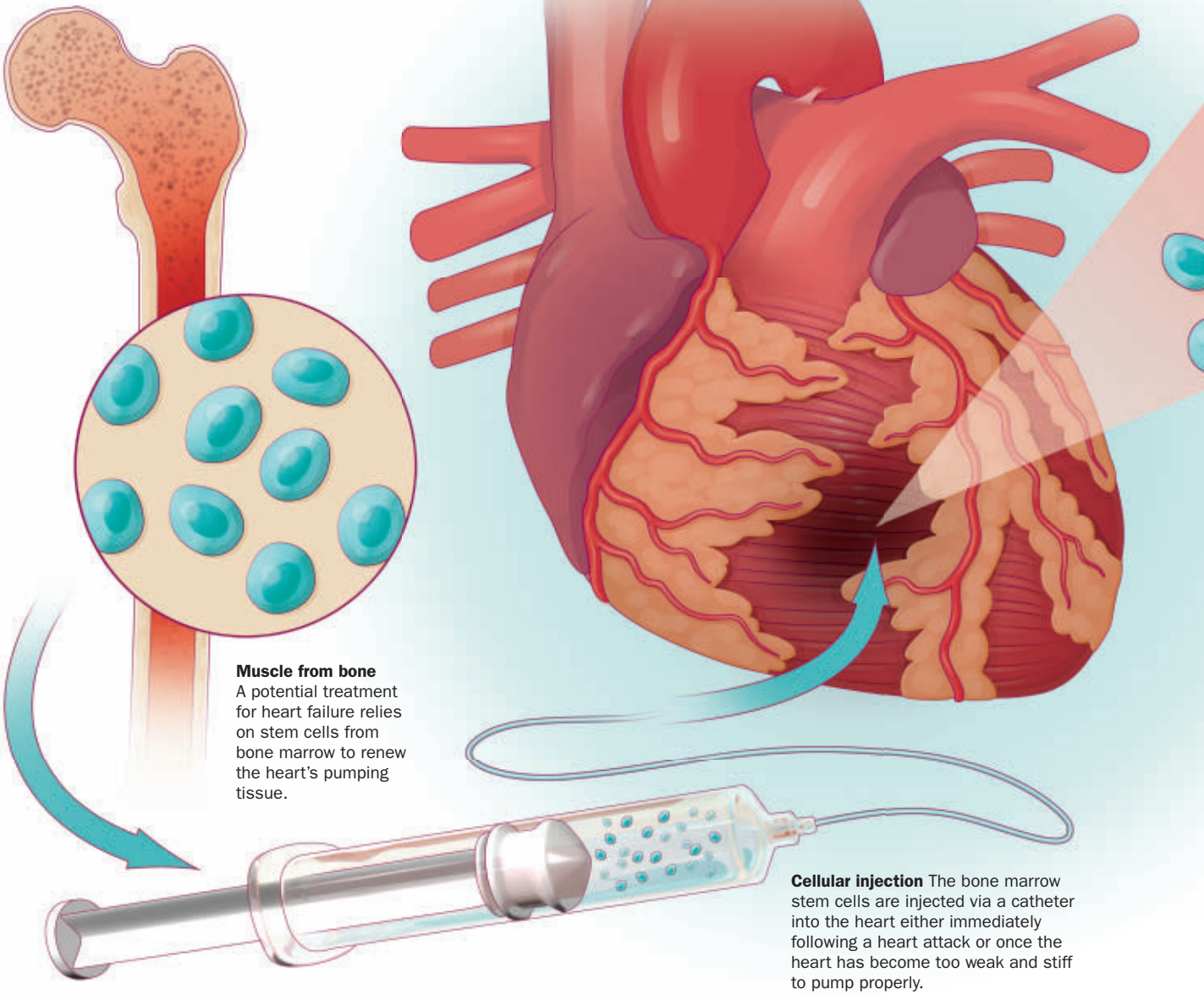
Only time will tell. ■

Explore more

- S.A. Diddams *et al*. "Standards of time and frequency at the outset of the 21st century." *Science*. November 19, 2004.

Reviving a tired he

With a bit of encouragement, the life-giving muscle may renew itself



Muscle from bone A potential treatment for heart failure relies on stem cells from bone marrow to renew the heart's pumping tissue.

Cellular injection The bone marrow stem cells are injected via a catheter into the heart either immediately following a heart attack or once the heart has become too weak and stiff to pump properly.

By Laura Beil

A generation ago, the battle to survive a heart attack was usually won or lost in the emergency room. Medical advances have now enabled more patients to win that fight and go home from the hospital — but millions of them will face another threat in the years to come.

The heart has a monstrous appetite for fuel as it goes about pumping 2,500 gallons of blood a day. During a heart attack, when an artery feeding heart muscle gets choked off, the heart's oxygen supply is interrupted. If starved of oxygen for too long, a portion of the heart can die, never to revive. Instead, lifeless muscle will be gradually replaced by an inflexible scar tissue not designed for pumping blood. To compensate, the remaining muscle pushes itself to work harder. Eventually, the heart can grow too stiff or too weak to efficiently eject the blood flowing into it, and a person lapses into heart failure.

Heart failure, a good portion of which is caused by heart attack, has become the leading reason older adults need

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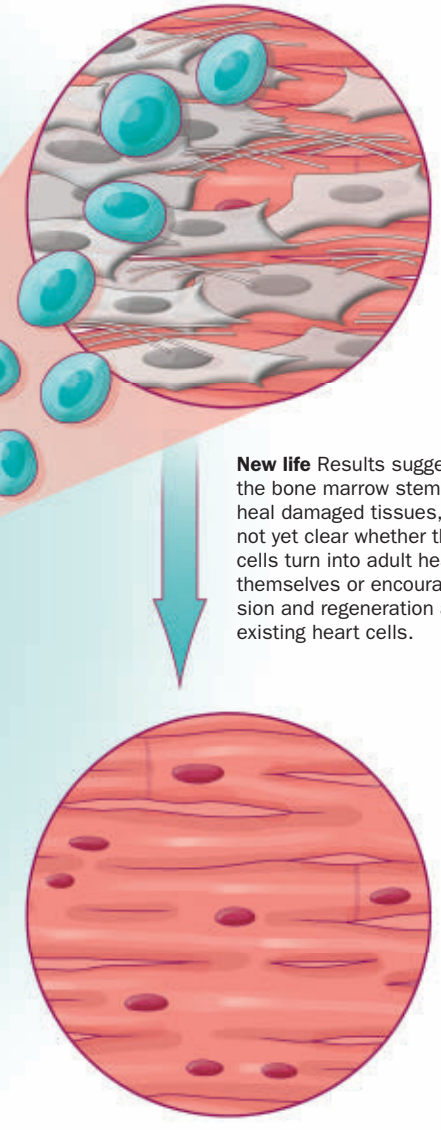


New life Results suggest that the bone marrow stem cells can heal damaged tissues, but it is not yet clear whether the stem cells turn into adult heart cells themselves or encourage division and regeneration among existing heart cells.

hospital care. Efforts to improve treatments for heart failure have not yet led to a cure, and roughly half of patients diagnosed with the condition will not live five more years.

But recent experiments have lent support to a drastically new approach: awakening damaged heart muscle to regrow and beat like new. "We're talking about transforming cardiology," says Joshua Hare, director of the Interdisciplinary Stem Cell Institute at the University of Miami Miller School of Medicine. "This is the beginning. It's like being at the start of antibiotics or vaccines."

Already, hundreds of clinical trials are attempting to cultivate new muscle inside the walls of damaged hearts, even while laboratory researchers work to understand where new heart cells come from in the first place. The combination of eagerness, uncertainty and staggering clinical potential has turned heart regeneration into one of the most competitive and controversial fields of modern cardiac research. "It's high-stakes, high-profile research in an area of great medical need," says Richard Lee, head of the cardiovascular disease program at the Harvard Stem Cell Institute.

Keep the beat alive

Attempts to grow heart muscle occupy one section in the larger arena of stem cell research. A stem cell is like a computer with a blank hard drive waiting for software, capable of assuming any programming it gets. These cells are naturally abundant in tissues that have to frequently rebound from injury or normal wear and tear — places like the skin, liver and skeletal muscle, or bone marrow, where stem cells provide the wellspring for new blood cells.

Organs that don't heal themselves, such as the brain and heart, are lacking in stem cells. The heart's pumping tissue is populated by cardiomyocytes, adult cells that live and die but do not divide. Even athletes who condition their hearts to extremes have to work with the heart cells they've got. For the most part.

"For many years, it was thought that you're born with a certain number of myocytes and you're going to die with them, minus the ones you've lost along the way," says Hesham Sadek, a cardiologist and stem cell biologist at the University of Texas Southwestern Medical Center at Dallas. New evidence, however, suggests that heart cells have some low-level churn — old ones expiring, new ones appearing. But the rate is too feeble for serious damage repair. It's like a body shop that offers to fix only a few dents after a serious wreck.

Yet there is a time in life when a damaged heart grows back as easily as a tadpole sprouts a new limb. Sadek and colleagues demonstrated this fact in a simple but powerful experiment reported in February in the journal *Science*.

When mice were 1 day old, the researchers surgically removed the apex of the animals' hearts. The hearts grew back, good as new. After repeating the test in different time frames, the researchers found that a mouse's heart could regrow until the animal was about a week old — a point corresponding to the first few months following birth for humans — after which the damage was permanent. For a time, at least, the heart emerged unscathed from a seemingly devastating loss of muscle. Could an adult heart ever do the same?

"Now that we know that the

What makes a weary heart

A number of complications can leave the heart too weak to efficiently pump blood, a condition known as heart failure.

Coronary artery disease and heart attack
Narrowed or blocked arteries can prevent the heart from getting the oxygen it needs, weakening its pumping ability.

High blood pressure
In people with high blood pressure, the heart has to work extra hard to circulate the blood through the body, causing the heart to thicken and stiffen.

Faulty valves
A damaged valve can make the heart work harder than it usually does to keep the blood flowing properly.

Damaged heart muscle
Infections, alcohol and drug abuse, as well as chemotherapy, can damage some heart muscle, putting more pumping pressure on the rest of the heart.

Other causes
Additional contributors to heart failure include inflammation, thyroid problems, heart arrhythmias and chronic diseases such as emphysema and lupus.

SOURCE: MAYO CLINIC

mammalian heart can actually regenerate itself, the question becomes relatively easier," Sadek says. "We can learn from the newborn heart." He notes that his mouse research parallels the experience of doctors treating birth defects. Babies born with serious cardiac problems can recover completely if corrective surgery occurs shortly after birth. But if too many months pass before treatment, heart muscle is lost for good.

It's not known why mammals would outgrow such a remarkable survival ability. (Some animals, including certain fish, enjoy a natural cardiovascular repair system for life.) Sadek speculates that during the course of evolution, before the human population lived long enough to grow old and have diseased arteries, a blow to the heart was usually fatal, so there wasn't a need for a heart to heal. The challenge for scientists is to awaken a long-forgotten repair mechanism — whether by getting adult heart cells to return to their infancy or encouraging division and differentiation among a small population of existing heart stem cells.

Divide and renew

Most scientists (though there are notable exceptions) have come to accept the idea that the heart contains stem cells, though there is no agreement on how plentiful or important they may be. (Estimates for the turnover of new heart muscle range from less than 1 percent per year to as much as 20 percent.)

Among those believing that the heart is capable of self-healing is Lee, from Harvard. Using genes that give new cells a telltale fluorescent glow, Lee's experiments suggest that after part of the muscle dies, the heart makes a weak attempt to mend. In mouse experiments that mimic the damage of a heart attack, more than 15 percent of the heart cells around the area of injury appear to be new, Lee and colleagues reported in 2007 in *Nature Medicine*. Later work supports that finding, he says.

"Our experiments suggest that mammals like humans have some repair capability," he says. Recovery happens, but "it is woefully inadequate."

> "The totality of evidence from the clinical trials is positive…. The heart is pumping more blood per beat."
>
> JOSHUA HARE

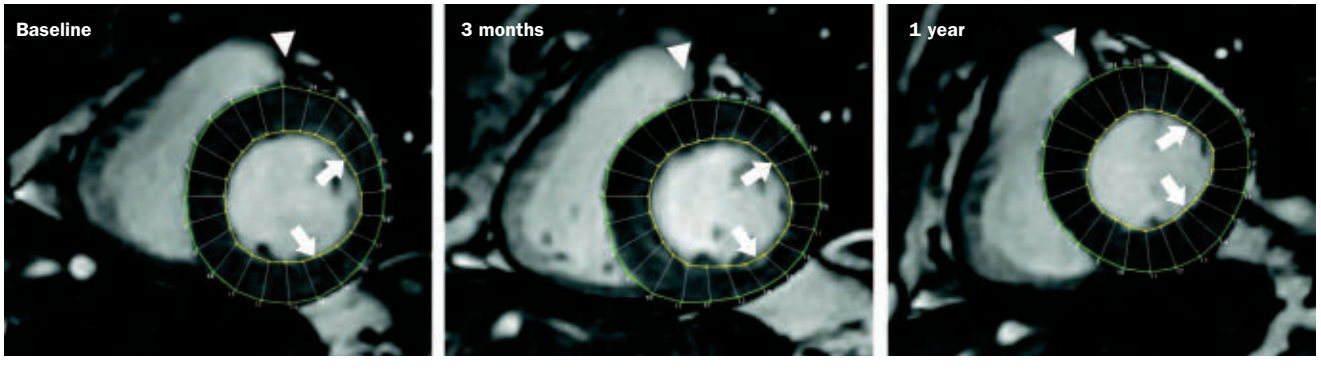
Scientists don't yet know which cells in the crippled heart are doing the dividing and why. Some researchers are tinkering with adult heart cell genetics, trying to find genes that turn a cardiomyocyte's growth switch off or on. Studies suggest that adult heart cells often go through the preparations for dividing, making copies of their genetic material and (in mice at least) forming a new cell nucleus.

"It's as if they try to re-enter the cell cycle," says Jonathan Epstein, scientific director of the Penn Cardiovascular Institute at the University of Pennsylvania School of Medicine in Philadelphia. "They make new DNA; they just don't divide." It's not uncommon for heart cells to develop not just one but several copies of their own genetic instructions, as if gearing up for the big event at several points in life. "The difference between a newborn heart and an adult may focus on the ability of cells to divide, and not be related to their ability to create new DNA," he says.

Epstein and others are trying to identify the genes and proteins necessary for a cell to take the additional step of cleaving itself in two once its DNA replicates. For example, last year, in *Developmental Cell*, Epstein's team reported that an enzyme called Hdac2 interacts with two other proteins in a heart cell, and together this trio of molecules impedes cell division. Hdac2 also appears to affect how genes are spooled together or packaged inside a cell, which controls their function.

Clinical trials are already under way for drugs that inhibit Hdac enzymes, though investigating cancer treatment rather than heart disease. Animal studies have suggested that taking these drugs improves cardiac function after a heart attack or in the presence of high blood pressure — but the explanation for this benefit remains unclear.

Clinical trials are also in progress to try to spur heart cell growth in people. For the most part, researchers are testing ways to give an ailing heart a dose of a patient's own bone marrow stem cells with the hope that they will transform into heart muscle, or revive cardiac stem cells that might already lie inside. The field got a kick start in 2001, when



Heart failure patients who received bone marrow stem cell injections showed improvements in pumping tissue. A year after injection, damaged heart tissue (arrows denote infarct zone) showed signs of remodeling (widening polygons between arrows).

A. R. WILLIAMS *ET AL/ CIRCULATION RESEARCH* 2011

scientists reported in *Nature* that they were able to regrow heart tissue in mice by coaxing injected bone marrow stem cells into taking on a new identity as heart cells.

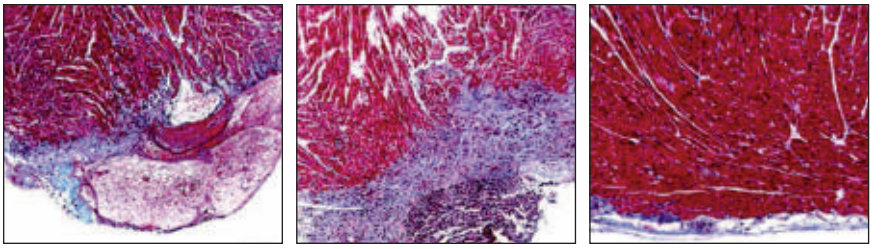
"The net result was that a new field was born," says Hare, from Miami. "Within a year there were papers where people had tried this in humans." Today, hundreds of trials giving bone marrow cells to heart patients are either ongoing or already completed. Some provide stem cells shortly after a heart attack to spare heavy damage; some involve patients already in heart failure.

"The totality of evidence from the clinical trials is positive," says Hare, who is conducting some of the trials and is on the board of Stem Cell Therapeutics, a Canadian-based company. "The heart is pumping more blood per beat." In March in the journal *Circulation Research*, his team described a study of eight patients who received injections of bone marrow cells near an area of the heart scarred due to heart attack. After three months, the patients' heart contractions were stronger. Even more important, their hearts later appeared to undergo some degree of "reverse remodeling," or an attempt to return to normal anatomy, though the precise mechanism isn't known.

Problem is, no one knows whether these kinds of improvements make any difference for a patient's survival. "The definition of working means, 'Do people live longer and feel better?' That study has just been funded in Europe," Hare says. A team of investigators coordinated by the European Society of Cardiology is aiming to recruit 3,000 volunteers, half of whom will receive bone marrow stem cell injections after a heart attack and half of whom will get a placebo. It will be one of the largest studies so far using stem cells to try to help heart patients, and will go on long enough to detect any survival advantage.

Heart of the matter

Cardiologists don't agree about whether this clinical trial and others are a good idea. They also have concerns about the inconsistency of many laboratory studies.



E.R. PORRELLO *ET AL*/*SCIENCE* 2011

A study in 1-day-old mice reveals that the mammalian heart has early potential to renew. Images above show an injury on (from left) days two, seven and 21. Pumping tissue takes the place of connective tissue (blue) that could lead to a stiff heart.

With full understanding of cardiac regeneration still lacking, some researchers have cautioned against launching headfirst into human experiments. "I think it's been reassuring and probably a little fortunate that we haven't hurt people," says Lee. Among the unanswered questions: Are the bone marrow stem cells turning into heart cells, or does the presence of bone marrow cells trigger some kind of dormant mechanism in stem cells already residing in the heart? Could other tissues be affected by the treatment?

"We don't understand the mechanism enough," Lee says.

For instance, he says, lab studies have suggested that the bone marrow stem cells do not survive well, if at all, once they are injected into the heart. If true, it means that the bone marrow cells are not becoming cardiac cells, but that some other property accounts for the study results. So patients might be receiving an injection of bone marrow cells that isn't necessary.

A study published in September in *Science Translational Medicine* raises the possibility that a heart attack damages a patient's bone marrow cells, giving them properties that make them less suited for transplantation. Other populations of stem cells might turn out to be more efficient; some scientists are working to create embryonic-like stem cells in the lab that may be even more open to a new identity than bone marrow stem cells.

"The closer we can get to understanding how these benefits occur," Lee says, "the closer we can get to treatment."

The scientists conducting the trials, such as Hare, believe human studies are necessary for progress, and can be done alongside vital basic research. "I would say it's been way too slow," he says of the pace of clinical trials. About 5 million Americans currently experience heart failure, left with options that will only slow the decline of their health but not offer a cure. He says he has no doubt that a deeper scientific appreciation will emerge with five more years of investigation. Some patients can't wait that long. "I see patients with permanent heart damage," he says. "Half of them are going to die while we sort out our scientific understanding."

Even if scientists learn how to prod the growth of new heart cells, other challenges will remain. Growing muscle is not enough. The new tissue forming alongside the old still has to beat and carry electrical signals in perfect sync with neighboring cells. No one knows whether that would happen, or how to make it happen.

If scientists all agree on one point, it is this: After years of seeing progress in heart failure treatment move forward incrementally, the prospect of cardiac regeneration has energized the field, opening up a new frontier for patients who otherwise have had no chance for recovery. "It starts to get discouraging if you don't have something on the horizon," Lee says. After a decade of experiments, perhaps the one undisputed payoff is optimism. ■

Explore more

- For more on heart development: J. Epstein. "Cardiac development and implications for heart disease." *New England Journal of Medicine*, 2010.

A More Perfect Heaven: How Copernicus Revolutionized the Cosmos

Dava Sobel

Daring to defy a centuries-old belief, Polish cleric and astronomer Nicolaus Copernicus spun the Earth on its axis and cast it as just one of several planets shuffling around the sun. Published in 1543, Copernicus' tome *On the Revolutions of the Heavenly Spheres* earned a spot on the church's list of prohibited books in 1616, where it sat for more than 200 years.

In her newest book, Sobel describes the evolution of Copernicus' heretical celestial system, a model that sparked a scientific revolution and challenged the prevailing Ptolemaic alignment, which pinned the Earth in place and set the other spheres swirling around it. In her typically elegant manner, Sobel introduces the reader to Copernicus — a cleric and physician, the nephew of a Catholic bishop, and a reclusive astronomer who studied the heavens in secret.

Sobel describes the events preceding the publication of Copernicus' theory, and along the way the reader meets German mathematician Georg Joachim Rheticus, a Lutheran. During the turmoil of the Protestant Revolution, Rheticus appears on Copernicus' doorstep, sticks around for two years and ultimately convinces the aging astronomer to publish his theory.

Sobel imagines and voices the pair's conversations in a drama tucked into the middle of the otherwise historical narrative. That drama, "And the Sun Stood Still," reads like a mini-screenplay, breathing life into these two conflicted, obsessive and ultimately revolutionary characters. Sobel says she's been wanting to dramatize the meeting between Copernicus and "the uninvited visitor who convinced him to publish his crazy idea" since 1973 — the 500th anniversary of Copernicus' birth. *— Nadia Drake*

Walker & Company, 2011, 273 p., $25

Empire of the Beetle: How Human Folly and a Tiny Bug Are Killing North America's Great Forests

Andrew Nikiforuk

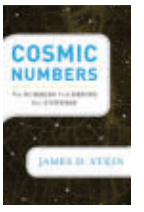
It's amazing that a small sackful of bark beetles, each no larger than a grain of rice, can in a matter of days kill a tree more than a century old. Yet maybe it's not surprising, considering that these voracious pests descend upon forests in swarms that can easily weigh more than a pod of killer whales.

Nikiforuk, a Canadian journalist, chronicles the plague of bark beetles that in the last quarter-century has killed more than 30 billion pine and spruce trees from Alaska to New Mexico. No creatures except humans, he says, can change a landscape as dramatically and quickly.

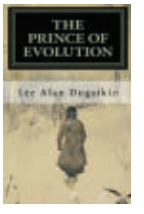
Several factors have conspired to set the beetles free of their natural constraints. A century of fire suppression has nearly tripled the proportion of old trees, which don't produce enough resin to create a gooey protective barrier against beetles. Climate change plays a role, too: Trees stressed by heat and drought can't mount a strong defense against a beetle blitz, and winters in many infested regions are no longer cold enough to kill the pests in large numbers.

Nikiforuk draws on interviews with scientists, foresters and rural residents to paint a nuanced picture of beetle outbreaks and their long-term implications. By managing woodlands to maximize timber, humans have taken patchy and diverse forests and transformed them into all-you-can-eat smorgasbords for beetles. Although climate change has rung the dinner bell for hungry beetles, the author suggests, human arrogance has surely set the table. *— Sid Perkins*

Greystone Books, 2011, 240 p., $17.95

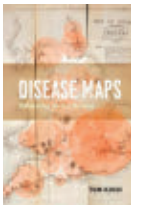


Cosmic Numbers
James D. Stein
The stories behind numbers — their discoveries and relationships to one another — come to life in this tale of universal constants. *Basic Books, 2011, 228 p., $25.99*

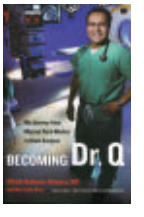


The Prince of Evolution
Lee Alan Dugatkin
A biologist tells the tale of Peter Kropotkin, a Russian prince whose adventures and studies of evolution and society made him an international celebrity. *CreateSpace, 2011, 121 p., $12.99*

The Dolphin in the Mirror
Diana Reiss
A dolphin researcher describes studies of the animals' intelligence and makes a case for their protection. *Houghton Mifflin Harcourt, 2011, 276 p., $27*



Disease Maps
Tom Koch
This unconventional history charts the rise of epidemiology by examining how maps have been used to follow the spread of disease. *Univ. of Chicago Press, 2011, 330 p., $45*



Becoming Dr. Q
Alfredo Quiñones-Hinojosa with Mim Eichler Rivas
An autobiography charts one man's voyage from migrant worker to brain surgeon. *Univ. of California Press, 2011, 317 p., $27.50*

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Lumpy lunar illusion

Are you folks aware of a phenomenon based on the universal expectation that objects are illuminated by light coming from above? Several startling optical illusions are based on this quirk of the mind. For example, the sharp moon map in "Orbiter delivers sharp moon map" (*SN: 7/30/11, p. 12*) makes the moon look like it is covered with big bumps! Turn the page upside down, and voila — the bumps turn into craters.
Jeff Brewer, Newton, Mass.

Count on crows to know

Regarding "When birds go to town" (*SN: 8/27/11, p. 26*), I have observed other corvids that recognize a specific animal that has proven to be a threat. We had a cat that successfully caught a Steller's jay chick. For the remaining five years of the cat's life, she was a marked assassin! She could not leave the house without invoking a posse of jays constantly squawking and following her. We had a second cat who was at best a spider hunter. He was mostly unnoticed by the jays. Incidentally, we did not find him being followed by spiders.
Larry Sage, Truckee, Calif.

My father, whose vendetta against crows was legendary, always kept a shotgun by the back door. As hundreds of crows gathered each evening across the pond, he would grab the gun and "stealthily" sneak around the house, hoping to blast a few of "the dratted critters." It was a joke among us kids, because the instant he peeked around the house, all the crows — with more racket than you can imagine — took off immediately. We began to experiment, sending my mom out with a broom using the same "sneaky" behavior exhibited by my father. The crows figured out the ruse immediately, sitting calmly on the ground or in the trees, drinking from the pond and generally thumbing their beaks at us.

P.S. My father managed to kill only one crow in his 50-plus years on the property. The crows came and went with impunity.
Ann Harmer, Costa Mesa, Calif.

In recent years I have interacted with the University of Washington's resident crow population as a two-legged peanut dispenser to enliven multiple quarter-mile strolls each day between my office and my car. "Old Gimpy" now approaches me within an arm's reach when I place a few morsels atop my red Subaru.
Fred Utter, Seattle, Wash.

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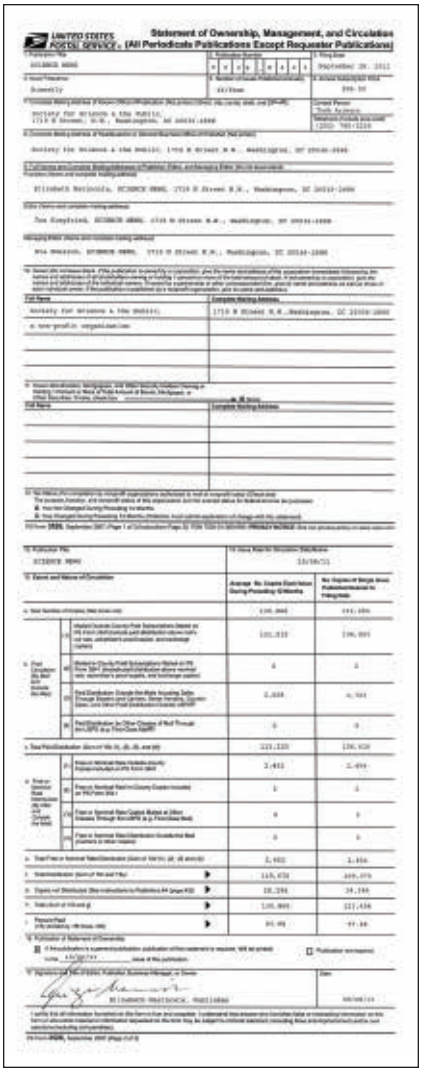

From the Archive

A doughnut and coffee mug have the same topology because one can be stretched into the other without any gluing or tearing.

Mathematicians think of everything as rubber

Topology, which you won't find defined in the ordinary dictionary, was on the tip of mathematical tongues at the Columbus science meetings. This new geometry is as popular with the mathematicians as exploration of the atom is with physicists.

To those who are used to Euclidean geometry such as taught in school, this relatively new branch of mathematics, bulking large in the science meetings, will seem strange.

As explained on behalf of the American Mathematical Society by Prof. G. Baley Price of the University of Kansas, you must think of all sorts of objects in the Land of Topology as made of rubber. It is not necessary to keep the distance between each two points unchanged when two figures are compared. It is expected that the two figures will be stretched and distorted in any manner so long as they are not torn or glued together in new places. Any two figures which can be made to coincide by such stretchings and distortions are said to have the same topological properties.

In Euclidean geometry there are right angled triangles and equilateral triangles, but in topology all triangles are the same. If the two triangles be thought of as cut from a sheet of rubber, they can be stretched until they coincide. The surface of a sphere is topologically different from the surface of a doughnut, because no deformation without tearing will change a sphere into the surface of a doughnut. The fact that a figure is made up of several disconnected pieces is a topological property; such a figure is distinct from one consisting of a single piece, for it is not permitted to glue the parts together when they are compared. Although distinct in Euclidean geometry, a sphere and an egg-shaped surface are the same in topology.

UPDATE

Topology tackles Königsberg and the entire universe

Mathematical curiosities related to the field of topology have existed since at least the 1700s. A well-known puzzle of that time asked whether a person could follow a path through the city of Königsberg crossing each of its bridges only once and returning to the starting point. In 1735, Leonard Euler found that such a trip would be impossible, later publishing his proof in a paper titled "Solutio problematis ad geometriam situs pertinentis," or "The solution of a problem relating to the geometry of position." Euler seems to have recognized early on that the problem was not about geometry as it relates to distances and angles, but rather about the qualitative shape of the landscape and how different positions are connected.

Still, the application of topology to serious scientific questions was novel enough in the 1940s for *Science News* to claim a "relatively new branch of mathematics." Since then, topology has been used by scientists working in a surprisingly broad range of fields, from cancer research to quantum computing. Some of today's topological thinkers are even exploring the idea of different possible shapes for the universe. While Einstein's general theory of relativity describes the geometry of spacetime, the theory allows different topologies. Instead of having the simplest possible topology, the universe may twist, loop or have doughnut holes, with implications for whether the cosmos is finite or infinite.

Understanding such complexity would allow researchers to think of the whole wide universe the way Euler thought of Königsberg's crosstown connections. Like a Prussian trying to traverse the city by passing once over all its bridges, could a spaceship headed off in one direction eventually return to its starting position? — *Elizabeth Quill*

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