Antimatter, Trapped | Continents' Rocky Cores | Before the Big Bang

ScienceNews

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MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ DECEMBER 18, 2010

Missing Inheritance

New clues to human variability

New Strategy Against HIV | Homemade Hawking Radiation | Orangutan Bottleneck

Are you in love with your home, but afraid of your staircase?

This innovative and affordable solution enables you to maintain your independence and stay in the home you love.

Like most people, the older I get, the more I miss life's simple pleasures. The thing is, I want to stay in the home I love, the home where my wife and I raised our children. Recently, when my doctor told me that I should not climb stairs, I thought I had no choice but to move. Our bedroom is on the second floor, and neither my wife nor I feel safe walking up or down the stairs. I had even started looking at brochures for homes in a senior community when a friend asked me why I would move when there was such an easy solution. It's called the Easy Climber™, and it's enabled me to stay put.

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What to look for

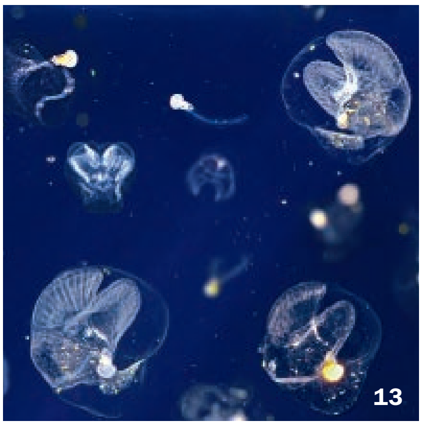
Quality Construction and Dependability: Look for a cable drive system that uses high-grade cable. Go for one that has a weight capacity of at least 300 pounds. Has the product been tested over thousands and thousands of cycles?

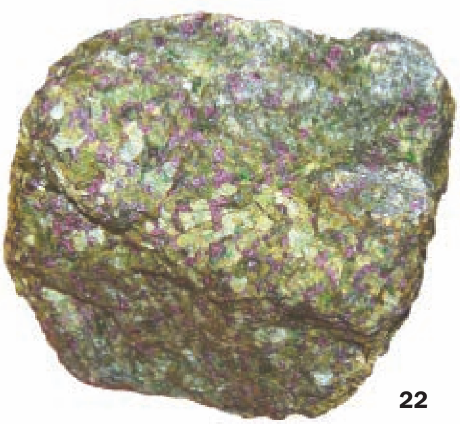
Safety: Insist on built-in safety sensors to stop the chair upon encountering any obstruction. Make sure there's a swivel safety switch that prevents the lift from operating if you are not in the proper position. Don't forget the seat belt!

Flexibility: Look for a system that can be installed on either side of the staircase, a control that can be put on either side of the chair and has multiple call/send controls. There are systems out there that let you choose either AC or DC operation.

Warranty*: Some systems are backed by limited drive-train and parts warranties—why stop there? Insist on a lifetime warranty on the drive train.❖

DECEMBER 18, 2010 • VOL. 178 • NO. 13





ScienceNews

In The News

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COVER From skin tone and eye shape to disease susceptibility, traits differ among people. Many of the inherited influences on such differences remain unknown. *Photos: Warren Goldswain/shutterstock*

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FROM THE EDITOR

Antimatter exemplifies mathematics' prescience

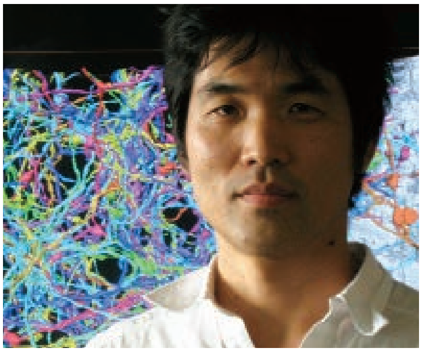
When the laconic physicist Paul Dirac devised an equation for describing the energy of electrons, he stumbled upon a mathematical clue to the existence of an unknown world. It was the antiworld, the realm of oppositely charged particles that annihilate their regular-world counterparts on contact. Such particles are known as antimatter, and they are widely used in medicine, basic physics research and as fuel for science fiction starships.

Antimatter is illuminating not merely for its peculiar properties and practical applications. It illustrates a recurring theme in science — the power of math to reveal realities not previously imagined. In the 1920s, nobody suspected that protons and electrons, the two particles of matter then known, possessed evil-twin partners. Dirac's equation forced him to confront apparently absurd phenomena that he interpreted, after a few false starts, as evidence for the existence of the electron's antiparticle. Until then, nobody had ever seen any such thing or had any reason to believe it possible. Yet the next year the antielectron was discovered in cosmic rays.

Four decades later, Stephen Hawking pondered the math describing processes near a black hole's outer boundary, the event horizon. And guess what popped up there? Antimatter! And from Hawking's equations describing antimatter emerged yet another phenomenon previously unimagined: radiation streaking away from the black hole, causing it to shrink. Once again mathematics had made a prediction about something existing in the physical world that no experiment had detected or human had suspected.

Now, as Marissa Cevallos reports in this issue (Page 28), various experiments have confirmed the reality of Hawking's radiation — not near a real black hole (too risky), but at laboratory analogs of event horizons created with water waves or laser pulses. And as Alexandra Witze writes (Page 5), physicists have recently advanced their skill in handling antimatter to the point where certain science fiction applications seem slightly less implausible.

To be sure, scientists still have much to learn about antimatter, including details about its role in the history of the cosmos and its implications for basic physical theory, along with new ways to use it. And it's a safe bet that the method that first betrayed antimatter's existence — the manipulation of mathematical equations — will someday deliver further scientific surprises. *—Tom Siegfried, Editor in Chief*

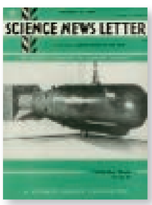


Scientific Observations

"Why did I choose to study this organ that is so awesome in its complexity that it might well be infinite? It's absurd. How could we even dare to think that we might ever understand this? And yet, I persist in this quixotic endeavor. And indeed, these days I harbor new hopes. Someday a fleet of microscopes will capture every neuron and every synapse in a vast database of images. And someday artificially intelligent supercomputers will analyze the images without human assistance to summarize [all the brain's neural connections into] a connectome. I do not know, but I hope that I will live to see that day. Because finding an entire human connectome is one of the greatest technological challenges of all time." —**COMPUTATIONAL NEUROSCIENTIST SEBASTIAN SEUNG OF MIT, IN HIS TED.COM TALK "I AM MY CONNECTOME"**

Science Past | FROM THE ISSUE OF DECEMBER 17, 1960

HEAVY SHIELD UNNECESSARY — Heavy shielding as protection for an astronaut against space radiations may not be necessary, at least for trips of less than 50 hours and at distances not greater than 618 miles from earth.... [B]iological specimens were encased in different types of metal to test their effectiveness as shielding materials. Some specimens were shielded only by the thin aluminum covering of the specimen capsule and the comparatively thin shell of the recovery capsule. Radiation dosimeters showed that aluminum provided better shielding properties than lead and that any heavy metal such as gold or lead becomes a hazard during a solar flare as high energy protons interact with these heavy metals to create damaging X-rays.



Science Future

December 26
Schenectady Museum in New York explores why bikes stand up. See www.schenectadymuseum.org

December 27
Author John Monahan signs copies of *They Called Me Mad* at the National Air and Space Museum. See www.nasm.si.edu

January 10
Deadline to submit original wake-up music for NASA's final space shuttle mission. Go to https://songcontest.nasa.gov

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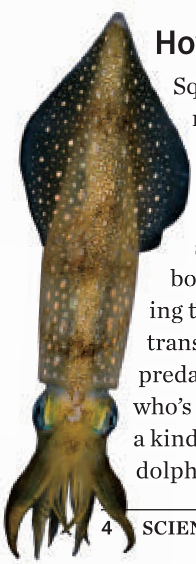
MATTER & ENERGY
Physicists propose a new way to spot atoms in weird high-energy levels. Read "Negative temperature, infinitely hot."

LIFE
Marmot studies suggest that getting picked on may run in the family. See "Getting dissed could be partly genetic."

GENES & CELLS
Mutations in those with Rett syndrome may make genes play musical chairs, explaining the disorder's variety of symptoms. Read "Genes jump more in one type of autism."

BODY & BRAIN
Baby fat may augur serious disease later. See "Extra weight in early childhood foretells later disease risk."

How Bizarre



Squid are about the same density as seawater, making them nigh invisible to sonar. That's what biologist T. Aran Mooney of the Woods Hole Oceanographic Institution and colleagues found by putting a longfin squid through a CT scanner while testing squid hearing. The squid's body blended into the tub water around it, meaning that squid do not reflect sound well. Such sound transparency may have evolved as a defense against predators that hunt with echolocation, says Mooney, who's preparing the data for publication. There may be a kind of "evolutionary arms race," he says, between dolphins' sonar and squid's acoustic camouflage.

Science Stats | ACHING JOINTS

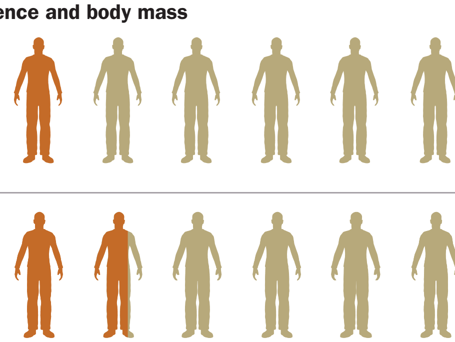
Adults with a high body mass index, or BMI, have a greater incidence of arthritis than those with a lower BMI, the CDC reports.

Arthritis prevalence and body mass

Arthritic
Non-arthritic

Normal/underweight adults
16.9 percent

Obese adults
29.6 percent



SOURCE: MMWR/CDC

CLOCKWISE, FROM TOP LEFT: COURTESY OF S. SEUNG; BEN HULSE; E. FELICIANO; T. KLEINDINST/WOODS HOLE OCEANOGRAPHIC INSTITUTION

> “The face shield contributes a lot to deflecting energy from the blast wave and not letting it directly touch the soft tissue.”
> — RAÚL RADOVITZKY, PAGE 16

In the News

STORY ONE

At CERN, atoms of antihydrogen that stick around

Physicists trap antiparticles almost long enough to study

By Alexandra Witze

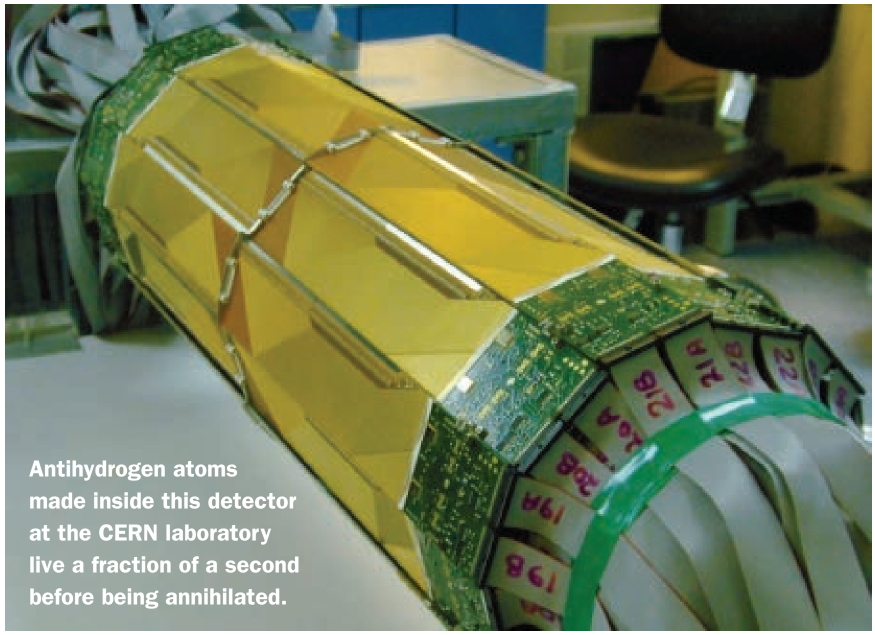
Researchers are a step closer to the *Angels & Demons* scenario dreamed up by novelist Dan Brown, in which a rogue priest tries to destroy the Vatican with a vial of antimatter.

In reality, the amount of antimatter created to date wouldn’t release enough energy to heat a pot of coffee. But physicists at CERN, the European particle physics laboratory near Geneva, have now managed to make and hold dozens of antihydrogen atoms for a fraction of a second, far longer than ever before.

The work, reported online in *Nature* November 17, is a significant step toward making antimatter stick around long enough to be able to study how it differs from ordinary matter.

“In 10 years people will forget Dan Brown, but we’ll be in the textbooks,” says team spokesman Jeffrey Hangst, a physicist at Aarhus University in Denmark.

Antimatter, whose existence was predicted by physicist Paul Dirac in 1931, is made of particles with electric charges opposite those of ordinary matter. While a hydrogen atom is made of a positively charged proton and a negatively charged electron, an antihydrogen atom is made of a negatively charged antiproton and a positively charged positron. When matter and antimatter meet, they annihilate.


Antihydrogen atoms made inside this detector at the CERN laboratory live a fraction of a second before being annihilated.

Theory suggests that equal amounts of matter and antimatter should have been formed in the Big Bang, nearly 14 billion years ago, and physicists have long puzzled over why matter prevails. Several experiments at CERN seek to explain matter’s predominance using an “antiproton decelerator” — a much smaller cousin to the more famous Large Hadron Collider — that slows the particles down to about a tenth the speed of light.

Physicists at the lab first made a few fleeting atoms of antihydrogen in 1995. In 2002 two teams reported ways to make lots of antihydrogen atoms at low energies — crucial for making measurements.

The new results come from Hangst’s ALPHA experiment, which cools a stream of antiprotons into a cloud of about 40,000 particles. The researchers then nudge that cloud very gently into a couple of million positrons chilled to 40 kelvins (40 degrees Celsius above absolute zero). About one time out of 10, an antiproton and a positron combine to make an antihydrogen atom.

For roughly every 100,000 antihydrogen atoms made, researchers managed to trap just one of them using strong magnetic fields. The *Nature* paper reports 38 such trapped antiatoms, which were held for more than a sixth of a second before they escaped and annihilated themselves against the matter in the sides of the container.

If scientists can keep more antihydrogen around for longer, they can do studies such as spectral measurements to reveal how the material’s internal energetics differs from those of ordinary hydrogen. “It’s so exciting because now we can subject antihydrogen to anything anyone has ever done with hydrogen in the past,” says Hangst. “There are 100-odd

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years of atomic physics that we can learn how to do again with antiatoms."

Antihydrogen looks to be a growing field. Two other new antihydrogen experiments are just getting underway at CERN. One of them, called ASACUSA, recently made its first antihydrogen atoms using a device called a cusp trap. This approach could allow scientists to make the first supersensitive measurements of antihydrogen at microwave wavelengths, the team reports in a paper accepted for publication in *Physical Review Letters*. ASACUSA plans to let the atoms leak out of the traps and study them in flight.

The most recent experiment, called AEGIS, hasn't made antihydrogen yet but plans to eventually study gravity's effects on antimatter.

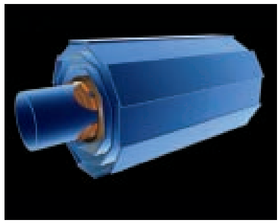
ALPHA's long-standing competitor is another experiment called ATRAP, which works about five meters down the antiproton beam. It is currently focusing on making much bigger, colder blobs of antiprotons that can then be combined with positrons to make antihydrogen.

In a paper published online in *Physical Review Letters* November 16, the ATRAP group reports centrifugally separating antiprotons from electrons, which could provide a new way to isolate low-energy antiprotons for making antihydrogen. "We have up to 3 million antiprotons whose temperature is less than 6 kelvin," says team leader Gerald Gabrielse of Harvard University.

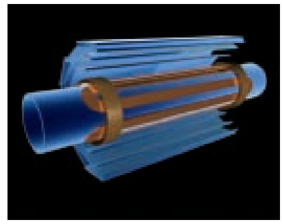
In 1987, Gabrielse proposed that it might be possible to confine and study cold antihydrogen atoms. "I'm naturally delighted at the news that a few atoms have been fleetingly confined," he says.

Hangst's group is now pushing to get temperatures (and thus particle energies) lower. CERN's antiproton beam has been shut down temporarily but will start up again in May for its next run. And if funding comes through, a planned upgrade in the next couple of years would increase the antiproton supply a hundredfold. Right now, scientists can get as many as 5 million antiprotons per hour. ■

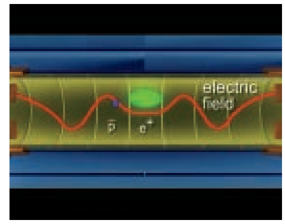
Antihydrogen: A how-to guide Trapping antihydrogen long enough to study it requires merging clouds of antiprotons and positrons at extremely low temperatures. Some of the particles will pair up to form antihydrogen atoms, which can be trapped for a fraction of a second by a powerful magnetic field before they make their way to the walls of the container and annihilate on contact.



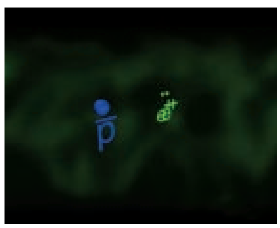
The outer shell of the ALPHA experiment detects particles generated when antihydrogen atoms annihilate, employing the same material that accelerators like the Large Hadron Collider use to detect some of the debris from particle collisions.



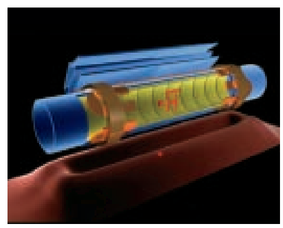
Inside the annihilation detector is a cylinder-shaped superconducting electromagnet designed to trap antihydrogen atoms in a "magnetic minimum"—the magnetic equivalent of trapping a marble in the bottom of a concave dish.



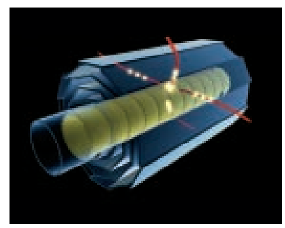
Still deeper is a cylindrical set of electrodes (gold) that holds clouds of charged antiprotons and positrons in place at a temperature of 40 kelvins. The electrodes produce an electric field that brings antiprotons and positrons together.



When a pair of positrons collide inside the mixed cloud, there is a chance that one of them will then bind to a nearby antiproton to form an atom of antihydrogen.



With the superconducting magnet turned on, antihydrogen atoms are trapped in the cylinder much like a marble settling at the bottom of a concave dish (brown).



With the magnet turned off, the atoms drift into the walls of the apparatus, where their destruction is sensed by the annihilation detector—proof that they did in fact exist.

Back Story | A BRIEF HISTORY OF ANTIMATTER

1931 Physicist Paul Dirac hypothesizes the existence of "a new kind of particle, unknown to experimental physics, having the same mass and opposite charge of the electron."

1932 Physicist Carl Anderson detects the presence of the electron's antimatter counterpart in cloud chamber tracks of cosmic rays.

1955 The Bevatron accelerator (left) in Berkeley, Calif., produces the first observed antiproton.

1995 Physicists at CERN produce the first antihydrogen atoms, but the particles are too short-lived to be studied in detail.

2010 The ALPHA experiment produces antihydrogen that lasts a fraction of a second, opening the door for experiments on the physics of antiatoms.

TOP: GRALLATOR/ALPHA/CERN; BOTTOM: ROY KALTSCHMIDT/LAWRENCE BERKELEY NATIONAL LAB/FLICKR

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This story breaks my heart every time. Allegedly, just two years after the discovery of tanzanite in 1967, a Maasai tribesman knocked on the door of a gem cutter's office in Nairobi. The Maasai had brought along an enormous chunk of tanzanite and he was looking to sell. His asking price? Fifty dollars. But the gem cutter was suspicious and assumed that a stone so large could only be glass. The cutter told the tribesman, no thanks, and sent him on his way. Huge mistake. It turns out that the gem was genuine and would have easily dwarfed the world's largest cut tanzanite at the time. Based on common pricing, that "chunk" could have been worth close to $3,000,000!

The tanzanite gem cutter missed his chance to hit the jeweler's jackpot...and make history. Would you have made the same mistake then? Will you make it today?

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Talking alike cements relationships

Similar speaking styles augur romantic success, studies find

By Bruce Bower

A subtle, surprisingly mundane banter lies at the heart of romance. Love's flames get fanned when two people similarly employ words such as *I*, *it*, *but* and *under* in conversation, a new study suggests.

Conversation partners' related use of function words — such as pronouns, articles, conjunctions and prepositions — augurs well for mutual romantic interest and stable relationships, says a team led by James Pennebaker and Molly Ireland of the University of Texas at Austin.

Unconscious coordination of this sort, called "language-style matching" by the researchers, signifies not how much two people like each other but how much attention each pays to what the other says, Pennebaker, Ireland and colleagues propose in an upcoming *Psychological Science*.

Function words tap into verbal coordination between people because these words are independent of conversation topic and require shared knowledge to be used effectively. If one friend works in an office and another in a quarry, for example, the friends will use different nouns and verbs to talk about their work but similar function words if the two feel connected and understand each other.

The researchers analyzed 40 conversations between speed daters, a recent focus of relationship researchers (*SN: 2/14/09, p. 22*). Opposite-sex pairs who used similar types and frequencies of function words were more than three times as likely to express mutual interest in dating as pairs whose speaking styles differed. A second experiment of 86 young-adult couples in committed relationships found that those using similar writing styles during 10 days of instant-messaging chats were particularly likely to stay together over the next three months.

Pennebaker suspects that language-style matching waxes and wanes with relationships. In the September *Journal of Personality and Social Psychology*, he and Ireland analyze function words in letters between psychoanalysts Sigmund Freud and Carl Jung, poems and plays of Elizabeth Barrett and Robert Browning and poems of Sylvia Plath and Ted Hughes.

Language-style matching diminished as each relationship soured. Notable declines occurred when Jung left Freud's psychoanalytic group, when Elizabeth Barrett welcomed death's approach while her husband dreaded it, and when Plath and Hughes' marriage fell apart.

Ancient horns played eerie tunes

Acoustic scientists put their lips to ancient conch shells to figure out how humans used these trumpets 3,000 years ago. The well-preserved, ornately decorated shells found at a pre-Inca religious site in Peru produced haunting, droning tones that could have been used in religious ceremonies, the team reported November 17 at the Second Pan-American/Iberian Meeting on Acoustics in Cancun, Mexico. Archaeologists had unearthed 20 complete *Strombus galeatus* marine shell trumpets in 2001 at Chavín de Huántar, an ancient ceremonial center in the Andes. Polished and etched with symbols, the shells had well-formed mouthpieces and distinct V-shaped cuts (top). The cuts may have been used as a rest for the player's thumb, says study coauthor Perry Cook, a computer scientist at Princeton University and an avid shell musician. —*Marissa Cevallos*

JYRI HUOPANIEMI, CHAVÍN DE HUÁNTAR INVESTIGATION AND CONSERVATION PROJECT

Theory trampled

Doubt cast on Lucy tool use

By Bruce Bower

Marks on two fossil bones, recently presented as evidence that Lucy's ancient hominid species butchered animals for meat, likely resulted from animal trampling instead, say anthropologist Manuel Domínguez-Rodrigo of Complutense University of Madrid and his colleagues.

Scientists working in Ethiopia unearthed a pair of 3.4-million-year-old animal bones that, in their view, bear incisions created as Lucy's kind, *Australopithecus afarensis*, sliced meat off carcasses with sharp stones (*SN: 9/11/10, p. 8*). But Domínguez-Rodrigo and his colleagues made similar marks just by walking over deer bones while wearing shoes with grass-covered soles, they reported online November 15 in the *Proceedings of the National Academy of Sciences*.

Earth

68 thousand Maximum extent of ancient Saharan lake (square km)

1.6 thousand Maximum extent of five ephemeral lakes in same region, 2001 (square km)

Radar images reveal Egypt's great lost lake

Drainage pattern analyses find ancient Saharan oasis

By Alexandra Witze

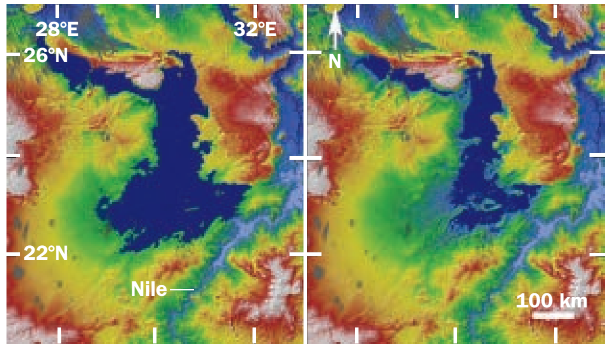
A huge lake once waxed and waned deep in the sandy heart of the Egyptian Sahara.

Radar images taken from the space shuttle confirm that a lake broader than Lake Erie once sprawled a few hundred kilometers west of the Nile, researchers report in the December *Geology*. After the lake first appeared about 250,000 years ago, it ballooned and shrunk until finally petering out about 80,000 years ago.

Knowing where and when such oases existed could help archaeologists understand the environment *Homo sapiens* traveled while migrating out of Africa for the first time, says team leader Ted Maxwell, a geologist at the Smithsonian National Air and Space Museum in Washington, D.C. Modern humans arose in Africa about 200,000 years ago.

"You realize that hey, this place was full of really large lakes when people were wandering into the rest of the world," he says.

Since then, desert winds have eroded and sands have buried much of the region's landscape, says Maxine Kleindienst, an anthropologist at the University of Toronto. But during next summer's field season, she and her colleagues will be checking for ancient shorelines at the elevations suggested in the new paper.



A low-lying area (dark blue) in the Sahara once held a large lake, a study of the topography west of the Nile reveals. False-color images show two possible extents.

T.A. MAXWELL *ET AL*/*GEOLOGY* 2010

Other studies have found evidence of megalakes in Chad, Libya and Sudan at various points over the last 250,000 years. The new study targeted Egypt, some 400 kilometers west of the Nile, where in the 1980s researchers reporting finding fish fossils in the desert.

That discovery, says Maxwell, triggered scientists to think about how those fish could have gotten there. In 2000, astronauts on the space shuttle Endeavour used radar to take high-resolution pictures of the area's topography. Maxwell and colleagues recently analyzed those pictures to deduce how water would have drained across northeastern Africa over the past few hundred thousand years.

In a region known as Tushka, west of the Nile, the scientists spotted a low-lying area where water would have pooled after overflowing from the river, carrying fish with it. At its maximum, this ancient lake would have stretched for 350 kilometers, down to the modern-day Sudan border.

Studies see 4 degrees of warming

Disruptive effects possible by 2060s, new analysis suggests

By Janet Raloff

There's not much time to reach binding international agreements for limiting greenhouse gas emissions if climate negotiators are going to meet the goal of keeping global average temperatures from climbing no more than 2 degrees Celsius above pre-industrial times. A business-as-usual approach to energy use could foster a 4-degree warming by as early as the 2060s, a new study concludes.

Such a temperature increase would be expected to trigger extensive, recurring droughts in some parts of the world, flood coastlines as sea levels rise and alter the types of crops that can survive where lands remain arable, notes Mark New of the University of Oxford in England. He coauthored one of 11 climate papers in the January 13, 2011 issue of *Philosophical Transactions of the Royal Society A,* posted early online to coincide with the start of a United Nations Framework Convention on Climate Change meeting in Cancun, Mexico, on November 29.

To keep maximum global temperature increases below 2 degrees C, human activity can spew greenhouse gases equivalent to no more than 1 trillion metric tons of carbon by 2200, researchers calculate. "We're just over halfway there" already, Oxford's Niel Bowerman says.

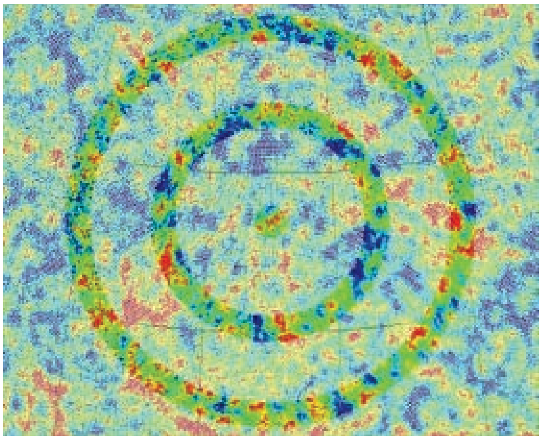
Richard Betts of the United Kingdom's Meteorological Office in Exeter led a team that looked at how soon a 4-degree warming might occur. The researchers considered seven different "business-as-usual" energy-use scenarios.

"We don't really know which [energy use and emissions] trajectory we're on yet," Betts says. By using the upper value for likely emissions into the future — based on what industrial nations are emitting and what rapidly industrializing nations like China and India probably will soon be releasing annually — "you get to this projection showing us reaching 4 degrees in the 2060s," he says. Emissions, Betts adds, will have to peak within five years if humankind hopes to dodge increases exceeding 2 degrees C.

Cosmic radiation analysis hints at series of universal reincarnations

Circular patterns suggest latest Big Bang was one of many

By Ron Cowen



Rings of lower temperature variability (enhanced above) in cosmic microwave background data may hint that the universe existed before the Big Bang.

Most cosmologists trace the birth of the universe to the Big Bang, 13.7 billion years ago. But a new analysis of the relic radiation generated by that explosive event suggests that the universe has cycled through myriad episodes of death and rebirth, with the Big Bang merely the most recent in a series of starting guns.

That notion, proposed by theoretical physicist Roger Penrose of the University of Oxford in England and Vahe Gurzadyan of the Yerevan Physics Institute and Yerevan State University in Armenia, goes against the standard theory of cosmology known as inflation.

The researchers base their findings on circular patterns they discovered in the cosmic microwave background, the ubiquitous glow left over from the Big Bang. The circular features indicate that the cosmos itself circles through epochs of endings and beginnings, Penrose and Gurzadyan assert. They describe their controversial findings in an article posted at arXiv.org on November 17.

The circular features are regions where tiny temperature variations in the otherwise uniform microwave background are smaller than average. Those features, Penrose says, cannot be explained by inflation theory, which posits that the infant cosmos underwent an enormous growth spurt, ballooning from something on the scale of an atom to the size of a grapefruit during a tiny fraction of a second. Inflation would either erase such patterns or could not easily generate them.

"The existence of large-scale coherent features in the microwave background of this form would appear to contradict the inflationary model and would be a very distinctive signature of Penrose's model" of a cyclic universe, comments cosmologist David Spergel of Princeton University. But, he adds, "The paper does not provide enough detail about the analysis to assess the reality of these circles."

Penrose interprets the circles as providing a look back, past the glass wall of the most recent Big Bang, into the universe's previous episode, or "aeon," as he calls it. The patterns, he suggests, were generated by collisions between supermassive black holes that occurred during this earlier aeon. Colliding black holes would have created a cacophony of gravitational waves — ripples in spacetime generated by the acceleration of the giant masses. Those waves would have been spherical and uniformly distributed.

According to the mathematics worked out by the physicists, when the uniform distribution of gravitational waves from the previous aeon entered the current aeon, they were converted into a pulse of energy. The pulse provided a uniform kick to the allotment of dark matter, the invisible material that astronomers believe accounts for more than 80 percent of the mass of the cosmos.

"The dark matter material along the burst therefore has this uniform character," says Penrose. "This is what is seen as a circle in our cosmic microwave background sky, and it should look like a fairly uniform circle."

Each circle would have a lower-than-average variation in temperature, which is just what Penrose and Gurzadyan found when they analyzed data from NASA's orbiting Wilkinson Microwave Anisotropy Probe and the balloon-borne BOOMERANG experiment. WMAP scanned the entire sky for nine years, while BOOMERANG studied the microwave background over a smaller fraction of the sky for periods of up to two weeks.

Because the researchers found similar circular features using two different detectors, Penrose says that it is unlikely that he and his collaborator are being fooled by instrumental noise or other artifacts.

But Spergel says he is concerned that the team has not accounted for variations in the noise level of WMAP data acquired over different parts of the sky. WMAP examined sky regions for different amounts of time. Maps of the cosmic microwave background generated from the regions that were studied the longest would have lower noise and smaller recorded variations in the temperature of the microwave glow. Those lower-noise maps could artificially produce the circles that Penrose and Gurzadyan ascribe to their model of a cyclic universe, Spergel says.

A new, more detailed mapping of the cosmic microwave background radiation, now being conducted by the European Space Agency's Planck mission, could provide a more definitive test of the theory, Penrose says. ■

V. GURZADYAN AND R. PENROSE

“You could be on a spacecraft and you could be able to navigate without having any help from Earth.” —ANGELO TARTAGLIA

Using pulsars to find a Starbucks

Cosmic GPS would employ pulsing stars instead of satellites

By Marissa Cevallos

To find your favorite coffee shop in an unknown city, getting directions via satellite works like a charm. But that technology won’t get you from Earth to Jupiter.

So theorists have proposed a new type of positioning system based on blinking stars instead of satellites. By receiving radio blips from pulsars — stars that emit radiation like clockwork — a spacecraft could figure out its place in space.

Unlike the Global Positioning System of satellites used by cars and smart phones, the pulsar system wouldn’t need humans to make daily corrections.

“You could be on a spacecraft and you could be able to navigate without having any help from Earth,” says Angelo Tartaglia, a physicist at the Polytechnic University of Turin in Italy.

Though the navigation system proposed by Tartaglia and colleagues is just a proof of concept, a system under construction in Europe could implement the idea within a decade, he says.

GPS receivers in a car or phone pick up radio signals from satellites orbiting the Earth. The satellites, synchronized with atomic clocks, emit signals simultaneously. Because the satellites are all different distances from the receiver, each signal arrives at a different time. From those time differences, a GPS device infers the distance to each satellite and can calculate its own position.

Because the satellites move so fast, the effects of Einstein’s relativity cause their onboard clocks to tick slower than those on Earth. Transmitting the correct time to each satellite is the task of the Department of Defense.

Pulsars, dense leftovers of supernovas, sweep beams of radiation from their poles at intervals with precision comparable to atomic clocks. A pulsar’s regular blips can be used to mark time just like GPS signals. But the pulsar-system math already accounts for relativity, so corrections aren’t needed.

The Italian team simulated its proposed system on computers that mimic pulsar signals received at an observatory in Australia. Inferring the distance between the pulsars and the observatory, the team tracked the trajectory of the observatory on the Earth’s spinning surface to an accuracy of several microseconds, or the equivalent of several hundred meters, the team reported in a paper posted at arXiv.org on October 30.

Pulsars are weak sources, and detecting them usually requires a large radio telescope. So the researchers propose planting bright radio wave emitters on celestial bodies like Mars, the moon or even asteroids.

It came from another galaxy

Extrasolar planet’s origin traced to beyond Milky Way

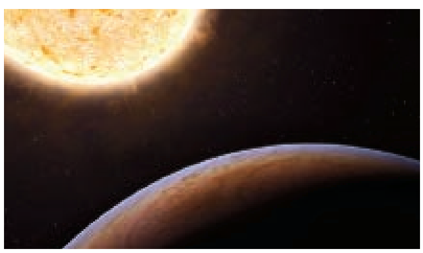
By Ron Cowen

Some extrasolar planets are truly out of this world.

Astronomers have for the first time discovered a planet in the Milky Way with extragalactic origins. The planet, with a mass of at least 1.25 Jupiters, orbits a star that was most likely ripped from a satellite galaxy 6 billion to 9 billion years ago.

Johny Setiawan and Rainer Klement of the Max Planck Institute for Astronomy in Heidelberg, Germany, and their collaborators describe the finding online November 18 in *Science*.

“The coolness factor is definitely that the planet and star came from another galaxy,” says Sara Seager of MIT. “The planet almost certainly formed during the time the star was in the other galaxy.”



L. CALÇADA/ESO

Planet HIP 13044b and its star, shown in an illustration, may have traveled to the Milky Way from a different galaxy.

Setiawan and colleagues homed in on the star HIP 13044, about 2,000 light-years from Earth, because it’s part of a stream of stars called Helmi that is believed to have originated in another galaxy. The researchers found the planet by monitoring HIP 13044 long enough to detect telltale wobbles indicating the tiny tug of an unseen body. HIP 13044 and the other stars in the Helmi stream stand out because their elongated orbits take them about 42,000 light-years above and below the plane of the Milky Way’s disk. Such orbits strongly suggest that the stars were torn from a satellite galaxy and were stretched by gravitational tidal forces into a stream.

The discovery, notes planet hunter Scott Gaudi of Ohio State University in Columbus, “is doubly weird: It is a weird planet around a weird star.”

The star is unusual because it has the lowest abundance of metals of any star known to have a planet. Also unusual is that HIP 13044 is old enough to have exhausted its supply of hydrogen fuel and passed through the red giant phase of evolution, in which it mushroomed in size. Since then the star has contracted to a diameter about seven times that of the sun and is now burning helium at its core. A star in this phase of evolution has never before been found to have a planet.

Life

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Borneo's orangs have rocky past

Endangered today, the apes have been to the brink before

By Susan Milius

Orangutans on the island of Borneo descend from a relatively small number of ancestors who apparently squeezed through a rough patch about 176,000 years ago, according to the broadest genetic analysis to date of their species.

The genetic data suggest an ancient population bottleneck in which animal numbers shrank and then expanded once conditions improved, says anthropological geneticist Natasha Arora of the University of Zurich.

A serious chill gripped the planet roughly 190,000 to 130,000 years ago, Arora and her colleagues point out in a paper posted online November 22 in the *Proceedings of the National Academy of Sciences*. Borneo itself wasn't iced over, but rain forests where orangutans live might have shrunk during this time, constraining the orangutan population.

Orangutans today live only on Borneo and Sumatra, in two endangered species that diverged several million years ago. The new genetic findings are "very surprising" in light of the ancient split, says Lounès Chikhi, a population geneticist in Toulouse, France, with the CNRS research agency.

"Something really important happened" roughly 170,000 years ago, Chikhi says. That something doesn't seem to have bottlenecked gibbons and macaques that shared ancient Borneo with the orangutan *Pongo pygmaeus*. But at least one other primate may have had a history similar to Borneo's orangutans. "There is a strange parallel with human evolution," Chikhi says. Based on mitochondrial DNA, the most recent common maternal ancestor among modern humans lived 170,000 years ago. "What happened between 150,000 and 200,000 years ago that influenced both *Homo sapiens* and *Pongo pygmaeus*?" he asks.

Evidence for the orangutan bottleneck turned up thanks to 17 researchers who isolated DNA from fecal and hair samples of 211 wild orangutans at 12 sites and built a genetic family tree from the data.

A bottleneck may be the simplest explanation for the recent shared ancestry of Borneo's orangutans, says Jakarta-based conservation scientist Erik Meijaard of People & Nature Consulting International. But some more complex scenario involving extinctions and repopulations might also fit the data.

The orangutan species found on Borneo went through a population bottleneck about 176,000 years ago.

The study also fuels some conservationists' worries by confirming that female orangutans don't move much, with rivers in particular being a big barrier. So what may look to a human like a fine stretch of rain forest for orangutans may in reality be impossible for them to reach.

"Once you've lost orangutans from a watershed," Meijaard says, "they're gone." ■

Amphibian species debut

Scientists on an amphibian expedition in Colombia's cloud and rain forests have discovered three new species, including a tiny beaked toad. The diminutive toad, at 2 centimeters or smaller in length, is a member of the genus *Rhinella*, making it a close relative of the giant cane toad (which can grow to a whopping 28 centimeters). The dull coloration of the newly identified beaked toad probably camouflages it on the forest floor, where it also lays its eggs. Oddly, the beaked toad seems to skip the tadpole stage: Its young hatch directly into toadlets, report scientists from Conservation International, the IUCN Amphibian Specialist Group, Global Wildlife Conservation, and Fundación ProAves. A new species of rocket frog, a kind of poison dart frog belonging to the genus *Silverstoneia*, also was described for the first time. So was a toad so unfamiliar that researchers can report only that it has bright red eyes and lives high in the Chocó montane rain forest. —*Rachel Ehrenberg*

FROM TOP: MURE WIPFLI; © ROBIN MOORE/ILCP

Genes & Cells

“Intuitively, you wouldn’t believe that just by chance things would be conserved for 500 million years.” —DANIEL CHOURROUT

RNA harnessed to control cells

Genetic devices could thwart cancer and signal infections

By Tina Hesman Saey

Scientists are one step closer to learning how to program cells the way some people program computers. Researchers led by Christina Smolke, a biochemical engineer at Stanford University, report the accomplishment in the Nov. 26 *Science*.

Smolke and colleagues created RNA devices that could rewire cells to sense certain conditions and respond by making particular proteins. Such biotechnology might be harnessed for creating cell-based therapies and cancer-fighting treatments. Someday, scientists might also be able to flip an RNA switch to make plants more tolerant to drought or coax yeast to produce industrial chemicals.

Other researchers have reported building RNA-programming components before, but Smolke’s group is the first to integrate all the pieces into a fully functional system, says Adam P. Arkin, a systems and synthetic biologist at Lawrence Berkeley National Laboratory and the University of California, Berkeley. “It’s sort of like building the first functional car,” says Arkin, who was not involved in the study. “Yeah, combustion was around and there were things that rolled, but actually putting them together” was the real breakthrough.

The invention reported in the new study is based on eons-old genetic material, RNA molecules. Smolke and her team rigged up RNA molecules to work a bit like a security system that is tuned to be triggered by only one type of intruder. In this case, the RNA molecules detect particular proteins and then turn on or off production of another protein in response.

The team’s first device made human kidney cells glow with a fluorescent protein when the RNA detected a protein from a virus that infects bacteria. Then the researchers got fancier and configured the system so that cells would kill themselves if the engineered RNA detected high levels of proteins involved in promoting cancer. These feats and others are described in the new study.

These simple programs are just examples of what researchers might be able to make cells do in the future, Smolke says. She envisions that such RNA devices might be used to program animal, plant and fungal cells to do a wide variety of tricks. And the technology could be configured so that multiple conditions need to be met before initiating a program — say, turning on a cholesterol-lowering drug in the liver only after a high-fat meal.

“My sense is that it’s not going to work for everything,” Smolke says, “but it’s going to work for a large subset of things.” ■

Tunicate genome found out of order

Scrambled genes suggest that arrangement may not matter

By Tina Hesman Saey

As any devotee of *Antiques Roadshow* can tell you, just because something has been saved doesn’t mean it’s valuable.

Likewise, a new study of plankton shows that hanging on to a well-preserved genome isn’t necessarily crucial. The genome of the tunicate *Oikopleura dioica* contains roughly 18,000 genes, nearly as many as the human genome’s 22,000 or so, but with the genes in a completely different order and less DNA stuffed between them, an international team reported online November 18 in *Science*.

The finding came as a surprise to researchers since it has been thought that the arrangement of genes on chromosomes helps determine how an organism’s body plan will be laid out. Humans and other vertebrates tend to have genes arranged in a similar order. Many researchers thought that this genomic structure was important since it was preserved over millions of years of evolution. But the tunicate genome’s scrambled gene order could indicate that other organisms’ genomes got and stayed that way without any pressure from natural selection.

Tunicates, some of the ocean’s most abundant zooplankton, are helping solve genetic mysteries.

JIRI SLAMA AND JEAN-MARIE BOUQUET, © *SCIENCE*/AAAS

“Intuitively, you wouldn’t believe that just by chance things would be conserved for 500 million years,” says coauthor Daniel Chourrout of the University of Bergen in Norway. This result suggests that the genome structure in most animals may have been maintained simply by inertia.

The tunicate genome also contains clues to the source of introns, chunks of DNA that are sandwiched between protein-coding parts of genes. Examination of tunicate introns indicates that many are copies inserted into the genome in new places. The new report gives the first direct evidence of this, says evolutionary biologist Michael Lynch of Indiana University in Bloomington. “Any insight into that is welcome,” he says.

Body & Brain

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

New drug boosts good cholesterol and lessens bad

Anacetrapib may be potent tool against heart disease

By Nathan Seppa

An experimental drug shows the ability to more than double a person's good cholesterol score, potentially filling a huge gap in cardiovascular care. If the new findings hold up in a larger trial, the drug, called anacetrapib, stands poised to become the best medication yet for boosting levels of heart disease–preventing HDL.

"This is a very exciting era we are entering," said Christopher Cannon, a cardiologist at Harvard Medical School and Brigham and Women's Hospital in Boston. He presented the findings on November 17, the same day they appeared online in the *New England Journal of Medicine*.

"These preliminary data are very promising," agreed Sidney Smith, a cardiologist at the University of North Carolina at Chapel Hill and a past president of the American Heart Association. "They show dramatic differences in HDL." High-density lipoprotein, or HDL, ushers bad cholesterol, or low-density lipoprotein, out of the blood. High levels of HDL are strongly associated with low risk of heart attack and stroke.

Cannon and his colleagues randomly assigned 1,623 people, average age 63, who had heart disease to receive either anacetrapib or a placebo for 18 months. All were already taking a statin drug to lower LDL. In the anacetrapib group, HDL levels shot up from an average of 41 milligrams per deciliter of blood to 101 mg/dl within weeks and stayed there. Anacetrapib also lowered LDL from an average of 81 mg/dl to around 45 mg/dl. People who received a placebo experienced very slight changes in their HDL and LDL scores. According to the American Heart Association, LDL below 100 mg/dl is optimal, and HDL above 60 mg/dl is considered protective against heart disease.

"These preliminary data are very promising. They show dramatic differences in HDL."
SIDNEY SMITH

Only eight people getting anacetrapib — compared with 28 in the placebo group — needed to undergo coronary revascularization during the trial, in which doctors surgically reopen or bypass a blocked artery to restore blood flow to the heart. "We're very encouraged by this," Cannon said.

The people in the study were in fair health despite having heart disease, he said. Yet the surgical data indicate that in some patients statin drugs were not staving off the disease's progression.

Data from this study are not enough to change medical guidelines, Smith cautioned, and Cannon agreed. Further work will be needed to show that the higher HDL levels seen in patients taking anacetrapib represent truly functional HDL, and that can be established only by a long-term reduction in heart attacks, stroke, angina and other tangible cardiovascular events. "If it does have a significant benefit on events, then we will have a very valuable potent new therapy to add," Smith said.

Some people naturally have higher HDL than others. Apart from niacin, which has a side effect of flushed skin, no drug has previously been shown to increase HDL both substantially and safely. Stopping smoking, losing weight and exercising can add 5 to 10 points to a person's HDL score, Smith said.

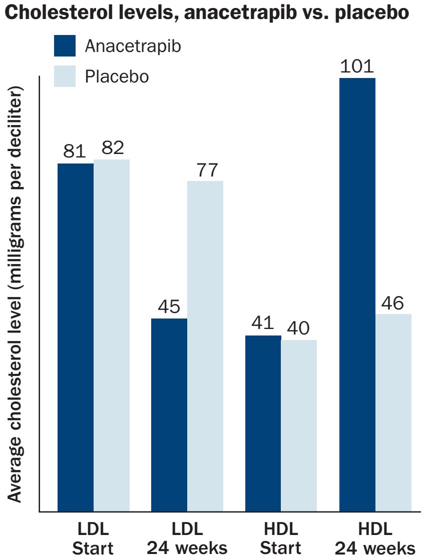
Anacetrapib works by inhibiting CETP, or cholesteryl ester transfer protein, a compound that influences how much LDL and HDL a person carries in the blood at any given moment. A promising drug called torcetrapib had shown the ability to inhibit CETP and raise HDL (*SN: 5/1/04, p. 285*). But research pitting the drug against a placebo was stopped in 2006 when it became clear that people taking torcetrapib were more likely to develop high blood pressure, experience heart problems or die than those on a statin alone. The result was a blow to the drug's maker, Pfizer, and left HDL-boosting drug hopes in limbo, although some work is ongoing (*SN: 4/14/07, p. 237*).

Anacetrapib has now shown "a very potent and impressive change in lipid profiles," said Thomas Lüscher, a cardiologist at University Hospital Zurich. "And such change occurred without a change in blood pressure." The number of deaths was also roughly the same in the two groups.

But 142 people had their LDL drop so low on anacetrapib plus a statin that they were taken off the experimental drug as a precaution. Scientists will next test anacetrapib, manufactured by Merck, in a trial of 30,000 heart disease patients over four years, paying close attention to that risk and any other that arises. ■

Bad down, good up In a clinical trial of 1,623 patients, anacetrapib decreased harmful LDL cholesterol and boosted "good" HDL.

Cholesterol levels, anacetrapib vs. placebo



SOURCE: C. CANNON *ET AL*/*NEJM* 2010

E. FELICIANO

Mining fat tissue for cardiac repair

Stem cells from abdomen may boost recovery after attack

By Nathan Seppa

Sifting stem cells from fatty tissue and shooting these nascent cells into the coronary arteries of people who just survived a heart attack may limit heart-tissue damage, researchers have found. The process, which takes a few hours, might rescue heart cells on the cusp of dying, said Henricus Duckers, an interventional cardiologist at Erasmus University in the Netherlands, who presented the new findings November 16. The small study is the first to reinfuse fat-derived stem cells into heart attack patients, he said.

Duckers and his colleagues recruited 14 people who had just survived a severe heart attack. All had undergone emergency treatment to reopen blocked coronary arteries. Surgeons removed fatty tissue from each patient's abdomen and placed it in a machine that separates fat cells from stem cells. The researchers then randomly assigned 10 of the patients to get the actual therapy, in which only the stem cells are injected within 24 hours into the individual's coronary artery, where they flow downstream into damaged parts of the heart. The other four patients received placebo infusions.

Over six months, the scar size of the treated patients shrank from 31.6 percent of the left ventricle — the huge pumping chamber of the heart — to roughly 15.4 percent on average, magnetic resonance imaging showed. This reduction by half goes well beyond the 10 percent typically seen in heart attack patients, Duckers said. In those who received a placebo, ventricle scar size remained unchanged.

Duckers said that larger trials of the fat-derived stem cells are planned.

Alcohol a benefit following bypass

In men, two to three drinks a day limited heart problems

By Nathan Seppa

The cardiac benefits of having a daily drink or two might extend to a surprising group — men with heart disease so bad that it required coronary bypass surgery.

The value of light-to-moderate drinking for cardiovascular health has shown up previously in healthy people, with studies showing that — other factors being equal — people who regularly drank in moderation had less heart disease and fewer strokes than did nondrinkers.

But moderate drinking's protective benefits may also extend to those who already have some cardiovascular disease, suggests work presented by cardiac surgeon Umberto Benedetto of the University of Rome La Sapienza. Benedetto reported the new findings November 14.

He and his colleagues recruited 1,021 men who had undergone coronary artery bypass surgery, in which a vessel is taken from another part of the body and grafted onto the heart. During a post-surgery follow-up period that averaged 3.5 years, about one in six had a heart attack, required more surgery, had a stroke or died. Those who continued to drink alcohol, though not to excess, were 11 to 39 percent less likely to encounter one of these problems than were teetotalers, the researchers found. The optimal alcohol intake for the men was about two drinks per day.

The study also looked at 200 women — not enough to do a separate analysis. But generally, moderate drinking for women is defined as one daily drink.

MEETING NOTES

Fish oil fails in arrhythmia trial

Fish oil, which has shown signs of benefit for the heart, doesn't seem to help people with atrial fibrillation, researchers reported November 15. The omega-3 fatty acids in fish oil had been shown in some studies, but not others, to stabilize irregular heartbeat. The new study randomly assigned 527 people with paroxysmal atrial fibrillation — a relatively mild form of the condition that resolves itself without medical intervention — to get either high-dose fish oil or a placebo capsule. After six months, there was no clear difference between the groups. —*Nathan Seppa*

Drug helps in mild heart failure

People with mild heart failure may benefit from a drug now prescribed for more severe forms of the condition and for high blood pressure. Physician Faiez Zannad of the Nancy University Hospital Center in France presented findings November 14 showing that eplerenone reduces the risks of hospitalization and death in patients with milder, chronic heart failure. Zannad and his colleagues randomly assigned 2,737 patients, average age 69, to get either eplerenone or a placebo. After people in the groups had been followed for 21 months on average, the trial was stopped because it became clear that the drug benefited those taking it. During follow-up, 26 percent of people getting the placebo were hospitalized for heart failure or died from cardiovascular causes compared with only 18 percent of those taking the drug. The findings were also published online November 14 in the *New England Journal of Medicine*. —*Nathan Seppa*

Body & Brain

"These helmets weren't designed to stop a pressure wave; they were designed to stop bullets." —ALBERT KING

Combat helmet should cover face

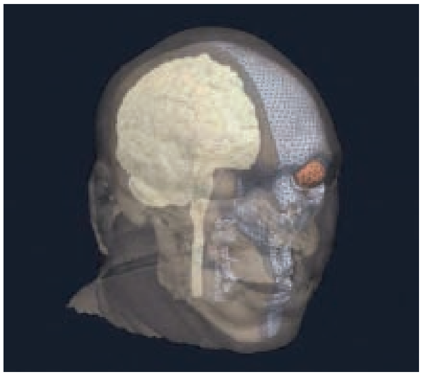
Current model lets blast forces into brain, simulations show

By Rachel Ehrenberg

Adding a face shield to the standard-issue helmet worn by U.S. troops could help protect soldiers from traumatic brain injury, the signature wound of the wars in Iraq and Afghanistan. A new study that models how shock waves pass through the head finds that adding a face guard deflects a substantial portion of the blast that otherwise would steamroll its way through the brain.

Nearly 200,000 service members have been diagnosed with mild traumatic brain injury since 2000, according to the Armed Forces Health Surveillance Center in Silver Spring, Md. While blunt impact clearly can injure the brain, the forces that are endured when explosives send shock waves crashing through the head are much more difficult to characterize.

Researchers led by Raúl Radovitzky of MIT's Institute for Soldier Nanotechnologies created a computer model of a human head that included layers of fat and skin, the skull, and different kinds of brain tissue. The team modeled the shock wave from an explosion detonated right in front of the face under three conditions: with the head bare, protected by the current combat helmet and covered with the helmet plus a polycarbonate face shield.



Researchers used a computer model of the head to simulate how explosive blasts pass through the skull and brain.

The study, published online November 22 in the *Proceedings of the National Academy of Sciences*, showed that today's helmet doesn't exacerbate the destructive force of an explosion, as some previous research suggested. But at least in terms of blast protection, the current helmet doesn't help much either. Adding a face shield would improve matters, the team reports.

"The face shield contributes a lot to deflecting energy from the blast wave and not letting it directly touch the soft tissue," says Radovitzky. "We're not saying this is the best design for a face shield, but we're saying we need to cover the face."

To validate the model, researchers will have to conduct more experiments in the real world. But the work does point to an intrinsic flaw in the current helmets.

"These helmets weren't designed to stop a pressure wave; they were designed to stop bullets," says Albert King, head of the Bioengineering Center at Wayne State University in Detroit. "Just like a football helmet wasn't designed to stop a concussion, but to stop skull fracture."

HIV drugs offer barrier to virus

Antiretrovirals limit infection rate among men at high risk

By Nathan Seppa

HIV-negative gay and bisexual men can lower their likelihood of acquiring the AIDS virus by taking an antiretroviral drug mix, concludes a study in which healthy men received either the medication or a placebo. The finding, published online November 23 in the *New England Journal of Medicine*, suggests that a preventive strategy might limit HIV spread.

"For the first time, we have evidence that a daily pill used to treat HIV is partially effective for preventing HIV among gay and bisexual men at high risk of infection," says physician Kevin Fenton of the Centers for Disease Control and Prevention in Atlanta. He cautions, however, that the results don't warrant abandoning other proven prevention techniques.

Robert Grant of the University of California, San Francisco and colleagues recruited 2,499 men who have sex with men from the United States, Peru, Ecuador, South Africa, Brazil and Thailand. Half were randomly assigned to get a placebo and half got a similar-looking pill that contained the antiretroviral drugs emtricitabine and tenofovir. During a follow-up period averaging slightly more than a year, 36 men on the drugs became infected with HIV, compared with 64 on placebo. Men assigned to the real drugs and who took them more than 90 percent of the time had the lowest infection rate.

In trials offering preventive drugs, there is always a risk that some of the participants' behavior will become more risky because they assume they are protected, says Connie Celum of the University of Washington in Seattle, who was not involved in the study. But in this case, high-risk behaviors actually decreased in both groups after enrollment, the authors note, possibly because participation included free condoms, counseling, regular HIV testing and treatment for other sexually transmitted diseases.

Celum is testing the prevention strategy in East African heterosexual couples in which one spouse is HIV-positive but the other is not. The HIV-negative spouses are being randomly assigned to get medication or a placebo along with counseling and other services. ■

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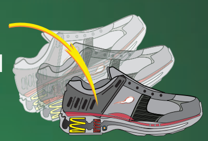

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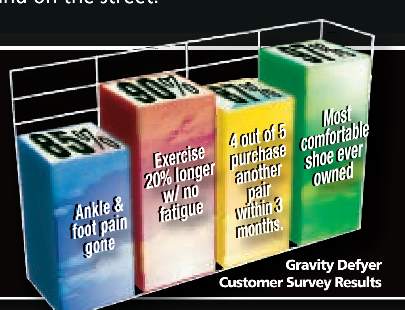

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Searching for new sources to explain human variation

By Tina Hesman Saey

Standing over Darwin's grave in Westminster Abbey, Andrew Feinberg had a realization.

Feinberg, a genetics researcher at Johns Hopkins University in Baltimore, looked to the left and saw Newton's grave. Just above Newton is a plaque honoring physicist Paul Dirac, a pioneer of quantum theory. Inherent in quantum theory is the idea of uncertainty in the interaction of subatomic particles.

"So I look back at Darwin's grave and it hits me; there's nothing like that in biology," Feinberg says. Nothing that deals with uncertainty.

Yet there is uncertainty in biology. Genes that run in families explain only some of the wide variety of physical appearances among people and their susceptibility to diseases. Much uncertainty in what causes these differences remains.

But biologists don't just accept this seeming randomness as a fundamental part of reality. Instead, they are seeking an explanation for unknown sources of variation in heritable traits, the way physicists are searching for a mysterious substance dubbed dark matter that could explain puzzling aspects of the cosmos.

And biologists have proposed some solutions. Feinberg's, scribbled down at a pub in the shadow of the Tower of London, is that chemical modifications to DNA could be the genetic dark matter.

Feinberg is in the minority, though; others have their own favorite theories about what the missing ingredient might be. Some think that researchers just need to hunt harder and longer for common changes in the sequence of genetic letters that make up DNA. But a growing number of researchers are turning to rare genetic changes or

PHOTOS: W. GOLDSWAIN/SHUTTERSTOCK

absent or duplicated chunks of DNA as important contributors. Others say that interactions among genes deserve more attention.

Whatever the ultimate explanation, understanding the complete heritability picture could allow doctors to design prevention and treatment plans catered to individuals' needs.

Unclear math

Factors determining how much people have in common with other people fall into two broad categories — nature and nurture. The nature part is a measure of how genetic variation contributes to the range of phenotypes — outward appearances, behaviors or disease risks — among people. Environmental factors, such as exposure to chemicals, nutrition, exercise or smoking habits, make up the nurture part.

Geneticists mainly concern themselves with the stuff of nature, the basis of heredity. Heredity plays a big role in how tall people will grow, their weight or their likelihood of getting the same disease that killed a grandparent, for example. Studies of families, especially identical twins, have helped researchers calculate how much genetic factors contribute to variation in a given characteristic.

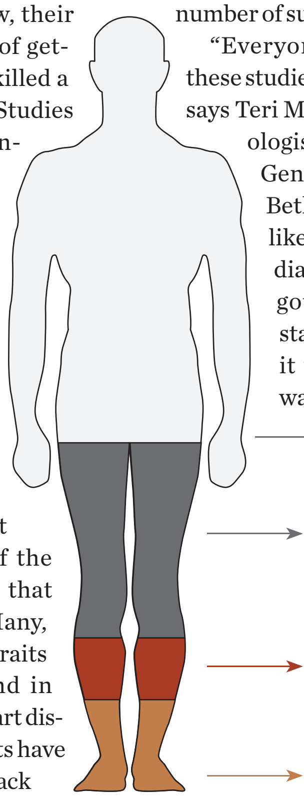
Sometimes the genetic contributions are simple. Inheriting a mutation in a single gene can lead to disorders such as cystic fibrosis, sickle-cell anemia or Huntington's disease. But usually it's not just one of the 22,000 or so human genes that is responsible for a trait. Many, many genes play a role in traits like height and weight and in complex diseases such as heart disease and diabetes. Geneticists have been trying for decades to track down how genetic variations in DNA lead to such diseases.

About five years ago, the pieces started coming together. Researchers began scanning the genomes of thousands of people using genetic markers called single nucleotide polymorphisms, or SNPs (pronounced "snips"), to try to pinpoint disease-causing and trait-linked genes. A SNP is a single-letter change in the sequence of A's, C's, T's and G's that make up the DNA alphabet. Though everyone has thousands of SNPs and some may have no effect, the genome-wide scans use statistical methods to figure out the likelihood that particular spelling changes contribute to a characteristic.

The impetus for these genome-wide association studies was a popular theory that common genetic variants — SNPs found in 5 to 10 percent of the population or more — could add up to cause common diseases. People unlucky enough to be weighed down with a backbreaking number of such variants would get sick.

"Everyone was so excited when these studies first started coming out," says Teri Manolio, a genetic epidemiologist at the National Human Genome Research Institute in Bethesda, Md. "Everyone was like, 'Wow, we have a gene for diabetes. We've got 10. We've got 50.' But then when we started looking more closely, it was apparent that there was a lot missing."

> "When we started looking more closely, it was apparent that there was a lot missing."
>
> TERI MANOLIO



Adding up Most variation in human height is genetic, but studies looking at common changes in DNA have failed to account for a huge portion. Many researchers are now turning to rare changes to explain the discrepancy.

SOURCE: J. YANG *ET AL*/*NATURE GENETICS* 2010, H.L. ALLEN *ET AL*/*NATURE* 2010

MYSONTUNA/SHUTTERSTOCK, ADAPTED BY E. FELICIANO

How tall a person will grow, for instance, is 80 to 90 percent heritable, meaning that genetic factors account for most of the centimeters and millimeters that separate the tallest from the shortest people. A recent study including more than 180,000 people uncovered 180 common genetic variants associated with height. But those differences account for only about 10 percent of the genetic contribution to height variation (*SN: 10/23/10, p. 15*). The consortium of researchers conducting the study, published online September 29 in *Nature*, calculated that more than 1,000 common genetic variants, each of which nudge height up or down a millimeter or two, could be involved in determining how tall or short people will ultimately be. Even then, adding the effects of all 1,000 variants would cover only about 20 percent of heritable variation in the human population, leaving a lot unaccounted for.

For most genome-wide association studies, the story is similar. They identify a large number of genetic variants with small effects, but none add up to fully explain heritability.

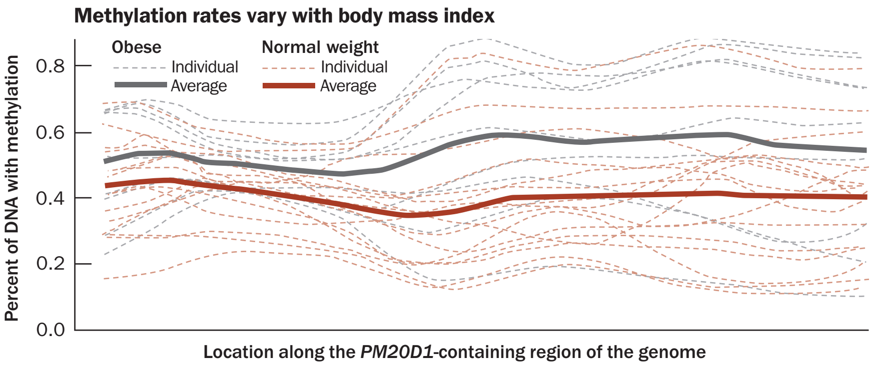
Researchers know that the cause of the unexplained genetic variation, dubbed "missing heritability," must be out there somewhere. Like dark matter, says Olivier Harismendy, a genomicist at the University of California, San Diego, "we know it's there, but we just can't grasp it."

A tagging matter

Unconvinced that common variants will ever explain all the missing heritability, Feinberg is looking under other rocks. His proposal involves a rock that genome-wide association studies have not flipped over.

Chemical tags that don't change genes but do modulate their activity may account for some of the variation, Feinberg thinks. These changeable tags are known as epigenetic marks, and a genome-wide association study can't uncover them because they don't

Beyond the letters Some researchers think chemical tags affixed to DNA through a process called methylation could affect traits and disease susceptibility. In a recent study, people with heavier methylation in the region including gene *PM20D1* were more likely to be overweight.
SOURCE: A. FEINBERG *ET AL/SCI. TRANSL. MED.* 2010



alter the letters of a person's DNA.

Researchers know about a host of different epigenetic tags that affix to DNA or to proteins closely associated with DNA (*SN: 5/24/08, p. 14*). The molecular equivalent of the two-sided open/closed signs that hang in business windows, these tags signal that genes are ready to be turned on or shuttered. Certain environmental conditions, including those encountered in the womb, can permanently flip the sign, and that flip can pass from one generation to the next.

Feinberg hypothesized that many epigenetic marks would be largely the same from person to person, but that at a few strategic locations — such as near genes involved in development — people might have widely different tagging. If an epigenetic mark made a gene less active, the tag could affect a person's outward traits or disease risk, and thus be an uncounted part of heritability. Or an epigenetic mark might change the activity of a mutated gene that would otherwise affect a trait, hiding that mutation's full contribution.

To see whether these chemical tags make a difference, Feinberg's team, including Johns Hopkins colleagues Rafael Irizarry and Daniele Fallin, measured a particularly stable kind of epigenetic mark known as DNA methylation. Affixing a methyl group to DNA generally has the effect of shutting down nearby genes.

The team mapped methyl tags in DNA samples taken 11 years apart from 74 Icelandic people (*SN: 10/9/10, p. 15*). The researchers reported September 15 in *Science Translational Medicine* finding four places in the Icelanders' genomes where more heavily methylated DNA correlated with a person's body weight.

This study is far too small to say how much of the missing heritability the addition or subtraction of chemical marks may account for, Feinberg says. "We're very careful to say that we don't have the magic missing answer," he says. But he thinks his data are strong enough to suggest that other researchers should expand searches to include the chemical marks. Most haven't yet gotten on board and continue to look for changes in the DNA letters themselves.

"Right now, we're hoping for a simpler explanation," says Rasmus Nielsen, a population geneticist at the University of California, Berkeley, "but if it's something more complex like epigenetics, it may take a lot longer before we get to the answer."

Spelling-centric view

Many researchers have pinned their hopes on rare variants, single-letter DNA changes found in only a small portion of the population. Studies of some diseases, including autism, schizophrenia and bipolar disorder, suggest that rare mutations — even some so rare that they appear only in a single person or family — can contribute in a big way to whether a person gets a disease. Some spelling mistakes linked to mental retardation, for example, are seen for the first time in people affected with that disability, according to a study published online November 14 in *Nature Genetics*.

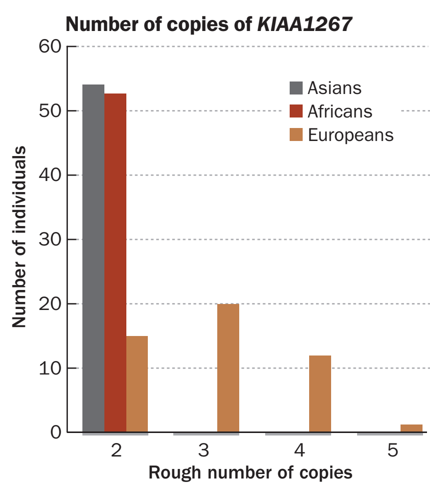
Genome-wide association studies can look for rare spelling changes by using SNPs present in only 1 to 5 percent of people or fewer, but variants that show up suddenly in just one person may elude these studies.

Enter the 1,000 Genomes Project, an effort to catalog all the genetic variation in 2,500 people from around the world by determining every letter in their genetic instruction books. The project made its debut in a study appearing October 28 in *Nature*. A consortium of researchers, including David Altshuler, a geneticist at the Broad Institute in Cambridge, Mass., cataloged 15 million SNPs, 1 million small insertions or deletions of parts of chromosomes, and about 20,000 larger missing or added chunks in more than 800 people (*SN: 11/20/10, p. 14*). About half of the variants had not been cataloged before. Conducting genome-wide scans that include these new variants may reveal some missing sources of heritability.

"It's easy to say, 'Oh, it must be rare variants,' but now we have the technology to really go after them," Harismendy says.

A companion study in the Oct. 29 *Science* also found that about 1,000 genes vary in numbers of copies in people, most

Doubling up Some genetic scans miss duplicated chunks of DNA, which alter the number of copies of a gene and can affect gene activity. A study found that copies of the gene *KIAA1267*, for example, vary among Europeans.



SOURCE: P.H. SUDMANT *ET AL/SCIENCE* 2010

E. FELICIANO

falling into the zero- to five-copy range but some reaching as many as 368 copies. The role that multiple copies play in heritability remains to be determined.

"We're just trying to unveil genetic variation," says Evan Eichler of the University of Washington in Seattle, who led the study. "But it's not a panacea. It's not like everything is solved now." Researchers should think about genomes as a whole, with all variations, to really understand contributions to heritability, he says.

A fruit fly study suggests the whole-genome approach may be the way to go. The Drosophila Genetic Reference Panel was launched two years ago to try to account for all the genetic factors that go into the fly's highly heritable traits such as aggressiveness, longevity, stress tolerance, sleep duration and recovery times after cold-induced comas, says Trudy Mackay, a geneticist at North Carolina State University in Raleigh and one of the project's leaders.

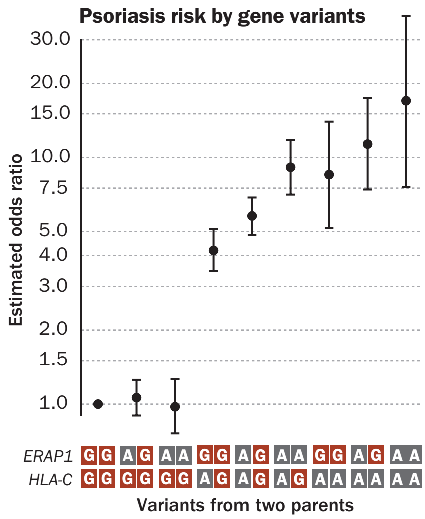
Mackay and her colleagues captured pregnant female *Drosophila melanogaster* fruit flies from the wilds of a farmers market in Raleigh and then inbred the offspring to create 200 different strains, each with a characteristic response to each test. Instead of doing genome-wide association studies to look for variants linked with each trait, Mackay and her colleagues determined the entire genetic blueprints for the strains. So far, the genomes for 162 are known, though the results are not yet published.

"What we find is that we can account for all the heritability, thank you very much," Mackay says. Most of the heritability comes from single-letter changes present in about 3 to 5 percent of the fruit fly population. Researchers probably don't have much further to go to understand heritability in humans either, Mackay says. "I think we're there, in theory, but we need more data."

Peter Visscher, a quantitative geneticist at the Queensland Institute of Medical Research in Brisbane, Australia, agrees that missing heritability is almost within researchers' grasp. He argues that the problem of missing heritability is a mathematical one. Using a statistical

Gene-on-gene People with a disease-associated variant (gray) of the gene *ERAP1* show no added risk of psoriasis unless they also carry a disease-related variant of the *HLA-C* gene — suggesting that gene interactions may be important to heritability.

SOURCE: AMY STRANGE *ET AL/NATURE GENETICS* 2010



model different from the one used in the recent height paper in *Nature,* Visscher and colleagues calculate that common variants account for about 45 percent of height's heritability, the team reports in the July *Nature Genetics.* And if most diseases have underlying genetic contributions similar to those for height, then researchers need only expand the search for common variants with tiny effects in ever bigger studies, or locate rare variants with larger effects, to find all the pieces.

Yeast weigh in

But Feinberg isn't alone in thinking that some of the work requires looking beyond DNA letters. Leonid Kruglyak, a geneticist and Howard Hughes Medical Institute investigator at Princeton University, finds it unlikely that having complete genetic blueprints for many individual fruit flies and people will tell the whole heritability story for every trait. He has been studying patterns of heritability in baker's yeast. Yeast have only about 6,000 genes and a much more streamlined genome than humans do, so in theory, it should be far easier to account for heritability.

Kruglyak and his colleagues tested yeast for their ability to withstand 17 different types of chemicals. Resistance to some chemicals is mainly controlled by one gene, while surviving other chemicals may require 20 or more genes, he and his colleagues reported April 15 in *Nature*. And while the researchers were able to find 14 regions of the genome that account for about 70 percent of the heritability of resistance to a chemical called 4-nitroquinoline, they could explain only about 10 percent of the heritability of resistance to some other types of chemicals, he says.

He is interested in exploring how interactions between genes may affect certain traits. Alone, a genetic variant may have a clear effect, but another genetic variant may cancel out or intensify the effect when it occurs within the same person.

A study of the skin condition psoriasis recently illustrated that point. A consortium of researchers reported in the November *Nature Genetics* that people who have a disease-associated variant of a gene called *ERAP1* have a risk of developing psoriasis that is no greater than average as long as they also carry normal copies of an immune system gene called *HLA-C*. But a gene variant of *HLA-C* can work with the *ERAP1* variant to dramatically increase psoriasis risk.

As scientists pursue possible hiding places for the missing heritability, many agree that the answer won't lie under just one rock.

"The missing heritability implies that it is sitting in a box somewhere and it will be obvious when we find the answer," Altshuler says. "There's no simple answer because the genetics of these complex diseases is complicated."

Each of the factors — additional common variants, rare variants, epigenetics, gene-gene interactions — may turn out to explain some of the missing heritability.

"I have no idea how it's going to shake out when we're sitting around in 100 years talking about heritability," says Kruglyak. "Anybody who will give you a precise breakdown is guessing." ■

Explore more

- *Nature*'s Scitable piece on estimating heritability: http://bit.ly/fbxxwc

Ancient expanses called cratons pose a geological puzzle

By Charles Petit

When Viennese geologist Leopold Kober gave geology a new word — *kratogen*, soon shortened to *craton* — for the flat, stony interiors of continents, he thought such places to be among the duller places for geological study. For him, the more flexible expanses of crust he called orogens, full of rising mountains and earthquake faults, were where the action was.

Kober could not know that today, 90 years later, cratons would be objects of intense study. A man of his time, he got little right. He was a fixist and a contractionist. A skeptic of the theory of continental drift first espoused by Alfred Wegener in 1912, Kober believed that the cooling Earth had shrunk just enough over time to explain the folds, mountains and valleys that rumple its crust. He thought ocean floors to be drowned cratons, unyielding and drift-proof, and he laid out his scheme in his influential 1921 book *Der Bau der Erde*, or "the construction of the Earth."

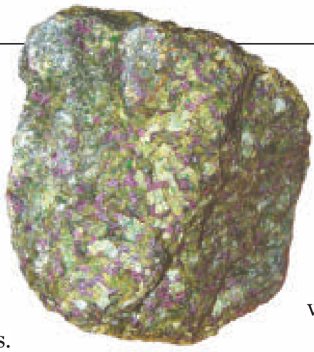
The discovery in the 1960s that ocean basins are made of young, spreading crust confirmed Wegener's basic ideas. Growing continuously from volcanic rifts, the seafloor dives back down when it cools, shrinks and gets dense — pushing continents and the tectonic plates they rest on about like rock scum. Ancient, stable cratons play no part in this underwater action.

But, far from boring, the unyielding hearts of continents to which Kober applied his term hold deep mysteries. Serene and nearly unchanging now, in their youth cratons were places of immense violence and dynamic geological behavior largely impossible on today's cooler Earth. How exactly cratons formed remains an open question, and geologists continue chipping away at the dogged rocks to try to uncover vital clues to an earlier age.

"Kober was a great field geologist and

NEW MOON/PANORAMIC IMAGES

made great contributions to our understanding of the eastern Alps," says Turkish geologist Celal Şengör, a top historian of the field who has at least 30,000 early geology books in his home overlooking the Bosporus. But as time went on, says Şengör, Kober got only weirder. "He developed the concept of a mysterious 'Atomgas' that welled up from the interior of the Earth and caused magmatism ... he was not entirely rational," Şengör says.



A sample of gem-studded cratonic rock from South Africa.

DAVID R. BELL/ASU

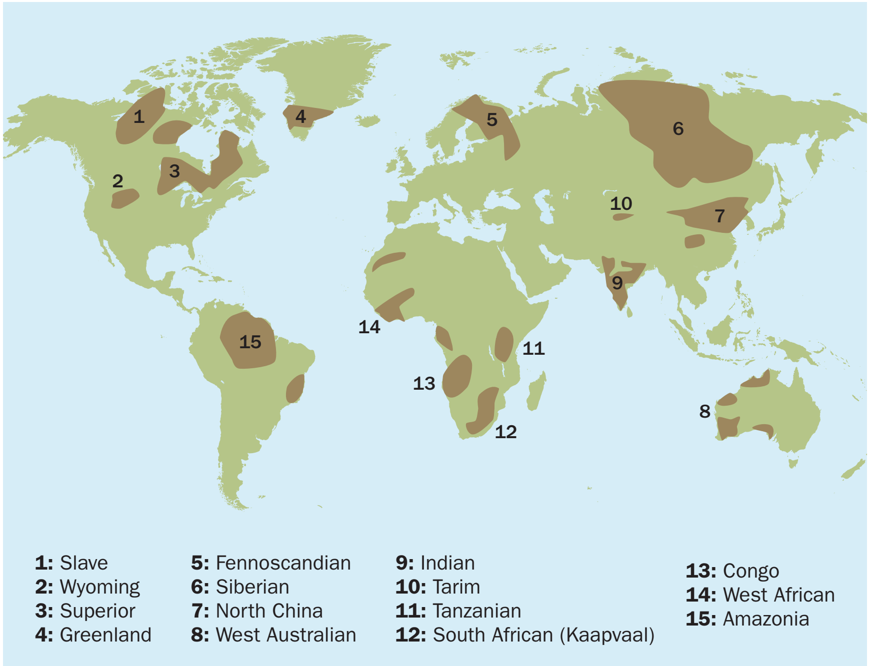
Kober got one thing right: *craton*. It is an almost perfect word, short and solid as a stone. It derives from *kratos,* meaning strong and unyielding. Greek myths personified the concept as the minor god Kratos (and the term also inspired the ends of the words democracy and meritocracy, not to mention the relentless warrior antihero of the popular video game *God of War*).

Cratons started gaining appreciation in the 1970s, when geologists first recognized that the rocks made no outward sense. As solid and cool as they are, cratons should have sunk below the Earth's surface. A good peg on which to fix the birth of modern craton theory and discovery is the early investigations of one man, Thomas Jordan.

"It became clear to me that cratons were just about the most puzzling things," says Jordan, of the University of Southern California in Los Angeles. Now 62, he holds an endowed chair in geological sciences at the university, is director of the Southern California Earthquake Center, a member of the National Academy of Sciences, former department chair at MIT, coauthor of a popular geology textbook and winner of many honors.

His role in the field is appropriate. In an odd way, his life history resembles that of a craton: wildly tumultuous youth full of disruption and crisis, followed by a sudden maturity, early adulthood and extended stability.

Yellowstone National Park sits on the edge of the Wyoming craton, which extends through the west-central United States.



Stable centers Cratons lie in the interiors of continents, largely undisturbed by processes of uplift, subduction and rock recycling occurring around them. The map above shows the names and global distribution of cratons dating back to the Archean, more than 2.5 billion years ago.

SOURCE: C.T. LEE

Jordan was 16 when he graduated from high school in Panama — where his Army-officer father was stationed. But he'd attended a dozen schools and, the eldest of seven kids, had lived in more than 20 houses. With ace scores in mathematics, Jordan went straight to Caltech. But, dazzled and distracted by the freewheeling counterculture of the '60s, he spent much of his time camping the coast near California's Big Sur and enjoying the times. "I just plain flunked out," he says. He planned to quit science.

But a job with a professor running seismometers in the Sierra Nevada above Pasadena made Jordan realize that he could work outside and do physics too. And earth science professors went to bat for him, getting him back into the university. Suddenly, as one of those professors, geophysicist Don Anderson, says, "He got his head on straight. He was worth saving. He was among the most natural born leaders I'd ever seen."

Jordan finished undergraduate studies and added a Caltech Ph.D. in just three years. Princeton University hired him as an assistant professor at a remarkably young age, 23. There he began developing the isopycnic hypothesis (pronounced like *picnic*), which attempted to explain cratons' puzzling qualities. Though some recent discoveries don't agree with all his forecasts, nearly all papers on the formation and stability of cratons refer to his early studies as seminal.

Isopycnic means equal density. To understand the idea's importance requires backing up a bit.

Deep enigmas

By the 1970s geologists already knew a good deal about craton surface composition and general size. The continental hearts account for a bit less than half the area of the world's dry land. Collections of cratons are called shields (or, if covered in thin sediment, platforms). The shield covering most of North America, for example, is an assemblage of smaller units with such names as Slave, Sask, Rae, Churchill and Superior craton. Their bedrock is made of gneiss and other metamorphic rocks whose mineral structures have gotten a long, deep bake in the high temperatures and pressures well underground.

Cratons are flat because erosion has stripped away literally miles of rock, some of it lofty crags. "We are standing among the roots of mountains when we go to the Canadian interior," Jordan says.

Cratons, like the Greeks' Kratos, are strong. Beneath the stiff surface lithosphere — the layer of the Earth that includes the crust and the upper part of the mantle and is broken up into tectonic plates — hot elastic rock churns. This slow convective overturning, in a region called the asthenosphere, may swallow whole oceans' worth of crust but has hardly touched most cratons.

In the 1960s the refraction and alteration of earthquake waves made clear that cratons are deep too. They have roots, or keels, extending at least 160 to perhaps 320 kilometers down and some, including Jordan, say even more than that. Compared with the Earth's 6,300-kilometer radius, this is like a minor irregularity in an apple peel. But the depth difference is still significant.

Cratons typically are two or three times as thick as oceanic lithosphere. Even mountain ranges such as the Himalayas rest on rock thinner than the low, flat cratons. While the asthenosphere into which the cratonic roots extend may sound like taffy into which a toe is dipped, it is not. "If you picked up a hot piece of the asthenosphere (with thick insulating gloves), it would be harder than steel," says Norm Sleep, a Stanford University geophysicist. That the cratons have survived through eons has been hard to understand and, to many, still is.

Cratons are cold, a relative term. Go down 240 kilometers in a craton and the rock, while nowhere near molten, is plenty hot — perhaps 1,300° Celsius. But one needs to go down just half as far or less to find rock so hot under the ocean floor (or even where new continental crust is forming in volcanic island chains, or in mountains thrust upward by an ocean plate squeezing its way underneath).

Diamonds pulled from cratons show they are old. The gems form deep in

T. DUBÉ, MAP: ROSENDO/ISTOCKPHOTO

cratons, embedded in rock called peridotite. Fast-moving volcanic eruptions pierce the cratons, dragging pieces of peridotite set with diamonds from the walls of the conduits and belching them, along with ash and residue, across the surface. For decades, geological analysis of decayed radioactive isotopes in the gems and in their host rock has shown that nearly every one in jewelers' display cases is over 2 billion and sometimes more than 3 billion years old.

The age of the diamonds puts the birth of many cratons during the eon known as the Archean, 2.5 billion years and more ago. Some may go back close to 4 billion years, just half a billion years after the Earth's birth. The appearance of more cratons seems to have petered out during the Proterozoic eon, which lasted until about 540 million years ago. After that, continents grew by accumulation of new and thinner, more flexible (and mountain-forming) crust.

Such qualities, Jordan saw, added up to a serious conundrum. One simply cannot take standard oceanic lithosphere, make it twice as thick or more, cool it a few hundred degrees, wait a billion or more years and expect it to still be there. Thermal contraction would not only drop its surface below sea level, but the density increase might also sink it altogether into the deep mantle. Even if such a slab of cool crust were to somehow stick around, its extra mass would be detectable with sensitive instruments. No such large gravity anomalies exist.

Jordan hinted at his isopycnic explanation in a 1975 paper in *Reviews of Geophysics and Space Physics*. In 1978 he followed up with a report in *Nature*, and elaborated more over the years. He proposed that to be as cold and thick as they are and still sit in the Earth's outer layers, cratons must be chemically distinct and must have started with a density low enough to compensate for thermal contraction. Such a process could give them an overall density no greater than the crustal average.

He argued that, in the higher temperatures of the Archean, volcanism pulled immense quantities of magma from the deep lithosphere. Up to 30 or 40 percent by volume of a region's upper mantle rock may have melted and redistributed itself to the surface. The volcanic action preferentially removed aluminum, calcium and iron-rich minerals from the deep, leaving behind a slag of peridotite. A coarse-grained mix of the greenish mineral olivine with a sprinkling of deep purple garnet crystals, peridotites are the most common rock type of the upper mantle. But under cratons, Jordan proposed, the depletion of heavier components through melting left peridotites sharply enriched in lightweight magnesium.

Remarkably, the process not only left the deep rocks lighter than they'd been — and lighter than those in melt-depletion zones still active on today's Earth — but the erupting lava underwent mineral changes to wind up with less density than its source rock as well.

A final step in Jordan's hypothesis was to greatly thicken the new, less dense crust. He imagines a process of "advection," or collisions among cratons as plate tectonics brought them together. Squeezed together by the dynamics of a young, hotter Earth, craton tops would be pushed higher and their feet pushed deeper into the mantle, a process of kneading that would let lighter material preferably move up while denser portions move down. He thus imagines cratons achieving an almost perfect match of density and depth to provide maximum stability.

"I haven't really changed the idea too much since then," he says. He still argues that the keels may extend down as much as 350 kilometers or 400 kilometers, for a thick layer that has moved as a unit since the Archean.

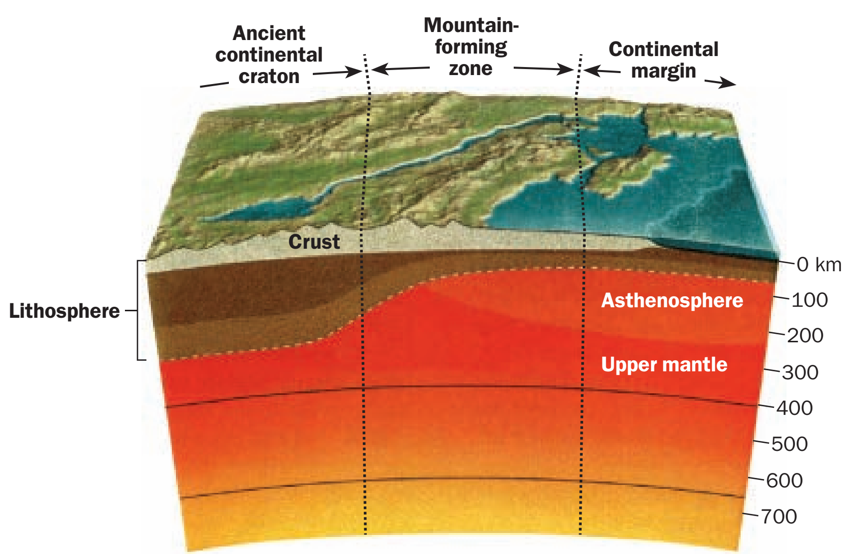
Chipping away

But even today great questions remain about how cratons formed. It is not at all clear that the isopycnic hypothesis in full will stand the test of time. For instance, the exact way that cratons got their

Quick comparison Craton lithosphere differs dramatically from oceanic lithosphere when it comes to such factors as depth and mineral composition.

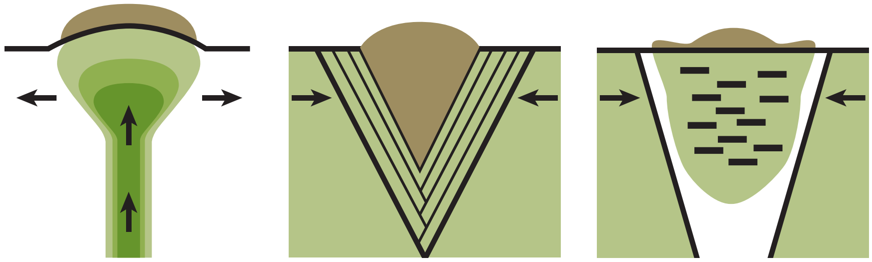
	Cratonic lithosphere	Oceanic lithosphere
Age	Up to 4 billion years	0 to 180 million years
Depth	150 to 320 kilometers	Less than 100 kilometers
Temperature at 80 km	Less than 800 degrees Celsius	1,000-plus degrees Celsius
Crust's composition	Peridotites depleted in heavier constituents	Dense, basaltic rock

What lies below Cratonic crust is cooler and stronger than oceanic crust. Typically such cooling would make a rock more dense, and it would drop below sea level. But cratons aren't so dense, possibly because a period of melting removed heavier constituents such as iron.



J. GROTZINGER AND T. JORDAN/*UNDERSTANDING EARTH*, 6TH ED., ADAPTED BY T. DUBÉ keels during the distant Archean is still unclear. Three hypotheses have been proposed. One, the surface crust was thickened from directly beneath by a rising plume of semimolten material from far deeper in the Earth. Two, subducting plates of Archean oceanic lithosphere sometimes got lodged beneath cratons, one after the other in an underplating process. And, three, cratons thickened through accretion. In this case, scraps of continental-type crust, possibly island arcs newly formed at sea, could raft against cratons to thicken them or, in Jordan's view, cratons themselves could squeeze together and thicken.

Adding depth Researchers don't understand why cratons are two to three times thicker than oceanic lithosphere. Scientists have three proposals for how cratons got so thick:



Bottom-up A rising plume of molten rock thickens cratons from below.

From the top As oceanic lithosphere converges, layers stack like a deck of cards to underplate the craton.

Crunched in Squeezed together by tectonic forces, scraps of crust—possibly island arcs—accrete and thicken through kneading.

SOURCE: C.T. LEE AND T. JORDAN

Recent technological improvements have allowed researchers to better probe deep keels, measuring seismic waves from distant earthquakes. Some resulting papers have favored the arc accretion model of craton thickening. After one survey across Canada's shield, a team led by Meghan S. Miller, one of Jordan's colleagues at USC, reported in *Geophysical Research Letters* detecting boundaries in the keels that suggest that island arcs smashed into cratons, piling up against them over time.

Barbara Romanowicz, director of the University of California, Berkeley Seismological Laboratory, says the patterns she sees in the North American craton also support the arc accretion hypothesis. In *Nature* in August, Romanowicz and Berkeley postdoc Huaiyu Yuan analyzed seismic shear waves coursing through a North American craton from 94 earthquakes around the world. The pattern of crystal alignment in rock that extends down to about 150 kilometers carries a fossil imprint of a consistent north to south flow. Such a pattern seems to rule out a rising plume, which would probably leave a radial pattern, as the source of the keel's deeper peridotites.

> **"This very powerful hypothesis allowed me to come up with a view of continents that has been, I think, basically confirmed."**
> THOMAS JORDAN

But the analysis also reveals two distinct layers, a finding that may erode Jordan's deep keel idea. Beneath the upper layer, a separate layer with a different crystal alignment, creating a distinctly different seismic wave velocity by direction, continues down to between 180 and 240 kilometers. Romanowicz thinks the deeper layer got put in place later than in the Archean—and that only the upper layer, to 150 kilometers down, is from that ancient age.

Still, Jordan's core insight of highly refractory, high-magnesium rock in the deep hearts of cratons has been consistently verified by studies of rocks dragged to the surface by eons of volcanic eruptions.

A key prediction, that the mineral olivine contained within the peridotite would be unusually dry, got powerful backing in recent studies in southern Africa by a team that included Anne Peslier of NASA's Johnson Space Center in Houston and David Bell of Arizona State University in Tempe. In the Sept. 2 *Nature*, the researchers reported testing hundreds of pounds of peridotite that Bell gathered from the waste heaps of diamond mines across southern Africa.

"Most of the rock down there is olivine, and what happens to olivine when it is wetter? It gets much weaker," Peslier says. But when she and her colleagues calculated how deep the rocks had been for most of the last 3 billion years, they found the deepest to be almost bone-dry. The team calculates that the water content was so low that the rock was 10 times stiffer than typical peridotite. "That is a big reason we still see them, they are so strong," she said of the cratons' bottom armor.

Jordan, for his part, is content that his main insight has held up: A vast episode of melting left cratons strong enough, yet light enough, to remain intact and afloat. The details of how they thickened and what that reveals about the early Earth remain to be determined, but researchers are inching forward.

Jordan is no Kober, not stuck in the past nor given to fantasy. But like Kober, Jordan did leave a new term for the field. *Isopycnic* may not be as elegant as *craton*, but Jordan's hypothesis does fill in some of the mystery of these inert continental interiors.

"This very powerful hypothesis allowed me to come up with a view of continents that has been, I think, basically confirmed," Jordan said recently. "People have been hot for it, and down on it. It is an area where I made a contribution. I hope to see it fully tested by evidence." ■

Explore more

- J. Grotzinger and T. Jordan. *Understanding Earth*. W.H. Freeman, 2010.
- Smithsonian National Museum of Natural History's "The Dynamic Earth" online exhibit: www.mnh.si.edu/earth

T. DUBÉ

Pioneering audiologist invents "reading glasses" for your ears.

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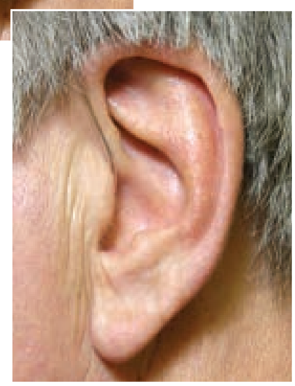

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Black holes in the bathtub

Scientists observe Hawking radiation in unexpected materials

By Marissa Cevallos

If you stuck your hand inside a black hole recently created in a Canadian laboratory, you wouldn't get sucked in like a string of spaghetti. You'd just get wet.

This black hole exists in a water tank, its forces afflicting water waves rather than unsuspecting space travelers. Technically this bathtub version is a white hole, an inverted black hole that keeps waves out rather than sucking them in. But the white hole can serve as an analog because it shares an important feature with astrophysical black holes — an imaginary boundary that emits an unusual kind of radiation.

Black holes are notorious for sucking matter in, but physicist Stephen Hawking proposed in 1974 that a signal of their existence, now called Hawking radiation, would also leak out. In the bubbling quantum vacuum surrounding a black hole, particle-antiparticle pairs pop into existence. An electron, for example, and its partner, the positron, would emerge from the vacuum and then burst into a flash of energy after colliding an instant later. But if one particle slipped inside the black hole, forever trapped, the other particle would whiz away.

Of even more interest to scientists would be particles of light, or photons, since they would provide an optical signature. As their own antiparticles, photons should pop up in twos at a black hole's edge. Spotting photons whizzing away from a black hole would confirm the existence of Hawking radiation, which might provide hints in the search for a theory to unite the physics of the really big with the bizarre behavior of the really small.

Unfortunately, though, radiation from real black holes is too weak to see. So scientists have taken another approach to observing Hawking radiation, building black hole analogs in Earth-bound labs.

The Canadian team with the water-based black hole analog now sees the radiation in the form of water waves. Another team observes photons emitted from a black hole analog in glass. Yet another has created a black hole in ultracold gas that could be probed for the signal in the form of sound. These lab-made emitters of Hawking radiation share one required feature with their astrophysical counterparts — a point of no return, analogous to the black hole's outer boundary, or event horizon.

"Once there is a horizon, in spite of the many approximations underlying the theory, Hawking radiation always survives," says physicist Iacopo Carusotto of the University of Trento in Italy. "It seems to be a robust phenomenon in nature."

Sister horizons

In an astrophysical black hole, the event horizon exists because of the pull of gravity created by the black hole's mass, which can be millions of times that of the sun. The horizon is the point at which nothing can escape. Even sound and light are trapped.

But black holes don't have to be astrophysical. Take, as an example, water rushing over Niagara Falls, sweeping along a tiny fish. If the fish could yelp as it began descending to the rocks below, the sound waves carrying its cries would propagate in all directions and the screams could be heard at the top of the falls.

But if the plunging water's velocity exceeds the speed of sound, an event horizon is created around the yelping fish. Sound waves traveling toward the

NICOLLE RAGER FULLER

top of the falls get pushed back by the plunging water and stuck behind the invisible horizon. The sound is trapped in a watery black hole.

It's like Alice's frustration in *Through the Looking-Glass* when sprinting to keep up with a certain monarch. "It becomes like the Red Queen running as fast as she can and never getting anywhere," says William Unruh, a physicist at the University of British Columbia in Vancouver.

The flailing fish was a cute opener for a lecture Unruh gave in 1972 on black holes, then unfamiliar objects to many scientists. It wasn't until 1980, while teaching a course on fluid mechanics, that he noticed the equations governing fluids looked suspiciously similar to the math for gravitational fields around a black hole. Unruh realized that if he could create an event horizon with water in the lab, he should be able to create Hawking radiation, too.

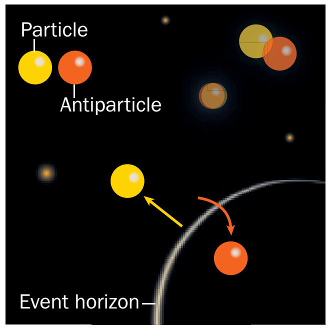
In August, Unruh and colleagues announced that they had made such a horizon in a water channel. Shielding the setup under a tent of black plastic, they sent a steady flow of water in one direction. As it passed over a piece of wood whittled in the shape of an airplane wing, the water traveled faster. In the opposite direction, the group created water waves. When these waves approached the wing, where water was flowing faster, they slowed to a stop. This created the inverted version of a black hole, or a white hole. Both types have horizons, so both ought to emit Hawking radiation.

In fact, pairs of short-wavelength waves were created at the horizon and swept away, Unruh's team reports in an upcoming *Physical Review Letters*. And the energy of these emitted waves matches what would be predicted from Hawking radiation around a real black hole.

"At first, we would have been happy to see any evidence whatsoever," says Unruh. "What was amazing was our results were far, far better than anything we expected."

Unruh's original idea for the experiment has spurred researchers around the world to create other analogs. A team of researchers led by Daniele Faccio at the University of Insubria in Italy has made an event horizon by pulsing laser light through glass. The laser pulse creates a small increase in the density of the glass that propagates like a wave at the speed of light. But because light slows when it passes from a less dense to a more dense medium, any light jogging to catch up won't make it past the region of increased density — trapped like the Red Queen. Photons popped into existence at the event horizon, the researchers report in the Nov. 12 *Physical Review Letters*. If they can tweak the experiment to show that the photons were emitted in opposite directions — a tougher task — the researchers will be more certain they've seen Hawking radiation.

Unruh says he is not sure the team's signal will turn out to be the sought-after radiation. "I still have questions about it," he says.



A black hole escapee
Particle-antiparticle pairs pop in and out of existence at a black hole's edge. If one particle falls in, the other can fly away as Hawking radiation.

B. RAKOUSKAS

Another research group, led by Jeff Steinhauer of the Technion-Israel Institute of Technology in Haifa, has made a black hole in an ultracold form of matter that should be emitting Hawking radiation, the team reports in an upcoming *Physical Review Letters*. In this material, called a Bose-Einstein condensate, supercooled atoms behave as one atom and flow with little resistance. Though the researchers haven't looked for Hawking radiation yet, computerized simulations done by a separate team suggest that the Bose-Einstein black hole sends off pairs of phonons, the particle-like carriers of sound vibrations.

Beyond black holes

These and other analog systems may help solve a lingering problem in Hawking's original proposal. His model suggested that radiating light could have wavelengths shorter than the Planck length, supposedly the shortest length allowed by quantum mechanics. If light could have such short wavelengths, and thus really high frequencies, one photon could carry more energy than contained in the entire universe — clearly fishy. Hawking had wanted to eliminate this possibility, but he couldn't make his equations work without it.

But now, Unruh says, black hole analogs — particularly his, which uses the math of water waves — exhibit Hawking radiation without running into the troubling energy problem. "This experiment gives one a lot more faith that Hawking radiation doesn't depend on the absurdly high frequencies," says Unruh. "It's basically not a problem."

The analogs may also offer insights into one of the most challenging open problems in the field: uniting quantum mechanics, the math describing the intricate dance of tiny particles, with the physics of gravity, the force that holds together galaxies, stars and planets.

Black holes are the ideal systems for seeking a theory of quantum gravity because Hawking radiation would be a quantum effect, yet black holes have strong gravitational fields. Just as measuring the energy levels of hydrogen was a crucial insight for deriving quantum mechanics, so is the classical understanding of black holes necessary for a theory of quantum gravity, says Gonzalo Olmo, a theoretical physicist at the University of Valencia in Spain. "The black hole is like the tip of the iceberg for quantum gravity," Olmo says.

Not all of the laboratory event horizons will necessarily bear theoretical fruit — some of the contraptions may get sucked into an academic black hole of sorts. But scientists are just getting their feet wet. ■

Explore more

- Kip S. Thorne. *Black Holes and Time Warps: Einstein's Outrageous Legacy*. W. W. Norton & Company, 1995.

Some We Love, Some We Hate, Some We Eat: Why It's So Hard to Think Straight About Animals

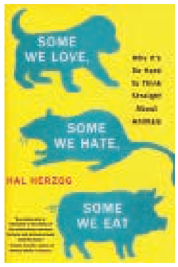
Hal Herzog

In his lively book on human-animal interactions, Herzog denies rumors that he feeds kittens to snakes. For a while, however, his academic research did focus on snake behavior, and his son did have a pet boa. Whispers circulated, but Herzog says the little snake could barely tackle a mouse.

The incident serves as an example of the complexity of human reactions to animals. The idea of scooping up little fluffballs and dropping them into a snake cage unsurprisingly repels most people. But at least one of Herzog's critics allows pet cats to roam outdoors, a practice that dooms an estimated billion birds and other small animals each year to becoming cat food.

Considering this, Herzog asks why animal lives are valued so differently. Maybe to feed pet snakes, it would be kinder to sacrifice shelter cats that are doomed anyway, he says, instead of purposefully raising more creatures as food. He says he would never take such an approach, but the thought experiment drives home how inconsistent human attitudes are toward animals.

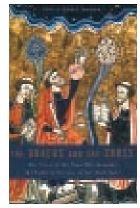
As he became more interested in such questions, Herzog's research shifted from reptile behavior to anthrozoology, the study of how humans and animals interact. *Some We Love* offers an engaging tour of this emerging field, including much that's intriguing to anyone who has ever loved a house pet.



Herzog comes across as a gentle observer seeking foremost to understand. He writes thoughtfully, for example, about cockfights and animal activism. While focusing on ethical questions, including animal research and eating meat, he pulls in plenty of research data. (One experiment, for example, found that dogs put on a sheepish look when their human companions inadvertently give them cues to act guilty, not when the dogs have actually misbehaved.)

At first Herzog found "flagrant moral incoherence" about animals troubling, he says. But in the end, he makes a case that such mixed feelings are inevitable — a finish that's both disturbing and comforting. *— Susan Milius*

HarperCollins, 2010, 326 p., $25.99.



The Abacus and the Cross

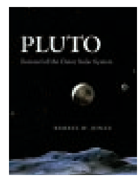
Nancy Marie Brown

The story of Pope Sylvester II, who introduced Islamic math and science to the West. *Basic Books, 2010, 328 p., $27.95.*

Cooking for Geeks

Jeff Potter

Learn the science behind sautéing and other cooking techniques in this combination recipe book and introduction to food chemistry. *O'Reilly Media, 2010, 432 p., $34.99.*



Pluto

Barrie W. Jones

An astronomer explores the demoted planet and shows how it has contributed to scientists' knowledge of the solar system. *Cambridge Univ. Press, 2010, 231 p., $35.99.*

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FEEDBACK

Receipt of BPA risk news

Thank you so much for your recent article ("Receipts a large and little-known source of BPA," *SN: 8/28/10, p. 5*) on the possible dangers of touching cash register receipts! One group you may have overlooked as being at risk was accountants and bookkeepers. I own a small tax and accounting shop where we handle literally thousands of clients' receipts every year. Sometimes we wear latex gloves, just because the receipts are dirty (such as from a machine shop or auto repair), but now I will insist my employees do so more often, especially any young women who may become pregnant. I am giving a copy of your article to everyone who works here and mailing one to other accounting offices in the area. Accounting offices everywhere should somehow be alerted to this danger.

Maggie Seedorf, Taylor, Mich.

I appreciate receiving the "heads-up" regarding BPA-laden receipts. Is anybody researching the risk from BPA ending up in recycled paper from the recycling of such receipts? One product made from recycled paper is facial tissue, which commonly comes into contact with our skin. Might not that further expose us to BPA? By the way, curious minds want to know if *Science News* address labels are thermally printed? If so, did I also just receive a free BPA sample on my label?

Terry Masters, Portland, Ore.

Recycled papers often contain BPA, or bisphenol A. A German study several years ago (SN: 5/24/03, p. 334) *turned up BPA in "sizable quantities — up to 45 milligrams per kilogram of paper — in two of three brands of recycled bathroom tissue tested." As for* Science News *mailing labels, those are ink-jet printed, not thermally printed like the receipts described in the recent article. Still, most printing inks contain BPA, says biologist Frederick vom Saal of the University of Missouri-Columbia, so washing hands after handling a newspaper or magazine might be prudent. — Janet Raloff*

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

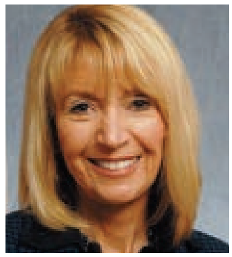
Marcia McNutt

For more Comment, visit Columns at **www.sciencenews.org**

A year on the job, she takes pride in disaster response

When she took over in November 2009 as the first female director of the U.S. Geological Survey, geophysicist Marcia McNutt already had her work cut out for her in streamlining and modernizing a historic scientific agency. That was before a string of natural disasters — earthquakes in Haiti and Chile, a volcanic eruption in Iceland and the Gulf of Mexico oil spill — made her job an even bigger challenge. In October she spoke at the Geological Society of America meeting in Denver about the roller-coaster ride of her first year. Science News *contributing editor Alexandra Witze compiled this edited version of McNutt's comments.*

On January 12, I was pulled out of a meeting to find out that Port-au-Prince had been nearly a direct hit for a magnitude 7.0 earthquake. My stomach started churning. This wasn't just another 7.0 earthquake; this was something pretty major. The USGS had a novel tool called PAGER [Prompt Assessment of Global Earthquakes for Response], which is a preliminary assessment of the damage from earthquakes that took into account things such as the groundshaking, proximity to population centers, and the building standards — which gave an immediate heads-up to the decision makers in our federal government so they could know what kind of response was appropriate.



USGS

We can't stop the plates from moving, but we can prepare so that the economic and human casualty toll is minimized.

In this administration, the leadership is eager to use science in decision making. We as scientists should be eager to make our science relevant and communicate it well so that they can.

In the aftermath of the Haiti quake, there were rumors going rampant in Port-au-Prince in the days and weeks following the main event, that there were going to be other triggered earthquakes as large as, or larger than, the main quake. Many relief workers were afraid of doing their jobs freeing trapped victims in buildings. So the USGS developed a statement on aftershock probabilities as a function of time that told relief workers what size aftershocks they could expect. All the relief agencies said it was very helpful. It helped people go about their jobs in a sensible way.

Then we had the monstrous 8.8 Chilean quake about six weeks later. This earthquake was a very interesting comparison to the Haiti earthquake. My colleague [USGS geophysicist] Ross Stein most aptly made the comparison: Imagine putting 400 people in a room and shaking it up. If there were 400 Haitians in the room, one would walk out alive. Put 400 Chileans in the room and shake it up, and 399 walk out alive. The difference in those two experiments is the decades of preparation in Chile for the big earthquakes. We need to have tools ready and deployable so that we can at least prepare people, so that the impacts are less. We can't stop the plates from moving, but we can prepare so that the economic and human casualty toll is minimized.

We still had people in the field in Haiti and Chile when a little-known and unpronounceable volcano in Iceland erupted and disrupted air traffic. Prior to Eyjafjallajökull, the airline jet engine manufacturers had had a zero-tolerance policy for engines flying through volcanic ash. This would be equivalent to the automobile tire manufacturers having a zero-tolerance policy for automobiles driving in the snow — saying we don't know if our tires perform well in snow so we're just going to say if it snows, don't drive. That's not acceptable.

Of all the events that happened this year, the one that touched me the closest was the Deepwater Horizon oil spill. I personally led the flow rate technical group, which did the calculations on the rate of flow release and came up with the government assessment that flow rate at the end of the incident was 53,000 barrels of oil per day. It had been 63,000 barrels per day at the start.

One of the efforts that I'm most proud of from the USGS was the well integrity team. There were grave concerns, both at BP and within the federal government, as to whether the various well casings and liners had kept their integrity or whether there were blown seals and cracks such that if we shut the well to stop its flow, oil might escape through those into surrounding formations and eventually up into the ocean. That could produce a worse environmental disaster than the one we already had.

We shut the well on July 15 for a well integrity test. [USGS hydrologist] Paul Hsieh stayed up all night modeling the reservoir beneath the well. The science advisers to the secretary of energy, out of an abundance of caution, had recommended that the well be reopened. The pressure was too high to take a chance. But Paul sent his most plausible scenario, which predicted a high depletion of the reservoir without any loss in well integrity. Based on Paul's modeling, the secretary of energy, the secretary of interior and [National Incident Commander] Thad Allen agreed to leave the well shut. It never leaked another drop of oil. That is a true example of science being used in a truly unique situation where it counted. ■