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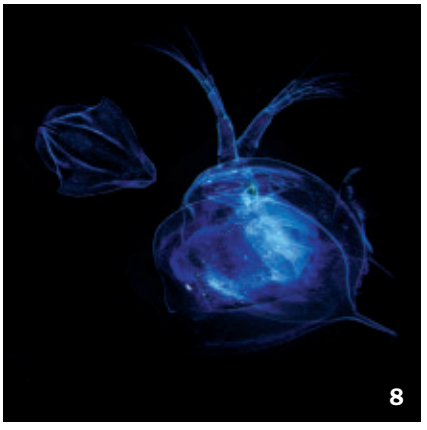

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COVER The first life on Earth emerged from the ruins of a world recovering from a cataclysmic collision, say scientists looking for signs of early cells in ancient rocks. *Kamira/Shutterstock*

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FROM THE EDITOR

Dark matter nothing to fear, if it's there or not

For several decades now, scientists have pondered the mystery of cosmic darkness. Most of the matter in the universe is not of the Earthly variety, but rather consists of some invisible (hence "dark") species of subatomic particles with very little tendency to interact with ordinary protons, neutrons and electrons.

This dark matter does fully participate in gravitational interactions, though, which is how astronomers came to be aware of its existence. Visible matter's gravity cannot explain how galaxies cluster together or the speed with which the outer edges of galaxies spin. Explaining the architecture of the cosmos requires vast amounts of dark matter; observations and calculations suggest that the Milky Way galaxy, home to the solar system, sits within a huge cloud of weakly interacting massive particles, conveniently acronymized as WIMPs.

As the galaxy turns, the Earth and sun would plow through this cloud, subjecting everyone going along for the ride to a constant bombardment: Billions of WIMPs pass through your body each second. But thanks to their reluctance to interact with ordinary atoms, few actually collide with any of your body's atoms. By one recent estimate, actual WIMP collisions with atomic nuclei in a typical person's body range from 10 per year to 1 per minute (about 100,000 times per year).

Such exposure to WIMPs is nothing to worry about, though, astrophysicists Katherine Freese of the University of Michigan and Christopher Savage of Stockholm University report. You probably get a higher radiation dose from cosmic rays and other natural radioactive substances each second than from a lifetime of WIMPs, the astrophysicists write in a recent paper online at arXiv.org (http://arxiv.org/abs/1204.1339).

And maybe the WIMP exposure is even less. A new study of the motions of stars in the solar system's galactic neighborhood doesn't see the gravitational influence expected if dark matter WIMPs are as abundant as they're supposed to be.

By some accounts, such a lack of WIMPs suggests a crisis in current theories of the cosmos. But as Nadia Drake reports (Page 5), the new finding may just indicate that the dark matter cloud isn't as uniform and spherical as the simplest calculations assume. And it's not clear that the method used to test for dark matter's presence could actually find it.

So there seems to be no reason to fear dark matter, or to fear that it isn't really there, either.

—Tom Siegfried, Editor in Chief

JIM WEBB

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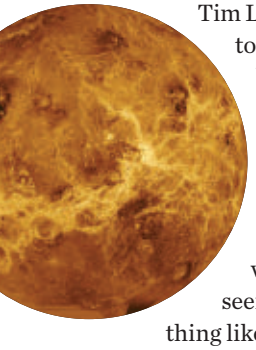
Say What?

Tuff *\TUF\ n.* A type of rock formed through the settling and compaction of ash and other debris that erupts from a volcano. Commonly used as a building material in cities near volcanoes (shown, Rome's Ponte Fabricio, which has a tuff core), tuff may not be as tough as scientists had thought. European researchers tested how high temperatures affected the strength of three kinds of tuff used in construction around Naples, Italy. When heated to 750° Celsius, two of the rock types maintained their integrity, but a third — Neapolitan Yellow Tuff, the most common building stone in the region — weakened noticeably. In a fire, this stone could crumble faster than residents might expect, the scientists write in the April *Geology*. — *Alexandra Witze*

Science Past | FROM THE ISSUE OF MAY 19, 1962

HAPPY HOME LIFE, YEAR 2000 — It is the year 2000. Mr. and Mrs. John Smith, Sr., prospering citizens of a prosperous America, have decided on a suitable wedding present for John, Jr.... They are going to let the boy have his old room in the Smith home, for keeps.... The room is detachable and readily transportable, as are all the rooms in this "home of tomorrow."... Interlocking room units that can be buckled onto a house as the family expands, then unbuckled and presented to the occupants when they grow up and leave home, may be in common use some 40 years from now.

Introducing | SOUNDS ON DISTANT WORLDS



Imagining a visit to another planet just got a little easier, with the first data-based simulations of extraterrestrial sounds. Space probes have never captured actual sounds on other worlds, but a team led by Tim Leighton of the University of Southampton in England has simulated such noises by calculating how sound would travel through various planetary atmospheres. For example, human vocal cords would vibrate more slowly in the dense atmosphere on Venus (planet shown), but sound waves would travel faster, making the speaker seem smaller. The overall effect: something like a bass Smurf, Leighton says. Listen to samples of the sounds at www.sciencenews.org/planetsounds. — *Erika Engelhaupt*

Science Future

May 26–27
The Mystery at the Museum tour has visitors meet characters and follow clues while visiting behind-the-scenes areas at the American Museum of Natural History in New York City. See bit.ly/SFammyst

June 5–6
See the transit of Venus across the sun, the last chance to see the event until 2117. The date and time of viewing will depend on location. See www.transitofvenus.org

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LIFE
A study documents homicide among chimps. Read "Chimps show lethal side."

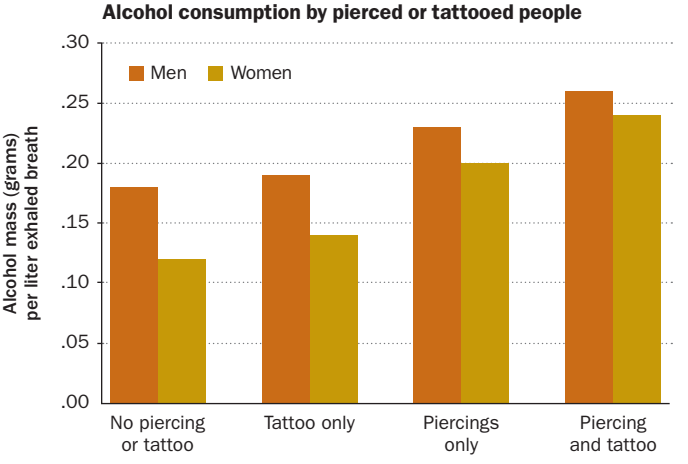
ATOM & COSMOS
Cameras spy a Martian dust devil in "Tall, devilish storm skids across Mars' surface."

DELETED SCENES BLOG
For two astrophysics studies, negative results were meaningful. See "A result of zero doesn't always mean zero results."

A dairy cow with a rare form of prion disease is probably not a threat to people. Read "California mad cow case no reason for panic."

Science Stats | PIERCING AND THE PUB

Young people with body piercings tested higher for alcohol when exiting French bars than unpierced or tattooed people. While piercing might imply a propensity for taking risks, it's becoming common; at least one-third of young U.S. adults have non-earlobe piercings, says body art expert Myrna Armstrong, retired from Texas Tech in Lubbock. SOURCE: N. GUÉGUEN/*ALCOHOLISM: CLINICAL AND EXPERIMENTAL RES.* 2012



CLOCKWISE FROM TOP LEFT: LUCIANO SELLER/FLICKR; NASA, JPL-CALTECH, UA; NASA

“We now have eight genetic molecules: RNA, DNA and these six.”
—GERALD JOYCE, PAGE 10

Life Pigeons’ compass hard to pinpoint
Molecules Designer molecules mimic DNA
Matter & Energy It’s its own antiparticle
Genes & Cells Hair club for mice
Humans Early *Homo* walked its own way
Body & Brain Caffeine kills rats’ work ethic
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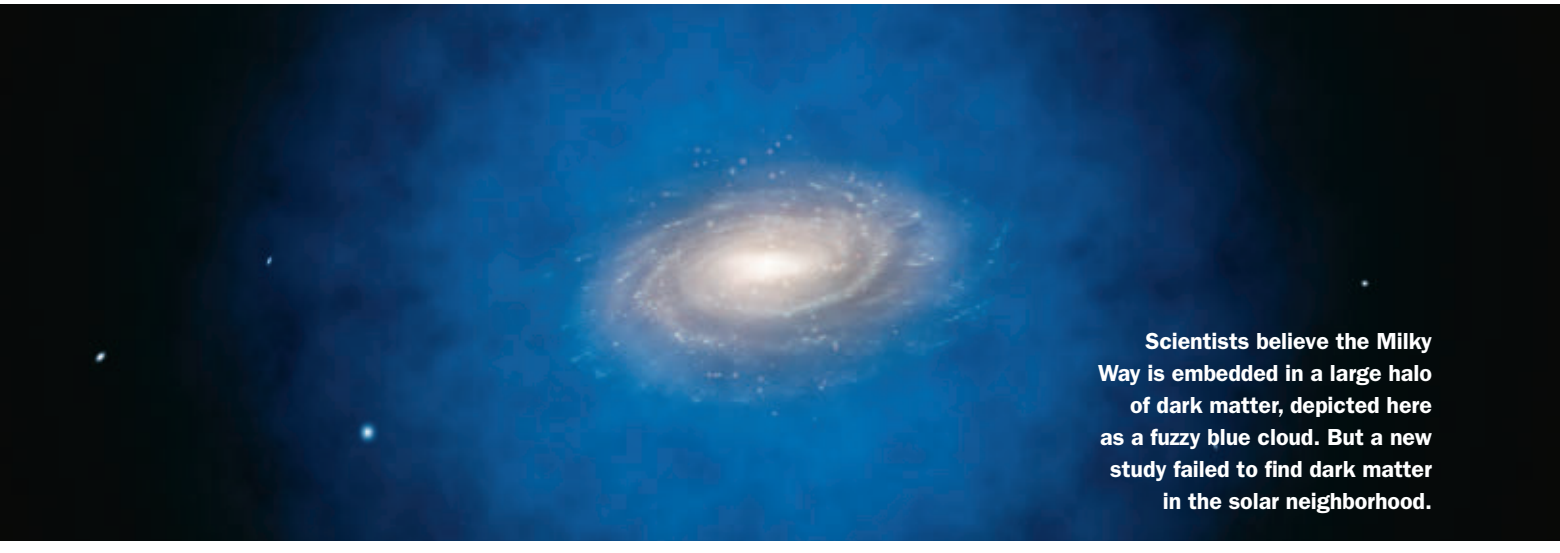
In the News



Scientists believe the Milky Way is embedded in a large halo of dark matter, depicted here as a fuzzy blue cloud. But a new study failed to find dark matter in the solar neighborhood.

L. CALÇADA/ESO

STORY ONE

Dark matter, where art thou?

New study finds dearth of invisible substance in the solar system’s neighborhood

By Nadia Drake

Scientists using Earth-based experiments to detect particles of dark matter might now know why they keep coming up empty-handed: There may be no dark matter in the solar neighborhood — at least, not within 13,000 light-years, reports a study appearing in an upcoming issue of the *Astrophysical Journal*.

Though a mysterious substance different from ordinary visible stuff supposedly makes up more than 80 percent of the matter in the universe, the new work suggests that the solar system lives in a dark matter desert. That’s a problem, because most astronomers think the Milky Way galaxy is embedded in a large dark matter halo.

If the results hold, scientists will have to reconsider what sort of shape that dark matter halo takes, although it’s unlikely to cause any major cosmological upheavals.

“This doesn’t mean that dark matter does not exist,” says study coauthor Christian Moni Bidin, an astronomer at the Universidad de Concepcion in Chile. “The result is only that dark matter is not where we expected it.”

Dark matter explains many things, including the rotation speed of the Milky Way. Its outer reaches spin more rapidly than expected based on the amount of mass sequestered in visible stars. Scientists have deduced that unseen matter, probably in the form of exotic subatomic particles, engulfs the speeding galaxy, exerting a gravitational force that accounts for the rapid rotation.

Since dark matter is invisible, scientists can’t directly observe it in space. Instead, they infer its presence by looking for its gravitational effect on things like stars, gas and light from distant galaxies. For the new work, a team in Chile went hunting for changes in the paths of stars crossing the sky, sinuous indicators that masses of the dark stuff lay nearby.

More than a year ago, astronomers studied the motion of roughly 400 red giant stars that hovered far above the galactic plane in the vicinity of the solar system. Now, the team has calculated the amount of matter needed to explain the stars’ movements. That total equals the mass of stuff astronomers can see.

Ergo, no dark matter.

It’s a challenging measurement, and one that may not have been done right, says Chris Flynn, an astronomer at Swinburne University of Technology in Melbourne, Australia. When Flynn applied the team’s method to a simulated galaxy with known quantities of dark matter and stars, it failed to detect

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the simulated dark matter. "My best bet is that something has gone astray in the measurements or analysis," says Flynn, a referee of the paper. "I was able to show to my own satisfaction that there was a problem of some kind in the method, but couldn't diagnose where the problem really is."

Moni Bidin says future observations of millions of stars should help sort out what's going on. Right now, he's hesitant to infer too much from the results and notes that scientists trying to capture dark matter particles on Earth might be fighting a losing battle. If the solar neighborhood really is a dark matter desert, there are broader consequences for the distribution of dark matter around the Milky Way.

Instead of being spherical, the dark halo might be elongated and shaped more like a cigar, a squashed beach ball or a rugby ball. A cigar or rugby ball oriented perpendicularly to the galactic plane would fit the absence of dark matter near the sun. "But models and theories have great trouble explaining the observation of this shape," Moni Bidin says.

Astronomer Sukanya Chakrabarti notes that theories describing the distribution and evolution of dark matter on galactic scales are incomplete. Perhaps, she says, reworking those theories will make it easier to generate something like a cigar-shaped halo piercing the heart of the galaxy. "We understand the skeletal structure of the universe quite well," says Chakrabarti, of Florida Atlantic University in Boca Raton. "But if you zoom in to one galaxy and try to understand the guts of galaxy evolution, there are many physics things we haven't put in."

Some scientists have already suggested that the Milky Way's halo is not spherical and is instead more like a squished beach ball — a shape consistent with the new results, says astrophysicist David Law at the University of Toronto. Law defined the halo's shape by looking at how the Milky Way's satellite galaxies behave. His measurements, published in 2010, suggested a squished sphere, with the distribution of dark matter dropping off in the solar neighborhood. That kind of shape is consistent with these results, Law argues. But he, too, says that the new results should be approached with caution.

"I don't think it's quite time to say that there is no dark matter in the solar neighborhood at all," Law says. "That isn't necessarily the most likely explanation." ■

Back Story | SEARCHING FOR WIMPS

Physicists suspect that dark matter takes the form of weakly interacting massive particles, called WIMPs. As the name suggests, WIMPs don't generally mingle with ordinary matter. But their sheer abundance should make them detectable to experimenters on Earth. Scientists trying to directly detect dark matter particles generally bury detectors deep underground — to avoid contaminating background signals from cosmic rays and other sources — and use a variety of substances capable of registering a collision with a WIMP. At least one team has found evidence for a WIMP-wind — or seasonal fluctuation in dark matter particles, the product of Earth's orbit carrying it through the galactic dark matter halo. But those reports are inconsistent with other experiments' negative results, and the WIMP sightings to date have been less than definitive, leaving scientists puzzled. So far, no Earth-based experiment set up to capture WIMPs has produced a confirmed detection.

The two tunnels at the entrance of the underground Gran Sasso Laboratory in Italy, where the XENON100, CRESST and DAMA experiments are housed.

INFN/S. SCHIAVON

CDMS, the Cryogenic Dark Matter Search, looks for WIMPs using germanium and silicon crystals chilled to nearly absolute zero. It's located in an old mine shaft hundreds of meters beneath Soudan, Minn. In 2009, it announced the detection of two possible WIMP particles, a finding that might have been due to background interference and so remains unconfirmed.

CoGeNT, in the same Minnesota cavern as CDMS, uses a wedge of germanium in its detector. In 2010, the team reported hundreds of potential WIMP particles, still unconfirmed. In 2011, researchers described suspected evidence for a seasonal fluctuation in dark matter, which is also still subject to debate.

XENON100, located beneath Gran Sasso mountain in Italy, relies on vats of liquid xenon. In 2011, researchers reported finding no evidence of WIMPs.

CRESST, another Gran Sasso experiment, uses calcium tungstate crystals. This team reported a potential signal in September 2011 that is still unconfirmed.

DAMA, also at Gran Sasso, uses a sodium-iodide detector. First in 1998 (and again in 2008 and 2010), the DAMA team reported detecting a seasonal dark matter fluctuation that remains unconfirmed by other groups.

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Life

Magnetic effects seen in bird brain

Source of signal in pigeons' nerve cells still mysterious

By Susan Milius and Rachel Ehrenberg

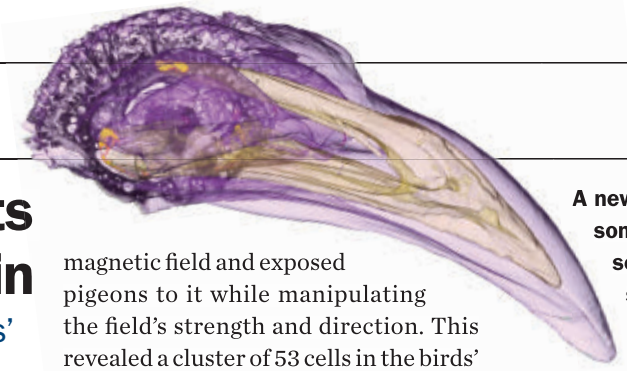
For navigating birds, the X that marks the spot for processing information about the Earth's magnetic field has been uncovered in the brain stem. Scientists have pinpointed a set of nerve cells in pigeons' brain stems that fire at different strengths depending on the direction and strength of the surrounding magnetic field.

The discovery, published online April 26 in *Science*, fills in a piece of the navigation puzzle, which has flummoxed scientists for years. But it doesn't resolve how birds sense the field to begin with. The researchers, from Baylor College of Medicine in Houston, suspect the field-sensing cells may be in the birds' ears. Previous research has implicated eye and beak cells, but in the April 19 *Nature*, other researchers challenged the identification of proposed sensors in the beak.

In the *Science* study, the researchers used coils to cancel out the Earth's magnetic field. Then they created a new magnetic field and exposed pigeons to it while manipulating the field's strength and direction. This revealed a cluster of 53 cells in the birds' vestibular brain stem — an area already implicated in bird navigation — that process information about a magnetic field's strength and direction. Where these cells get the information and how it is integrated with a bird's mental map remains a mystery.

Earlier work identified six clusters of iron-containing cells in the bird's beak that appeared to serve as biological compass needles. That identification turns out to be "totally wrong," says neuroscientist David Keays of the Research Institute of Molecular Pathology in Vienna. Keays and colleagues looked for these cells in about 250,000 thin slices of tissue from beaks of almost 200 pigeons collected across Europe.

But one pigeon had 108,000 cells containing iron, while another of the same age and sex had only about 200, Keays and colleagues report. Another pigeon had tens of thousands of iron-containing cells clustering at the site of a beak infection, suggesting that they were from the immune system.

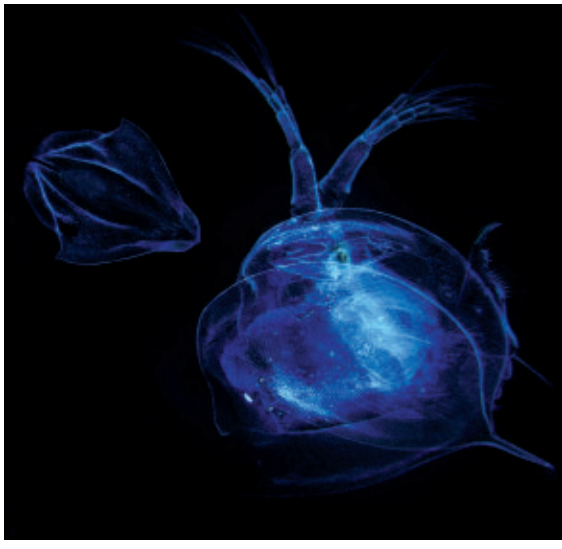


A new study challenges whether some cells in pigeons' beaks sense magnetic fields. Yellow shows bone (imaged by CT scans) and purple soft tissue (from MRI scans).

"Not having found the structures ... does not mean that they do not exist," say Gerta and Günther Fleissner of Goethe University Frankfurt in Germany, the coauthors of the 2003 paper that proposed the iron-containing beak cells were compasses. They say they never claimed that magnetically sensitive nerve cells are the only beak cells rich in iron, and emphasize that the iron-containing nerve cells are hard to find. "It is not astonishing at all that these authors obviously have overlooked them."

Brain imaging and other research using magnetic fields in the lab suggest that birds can pick up information from sensors in or near their beaks or in their ears. Other research suggests that a protein called cryptochrome in the retina of the bird eye may be even more important in detecting the magnetic field.

Keays says he's not challenging the idea that birds can detect Earth's magnetic field, and he hopes researchers will keep looking for the detector cells.



Molting as parasite defense

Getting naked may protect a species of tiny water flea. When *Daphnia magna* molts, its discarded body armor (shown) can carry away harmful bacteria, a new study finds. The work is the first to show that molting can safeguard against parasites, says evolutionary biologist David Duneau of Cornell University. "The common view of molting is that it's a weakness for these types of animals," says Duneau, coauthor of the study, published online April 11 in *Proceedings of the Royal Society B*. Duneau coated the carapaces of water fleas with spores of *Pasteuria ramosa*, a species of parasitic bacteria that can infect its host in half a day. *D. magna* that sloughed off their cuticles before the bacteria penetrated were less likely to be infected than comrades that retained their outer coverings. Molting may defend larger creatures, Duneau speculates — including snakes carrying ticks. — *Devin Powell*

FROM TOP: M. LYTHGOE AND J. RIEGLER/UCL CENTRE FOR ADVANCED BIOMEDICAL IMAGING; D. DUNEAU

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Early burrower may have been worm

Seafloor diggers could have stirred up evolutionary explosion

By Devin Powell

Worms may have first burrowed into mud more than 550 million years ago. The tunnels they apparently created in the seafloor, preserved in fossilized sediments, could be the earliest example of animals churning up the ground.

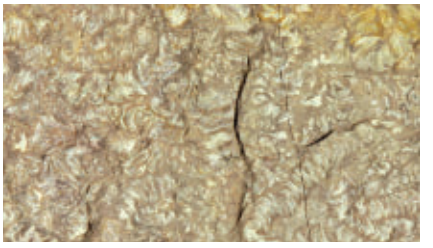
That newly plowed seafloor in turn might have helped to spur the rise of new kinds of macroscopic life late in the Ediacaran period — just before the Cambrian explosion produced most of the major animal groups around today.

"We think that Ediacaran organisms diversified as a reaction to habitat remodeling by ... burrowing," says paleontologist Dima Grazhdankin, coauthor of a new study published online March 19 in *Geology*.

Grazhdankin and colleagues found the fossils in central Siberia, in rock that had once been mud deep underwater. Tiny, crescent-shaped traces cutting through five centimeters of former sediment looked like small tunnels made by creatures scooping and flinging dirt from front to back.

Only a creature with bilateral symmetry — not just a front and back, but a top and bottom as well — could have made such a pattern, says Grazhdankin, of the A.A. Trofimuk Institute of Petroleum Geology and Geophysics in Novosibirsk, Russia. He credits a primitive worm.

Digging could have helped the worm find food, as well as opening up new living spaces for other creatures. Mud that's been churned up, or bioturbated, would be softer, freed of the stiff microbial mat that covered much of the seafloor. Softer mud would be easier to colonize.



Crescent-shaped trace fossils in mudstone, shown in a horizontal slice, could be tunnels dug by primitive worms.

The appearance of bioturbation so early could even have had a planetwide impact, says Shuhai Xiao, a paleontologist at Virginia Tech in Blacksburg. But previous evidence of bilaterians this early in the fossil record has been controversial, and Xiao says he still needs some convincing. Since none of the densely packed traces in the rock crisscross, he wonders whether the patterns are burrows at all — or simply the imprint of a creature that died an inglorious death in the mud.

Europe bat pest more potent

White-nose syndrome in U.S. is less virulent strain

By Janet Raloff

The fungal species wiping out hibernating American bats also strikes their European kin — although it doesn't kill them. But that's not because the European strain of the white-nose syndrome fungus is less virulent, a new study finds.

"The European version is even nastier than the North American one," says Craig Willis, a wildlife biologist at the University of Winnipeg in Manitoba.

The finding emerged from a trial infecting 36 healthy Canadian little brown bats with the fungus *Geomyces destructans*. Half of the animals got fungus isolated from North America, the others fungus from Europe. All animals quickly developed white-nose syndrome, a disease named for the mask of threadlike fungal growths it leaves on bat faces. Harder to see but more devastating, *G. destructans* eats through the skin of a bat's wings and begins digesting inner tissue.

Bats receiving the European strain of the fungus died about a month sooner than those infected with the American strain, Willis and colleagues report online April 9 in the *Proceedings of the National Academy of Sciences*. These findings suggest the American strain is a recent immigrant from Europe. Because the naïve populations the strain encounters in North America die so easily, Willis suspects that the American strain of the fungus has evolved to be less deadly.

Jeff Foster, a wildlife disease ecologist at Northern Arizona University in Flagstaff, agrees. His team compared the entire genetic blueprint of *G. destructans* from both continents, confirming they are nearly identical. But slight genetic variability showed up among strains from Europe, with no variability in those from North America. That suggests the fungus arrived in America recently.

Periodically, hibernating bats rouse, burning fat to bring their temperature to normal. Willis' study found that compared with healthy bats in the lab, those infected with the American fungal strain roused three times as often — and those with the European strain four times as often — during hibernation. Some white-nose victims become too weak to rouse at all. "They just run out of fuel," Willis says.

Up to nearly 7 million North American bats have succumbed to white-nose syndrome since late 2005, the U.S. Fish and Wildlife Service estimated in January. And the disease continues to spread. On April 2, the Missouri Department of Conservation announced the disease had hit its state, the first time it has crossed the Mississippi River.

D. GRAZHDANKIN

Molecules

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Synthetic genetic molecules can store info, pass it on — and evolve

XNAs might find uses in drugs and studies of life's origins

By Rachel Ehrenberg

By swapping out the sugars that put the D in DNA and creating designer enzymes to read these molecules, scientists have made new hereditary molecules that can undergo Darwinian evolution.

Getting the six new molecules, collectively called XNAs, to replicate is a major technological advance that could lead to all sorts of new drugs, sensors and diagnostic devices. The research, reported in the April 20 *Science*, could also provide clues to how life evolved on Earth.

"What makes DNA and RNA so cool is they are the genetic molecules, they are the basis for propagating information through generations," says biochemist Gerald Joyce of the Scripps Research Institute in La Jolla, Calif. "Well, we now have eight genetic molecules: RNA, DNA and these six."

While just creating the XNAs (short for xenonucleic acids) represents a feat in itself, the molecules can't do the entire evolution thing on their own: DNA still lends a hand at the replication stage. But the work is a step toward envisioning an alternative kind of life and as such is "a wonderful achievement," says Joyce, author of a commentary on the work in the same issue of *Science*.

"We only know this one example of life — it's what's been on Earth for 4 billion years," he says. "Maybe we'll find evidence of some kind of life on Europa [a moon of Jupiter] or fossilized life on Mars. Or maybe we'll just make it. That's my bet."

In the backbone of every DNA molecule there are repeating units of deoxyribose sugar; in the RNA backbone, it's ribose sugar. Instead of those sugars, each XNA has a different molecule in its backbone: A five-carbon sugar called arabinose in ANA, the ringed structure anhydrohexitol in HNA, and threose, a four-carbon sugar in TNA. The scientists also created XNA molecules called FANA (2'-fluoroarabinose), CeNA (cyclohexene) and LNA ("locked" ribose analog).

Researchers led by Philipp Holliger of the MRC Laboratory of Molecular Biology in Cambridge, England synthesized the six molecules — four of them for the first time — and created special enzymes for all six XNAs so that they could evolve.

> **"Maybe we'll find evidence of some kind of life on Europa or fossilized life on Mars. Or maybe we'll just make it. That's my bet."**
> GERALD JOYCE

The enzymes could "read" the order of molecular components in a strand of XNA and use that information to build a complementary strand of DNA. Working with an enzyme from a sulfur-loving microbe, the team selected for versions of the enzyme that could read each of the XNAs. The researchers also made enzymes that could do the reverse: Read DNA and use that information to build XNA.

Because the XNAs can't copy themselves without help from DNA, it's not truly synthetic life, says Joyce. But the molecules do undergo good old-fashioned evolution. With HNA, for example, the researchers created a random population of HNA molecules, then exposed them to a bunch of target molecules (such as proteins or RNA) for the HNA to attach to. Most of the HNAs didn't do diddly-squat, but a fraction were slightly better at connecting to the target molecules.

Scientists selected the handful of HNAs that did show some affinity for the targets and replicated those with the help of DNA. After several generations of such HNA selecting and copying, the researchers had a group of HNAs that were pretty good at attaching to their targets.

"Thus, heredity and evolution, two hallmarks of life, are not limited to DNA and RNA but are likely to be emergent properties of polymers capable of information storage," the researchers write.

TNA, which has been previously synthesized using ordinary enzymes, is especially intriguing to scientists. Earlier work showed that TNA can pair up with DNA and RNA, and TNA's four-carbon sugar threose is a simpler molecule than the five-carbon sugars found in DNA and RNA. Simple is good when speculating about what the first molecules of life might have looked like, says Joyce. "TNA has the right look and feel of something that might come first," he says.

Because ordinary enzymes that snip and degrade things in the body shouldn't recognize the XNAs, the molecules should be very stable — in fact some are just more stable to begin with due to their chemistry, says coauthor Vitor Pinheiro, also from the MRC Laboratory. After incubating HNA in an extremely acidic solution for an hour, for example, the molecule was fine. "DNA just would have been shredded," says Pinheiro.

This stability suggests the XNAs have great potential as biotechnology and materials science tools. RNA and DNA are used in vaccines and drugs but often have to be modified to be made more durable. And because the XNA molecules can evolve, researchers can select for traits they want in a particular XNA and then direct its evolution.

Steven Benner of the Foundation for Applied Molecular Evolution in Gainesville, Fla., says the work is not only relevant to biotechnology here on Earth, but also "for the possible forms that life might take throughout the cosmos." ■

Matter & Energy

"It is the fulfillment of a great intellectual challenge that has been with us since 1937." —MARCEL FRANZ

Elusive type of fermion reported

Majorana particles could be useful in quantum computing

By Rebecca Cheung

The hunt for a long-sought particle that does not have a distinct antiparticle twin might be over. Dutch physicists report making a new device that appears to create the mysterious entity, called the Majorana fermion.

"It is the fulfillment of a great intellectual challenge that has been with us since 1937," says Marcel Franz, a physicist at the University of British Columbia in Vancouver. The work, led by Leo Kouwenhoven of the Delft University of Technology in the Netherlands, appears online April 12 in *Science*.

Fundamental subatomic particles that make up matter, such as electrons, have antimatter companions. But Majorana fermions, first theorized over 70 years ago, are a class of particles that are their own antiparticle. They might have potential applications for storing data in future quantum computers.

Previously, scientists have published ideas about how to engineer the elusive Majorana fermions, but no team had actually constructed such a device.

Kouwenhoven's team assembled a device using an indium antimonide nanowire about 100 nanometers across. The scientists put a gold metal electrode at one end of the wire and a superconducting electrode near the other end, then applied a magnetic field.

Surprisingly, the scientists found that maximum electric charge moved from the gold electrode end to the superconductor end at zero voltage. This pattern suggests that a pair of Majorana fermions formed at opposing ends of the nanowire, Kouwenhoven says. Otherwise, scientists wouldn't have expected to see electric charge navigate the gap between the thin wire and the superconductor.

When the physicists adjusted the direction of the magnetic field or removed the superconductor, the behavior disappeared. "Every time we take out one of these special ingredients, the Majorana disappeared," Kouwenhoven says.

Though promising, the work is not definitive evidence of Majorana fermions.

"I would not describe this as a discovery yet," says Patrick Lee, a condensed matter physicist at MIT. Lee says the study's conductance measurements need to be more precise to prove the existence of these particles. "There could be a Majorana hiding behind there," he says. "It's not an open-and-closed case."

Genes & Cells

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Anesthesia by day gives bees jet lag

Internal clocks get out of sync when the insects go under

By Susan Milius

A widely used anesthetic gives honeybees jet lag, but only if they're knocked out during the day.

Honeybees, as stand-ins for surgery patients, confirm that a bout of the general anesthetic isoflurane acts directly on the biological clock that governs body rhythms, reports chronobiologist Guy Warman of the University of Auckland in New Zealand. Nighttime anesthesia hits the internal clock at a different phase, when the drug effects don't break the rhythm, he and his colleagues report May 1 in the *Proceedings of the National Academy of Sciences*.

Warman doesn't advise scheduling all surgery at night as a result of the new findings. "Then your anesthetist and your surgeon are exhausted and more likely to make errors," he says.

Instead, the research has inspired him and his colleagues to start developing ways to keep the internal clock ticking normally, perhaps by adding light therapy to surgery protocols.

Honeybees wearing tags to allow for automated monitoring of arrivals and departures from hives developed a version of jet lag after daytime anesthesia.

Doctors have seen that people often emerge from general anesthesia disoriented in time and may sleep fitfully for a while afterward. To see whether anesthesia itself causes the effects and whether it does so by acting directly on the underlying master clock, Warman and his colleagues designed experiments using honeybees. Honeybees are great for testing effects on biological clocks, Warman says, because their clock genes are more similar to mammals' than to those of other insects studied so far.

Researchers trained bees to fly out of their hives to visit an artificial flower for sugar water. For the test, researchers caught the bees as they buzzed in for a sip and anesthetized them for six hours. When the bees woke up and set off for their hive again, they flew at the wrong angle. Honeybees navigate in part by the position of the sun, and their built-in biological clock lets them correct course for the sun's movement across the sky during the day. After anesthesia, though, the bees made their "correction" as if the time were hours earlier.

In a test inside the lab with no outdoor cues, daytime anesthesia threw off the usual activity patterns in the hive for the next several days. But the researchers didn't see a similar disruption to the bees' behavior and gene activity after nighttime anesthesia.

Testing for clock effects in bees is a good start because researchers could control for most of the factors that can confound results in human trials, says neurobiologist Nancy Chamberlin of Beth Israel Deaconess Medical Center in Boston. "The results of this study make the more difficult human studies worth doing to see if there is a clinical relevance or not," she says.

FROM TOP: COURTESY OF G. WARMAN; © FLORIAN SCHULZ/WWW.VISIONSOFTHEWILD.COM

Polar bears go way back

Polar bears might have originated about 600,000 years ago, Frank Hailer of the Biodiversity and Climate Research Center in Frankfurt and colleagues report April 20 in *Science*. Previous studies suggested that the species, *Ursus maritimus*, emerged about 150,000 years ago. But those estimates were based on genetic information from mitochondrial DNA, which is passed down only through the maternal line. In the new study, researchers studied nuclear DNA, inherited from both parents, from 45 polar, brown and black bears. An earlier origin for polar bears would mean the imperiled species probably survived several glaciation and warming cycles. The population's lack of genetic variation suggests that the warm phases wiped out many bears, creating a genetic bottleneck. Added to stresses such as pollution and hunting, today's climate change and resulting habitat loss might threaten the bears' survival, Hailer says. —*Rebecca Cheung*

100 thousand Estimated number of follicles on human scalp

120 million Estimated number of rods in human retina

Engineered cells sprout new hair

A cell-based approach to making follicles takes root

By Rebecca Cheung

A hair-raising trick may lead to better hair transplants. Engineered hair follicles patched into skin can be coaxed to connect to surrounding tissue and to grow hair in an organized way, a study in mice finds.

Unlike current hair transplant methods, which simply move existing hair follicles from one area of the scalp to another to cover a bald region, the approach would spur the creation of new hair follicles from existing cells.

"It's exciting because it shows a cell-based approach for treating hair loss is maybe feasible," says George Cotsarelis, a dermatologist at the University of Pennsylvania in Philadelphia.

The results also mark a step forward in efforts to regenerate organs such as salivary glands that form in a process similar to hair early in their development, says study coauthor Takashi Tsuji of Tokyo University of Science in Chiba, Japan. Tsuji and his colleagues describe the findings in the April 17 *Nature Communications*.

Hair follicles develop when two different types of cells — epithelial and mesenchymal cells — interact with each other. Epithelial cells grow very quickly and shed, while mesenchymal cells direct epithelial cells to make a follicle.

Previously, Tsuji and colleagues had bioengineered follicles and hair shafts in the lab using epithelial and mesenchymal cells from mouse embryos. Until now, it was unclear whether these organized clusters of cells would make normal hair if inserted into mouse skin.

In the new work, the team transplanted a group of the engineered follicles into the skin on the backs of hairless mice. After about two weeks, hairs began to sprout. Under the microscope, the hair grown from the bioengineered mouse follicles resembled normal hair, scientists found. And the mouse follicles went through the normal cycle of growing hair, shedding and making new hair.

When researchers injected the region around the bioengineered follicle with acetylcholine, a drug that causes muscles to contract, the hairs perked up. This finding suggests that the transplanted follicles had integrated with surrounding muscle and nerves like normal hair follicles do.

The researchers were able to ensure hair didn't become ingrown or point in the wrong direction by attaching a nylon thread to the engineered follicles and guiding the hair to grow outward.

Applying similar methods to cells collected from the scalps of men with male pattern baldness, researchers created individual follicles that grew hair once transplanted into hairless mice.

Still, Cotsarelis says that these findings do not show whether the number of human hair follicles can be amplified, so that more hair is produced.

Bioengineered follicles can grow tufts of hair on the scalps of normally hairless mice. The technique may improve treatments for male-pattern baldness.

T. TSUJI/TOKYO UNIV. OF SCIENCE

Transplants help night-blind mice

Injecting light-gathering rod cells restores vision in rodents

By Tina Hesman Saey

The farmer's wife in the nursery rhyme "Three Blind Mice" may need a different hunting strategy. Thanks to cell transplants, some formerly night-blind mice can see in the dark, perhaps even well enough to evade a swinging carving knife.

Light-gathering nerve cells called rods injected into the retinas of night-blind mice integrated into the brain's visual system and restored sight, Robin Ali of the University College London Institute of Ophthalmology and colleagues report online April 18 in *Nature*. The finding gives hope that cell transplants may reverse damage to the brain and eyes caused by degenerative diseases and help heal spinal cord injuries.

Other researchers have tried unsuccessfully to repair damaged retinas with stem cell transplants, says Christian Schmeer, a neurologist at the University Hospital Jena in Germany. The new study is the first to demonstrate that transplanted nerve cells can restore function.

Ali's group transplanted immature rod cells from newborn mice into the retinas of night-blind adult mice. The researchers were able to coax about 26,000 rod cells, which work in dim conditions, to become incorporated into each retina.

Other retina cells called cones sense bright light. Humans rely more on cones than nocturnal mice do; so far Ali's team has had no luck transplanting cones.

Other problems also remain to be solved before researchers can even consider trying cell transplants in human eyes, Ali says. The mice in the study all had healthy retinas, so Ali wants to see if the technique will work as well in diseased eyes. Getting a good source of cells to transplant is another problem. Ali plans to try implanting rod cell precursors made from stem cells.

Humans

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Ancient walking gets weirder

Hominid fossils suggest a diversity in gait and stance

By Bruce Bower

The simple act of walking continues to take strange detours among ancient human ancestors.

To wit, 1.5-million-year-old fossil footprints excavated in Africa, initially thought to reflect a thoroughly modern walking style, were instead made by individuals that walked differently than people today do, researchers reported April 13. Another team presenting April 12 revealed the surprisingly apelike qualities of foot fossils from a 2-million-year-old species that some researchers regard as the root of the *Homo* genus.

These reports come on the heels of evidence that a previously unknown member of the human evolutionary family who lived 3.4 million years ago possessed a gorilla-like grasping big toe and an ungainly stride (*SN: 5/5/12, p. 18*).

Depth measurements of the African footprints, discovered at Kenya's Ileret site, differ at 10 landmarks from the footprints of people who live in that area today, said Kevin Hatala of George Washington University in Washington, D.C.

A new analysis of 1.5-million-year-old footprints suggests they were made by a possible human ancestor with a gait different from that of modern humans.

"We can infer that the ancient Ileret individuals had a normal, functional gait, but they may have walked differently than we do," Hatala said. For now, it's uncertain just how these hominids walked and whether they belonged to *Homo erectus*, a possibly direct human ancestor, or to the side-branch species *Paranthropus boisei*.

Hatala and colleagues compared five preserved Ileret footprints with those of 38 Daasanach herders in Kenya, most of whom had never worn shoes. Participants walked across a pressure pad before walking across moistened Ileret soil similar to that under which the ancient footprints were made. Pressure measurements at 10 spots across the bottom of the foot closely corresponded to depth measurements at the same spots on volunteers' footprints.

Depth measurements at most of the footprint spots differed between Daasanach volunteers and Ileret hominids, signaling that the extinct species walked unlike people today.

Other comparisons indicated that two sets of Ileret tracks were made by individuals who were walking, not running, and who stood about 5 feet, 6 inches tall and weighed 110 pounds. That's in the size range of Daasanach people today.

Meanwhile, new analyses of foot bones from two partial *Australopithecus sediba* skeletons show that this hominid had an upwardly curved, mobile mid-foot built for tree-climbing, reported anthropologist Jeremy DeSilva of Boston University. Previous work had identified thin, apelike heels combined with humanlike ankles and arches in these fossils.

"This is a really weird foot," DeSilva said. "Diversity in upright stances must have extended for a long time during hominid evolution."

MEETING NOTES

Stone Age Southeast Asians
Researchers have discovered the oldest known human remains in Southeast Asia, a partial human skull dating to at least 40,000 years ago. Excavations at Tam Pa Ling cave in northern Laos produced a dozen pieces from a Stone Age person's skull, including a skullcap and a lower jaw, anthropologist Laura Shackelford of the University of Illinois at Urbana-Champaign reported April 14. Small front teeth, a rounded braincase and other traits identify the reassembled fossil as a modern *Homo sapiens*, Shackelford said. The find supports proposals that at least some human migrations out of Africa around 100,000 years ago followed a southern route that led to Southeast Asia. —*Bruce Bower*

Neandertal ancestors speak up
A proposed ancestor of Neandertals and *Homo sapiens* that lived around 500,000 years ago in a mountainous part of what's now Spain may have had the gift of gab. A new analysis of a *Homo heidelbergensis* individual's skull and upper spine bones, as well as a horseshoe-shaped neck bone called the hyoid, suggests that this long-extinct species could have produced speech sounds, paleontologist Ignacio Martínez of the University of Alcalá, Spain, reported on April 12. Humanlike inner ear bones made it possible for *H. heidelbergensis* to hear conversational speech, Martínez said. "We don't know if *H. heidelbergensis* spoke, but it possessed anatomical characteristics for efficient production and perception of speech," he concluded. —*Bruce Bower*

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Autism linked to obese mothers

Extra pounds add to kids' risk of developmental delay

By Nathan Seppa

Obese women are more likely to have children who develop autism than are normal-weight women, a new study suggests, adding another possible explanation for the apparent rise in autism.

Reporting in the May *Pediatrics*, researchers also found that women who were obese or had some form of diabetes during pregnancy were more likely to have kids with developmental delays. And tests show that a woman's obesity, diabetes or high blood pressure during pregnancy might place her offspring at risk of slightly impaired learning even if they don't have autism.

The new research "underscores the importance for people who are pregnant — or trying to get pregnant — of controlling their risks," says epidemiologist Hannah Gardener of the University of Miami in Florida. "This is a very strong study."

The authors note, though, that the results show associations, not causes. "We can't establish causation from this study," says coauthor Irva Hertz-Picciotto, an epidemiologist at the University of California, Davis. "But it is interesting that obesity and diabetes are increasing as autism incidence is." A recent study from the Centers for Disease Control and Prevention estimated that 1 in 88 children born in the United States develop an autism spectrum disorder.

Previous studies have suggested that diabetes and hypertension in pregnancy might pose developmental risks, but obesity has been studied less, Hertz-Picciotto says.

> "We can't establish causation from this study. But it is interesting that obesity and diabetes are increasing as autism incidence is."
>
> IRVA HERTZ-PICCIOTTO

The researchers compared the pregnancy histories of mothers of 315 children who were developing normally, 172 children with developmental delays and 517 kids with an autism spectrum disorder — autism, Asperger's syndrome or other social interaction problems. Symptoms of these disorders typically include repetitive or restrictive patterns of thoughts and behavior and struggles with language, communication, physical coordination, social skills and the sharing of emotions.

Obese mothers were 67 percent more likely to have an autistic child than normal-weight, healthy moms, the data show. Diabetes in pregnancy had no effect on autism risk, but mothers who were obese or who had some form of diabetes during gestation were about twice as likely to have a child with some form of developmental delay compared with healthier moms.

Many women who were obese, diabetic or hypertensive during pregnancy had children unaffected by autism spectrum disorders. Yet, on average, these children scored somewhat lower on tests of learning and adaptive behaviors than kids without autism who had healthy, normal-weight moms.

The associations held even after researchers accounted for differences in race, education, time of year the kids were born, geographical region and mother's age at delivery.

Slacker rat, worker rat

Caffeine and amphetamine turn hardworking rodents lazy

By Laura Sanders

When it comes to intellectual challenges, rats, like people, fall naturally into categories of slackers and workers. And a shot of stimulant sometimes gets slackers to work harder while prompting the workers to ease off, researchers report online March 28 in *Neuropsychopharmacology*.

Animal studies that explore the costs and benefits of difficult tasks usually involve rodents physically working, such as pushing a lever or scaling a wall for a reward. But such experiments don't account for mental effort, says Jay Hosking of the University of British Columbia in Vancouver.

"In everyday life, it's the cognitive side where people really have to make those decisions, like whether you work harder throughout the day in hopes of getting a promotion," Hosking says.

In the study, rats poked their nose into one of five holes to indicate the location of a flash of light. By pushing a lever before the trial began, the rats chose either an easy version (the light shined for a full second, making it simple to spot) or a hard one (the light flashed for a fifth of a second, so rats had to concentrate to choose the right hole). The harder task offered double the sugar-pellet reward.

Some individuals reliably went for the easy version and collected their small reward. Other animals overwhelmingly chose the intellectually harder route. The differences persisted across many trials.

Giving rats stimulants produced varied effects. For slackers, amphetamine sharpened the mental work ethic, making the animals more likely to choose the harder task. But for workers, amphetamine caused the animals to prefer the easier option. Caffeine turned workers into slackers but didn't make slackers work harder.

605 thousand U.S. people age 12 and up who reported in 2009 using heroin at least once in last year

359 thousand Number of U.S. heroin addicts, 2010 estimate

Video helps diminish drug cravings

'Extinction' sessions fight addiction by weakening memories

By Laura Sanders

Watching a five-minute video can help whitewash memories of past drug use in former heroin addicts and ease their cravings, a new study shows. By weakening mental ties between drug-related paraphernalia and the desire to use, the method may be a powerful and long-lasting way to help people struggling with addiction stay clean.

"The process is really simple," says study coauthor David Epstein of the National Institute on Drug Abuse in Baltimore. "But it's based on some really important ideas."

The method, described in the April 13 *Science*, seems to work by dampening the association between using a drug and cues that remind someone of using. Walking by a familiar corner where a dealer works or bumping into an old friend from drug-using days, for example, can be hard for people battling addiction.

Led by neuroscientist Lin Lu of Peking University in China, researchers first tested the idea in animals, easing drug-seeking behaviors in rats by calling up and then dampening drug-related memories. Next, the team turned to people who were battling heroin addiction in China.

Sixty-six people underwent a two-step process: First, volunteers watched a video of either a natural scene or of people smoking and injecting heroin. The heroin movie served as a quick reminder, calling up former memories of drug use. Each time such memories are called to mind, the former drug users' memories become fragile, vulnerable to being rewritten or modified, Epstein says. "It's not like a tape recorder playing something back," he says. "It's more like a computer pulling up a document, potentially editing the document, and then resaving the document." This process is called reconsolidation.

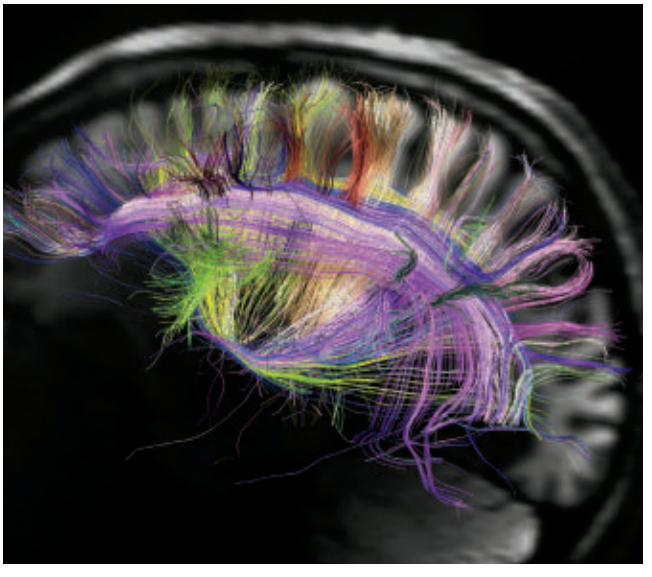
After this reminder, participants spent an hour watching more drug-related movies and slide shows, and even handling fake heroin, a trial called an "extinction session." The researchers varied the time between the reminder and the extinction sessions: Some people waited just 10 minutes, and others waited six hours. This process was repeated on two consecutive days.

In later tests, people whose memories were primed with the drug reminder 10 minutes before extinction reported less craving for heroin after seeing drug cues one, 30 and 180 days after the extinction session. Bodily responses to drug cues were blunted, too: People who had been primed in the 10-minute window showed less of a blood pressure rise in response to seeing drug paraphernalia than people who hadn't received the reminder.

"What was just so striking about the human data was how persistent the effects were," says neuroscientist Jane Taylor of the Yale School of Medicine.

People who waited six hours before undergoing the extinction didn't get the same effect. The results suggest that there's something important happening in the window right after the reminder.

"I think it's a very interesting, very intriguing set of data," says psychologist Stephen Tiffany of the University at Buffalo in New York. It remains to be seen whether the effects persist in people's real lives, outside of the lab, he says, and what relationship may exist between drug craving and drug relapse. ■



COURTESY OF MGH-UCLA HUMAN CONNECTOME PROJECT

Mapping your noodle

The impossibly complicated brain just got a little simpler. Instead of looking like a tangled mess of noodle soup, pathways in the brain are arranged more like a package of neatly interwoven ramen noodles, a new brain scanning study reveals. The results offer more clues to how the human brain gets built and how it has evolved. Scientists led by Van Wedeen of Massachusetts General Hospital and Harvard Medical School in Boston used a scanning technique called diffusion magnetic resonance imaging, which detects the direction of traffic flow along white matter tracts, the brain's information superhighways. The scans revealed that these brain signals form a grid made up of parallel and perpendicular tracts woven together into curved sheets. This grid is a general feature of primate brains, suggesting it has deep evolutionary roots, Wedeen and colleagues report in the March 30 *Science*. — *Laura Sanders*

Atom & Cosmos

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Two planets may shape stellar ring

Dust disk around Fomalhaut hints at a pair of 'shepherds'

By Nadia Drake

Two small planets might be sculpting an enormous dust ring around the star Fomalhaut, 25 light-years away from Earth.

But it's not likely that either planet is the notorious Fomalhaut b, which once held the title of the first directly imaged exo-world (*SN: 2/25/12, p. 12*).

New observations have revealed that the ring is thin, with sharp inner and outer edges — an unlikely shape, unless something is keeping the ring particles neatly in line.

"The best explanation so far is that there are two planets out there," says astrophysicist Aaron Boley of the University of Florida, coauthor of a study to appear in *Astrophysical Journal Letters*.

Boley and colleagues examined the Fomalhaut system to study how planets very far from their star might differ from planets that are snuggled closer in. Fomalhaut's ring is more than 100 times farther afield from its star than Earth is from the sun, and any potential ringscaping planets would be similarly far-flung.

The team observed the system with the Atacama Large Millimeter/submillimeter Array, a collection of radio telescopes in the Chilean desert that can detect dust particles up to a millimeter across. Particles of this size are tugged around by only the gravity of planets and not by the radiation from a star.

The new work shows a dusty ring with unexpectedly well-defined edges — the trademark of what are called shepherding bodies. "We do see a similar scenario in our solar system, with the Epsilon ring of Uranus being herded by two small moons," says Ray Jayawardhana, a University of Toronto astrophysicist.

Instead of moons, though, shepherd planets might be responsible for the Fomalhaut ringscaping — one brushing up the inner edge, and the other tidying the outer edge. The orbs are each probably between the size of Mars and a super-Earth, too small to be directly detected.

"These sharp edges of the disk do indicate that there should be some planet in there that hasn't necessarily been seen yet," says astronomer Markus Janson of Princeton University. But he advises caution until more observations are made.

Neutrino search comes up empty

Gamma-ray bursts elude blame for high-energy cosmic rays

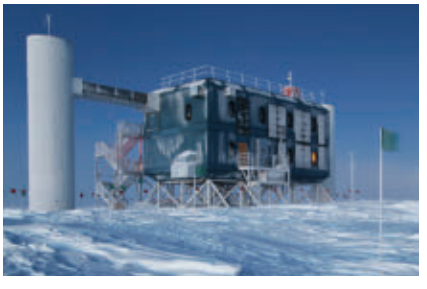
By Nadia Drake

Instead of clearing up a half-century-old mystery, scientists have tossed a bit of mud into an already murky pool of suspects behind the highest-energy cosmic rays. New findings cast doubt on gamma-ray bursts as producers of these enigmatic particles, which carry energy exceeding 10 billion billion electron volts.

But there's some wiggle room in the evidence. If theorists rejigger equations describing the cosmic objects, gamma-ray bursts could still be in the lineup, scientists report in the April 19 *Nature*.

The results come from the IceCube neutrino telescope, a cubic kilometer of detectors buried beneath the South Pole. Over a period of two years, the telescope didn't detect any of the neutrinos expected to arrive following 307 gamma-ray bursts. Neutrinos act as proxies indicating that cosmic rays are produced.

"Either gamma-ray bursts cannot be the source of all ultrahigh energy cosmic rays, or there has to be some physics going on inside the gamma-ray burst that makes neutrino production different" from what scientists expected, says Abigail Vieregg, a physicist at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass.



A detector under the South Pole's IceCube Laboratory (shown) did not spot neutrinos after gamma-ray bursts, suggesting that something else is responsible for ultrahigh energy cosmic rays.

S. LIDSTROM/NSF

Ultrahigh energy cosmic rays, which are actually charged subatomic particles, arrive at Earth with millions of times the energy generated inside CERN's Large Hadron Collider. Since first detecting these rays in 1962, scientists have sought the astrophysical accelerator whence the rays come — an object capable of superflinging particles across the cosmos.

"You expect it to be something very violent," says astrophysicist Nathan Whitehorn of the University of Wisconsin–Madison, a study coauthor. Gamma-ray bursts are prime suspects.

For two years, IceCube scientists watched for neutrinos after gamma-ray bursts, focusing on the muon neutrino subtype. It leaves long footprints that point toward home. "If we measure the arrival direction on Earth, we can look back and see where they came from," says astrophysicist and study coauthor Spencer Klein of Lawrence Berkeley National Laboratory in California.

But no neutrinos arrived.

"I'm kind of inclined to think that it's because gamma-ray bursts are not the source of the ultrahigh energy cosmic rays in the universe," Klein says.

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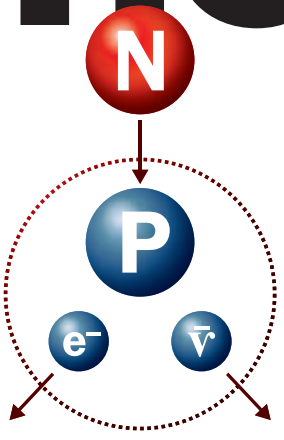
Secret of a lifetime

How long a neutron lives holds clues to the cosmos

By Rebecca Cheung



When a neutron "dies," it decays into a proton. An electron and an antineutrino are emitted in the process.

In the nuclear family, the neutron is clearly the black sheep.

Unlike its sibling the proton, the neutron is eccentrically — and irritatingly — neutral. Because they have no electrical charge, neutrons are hard to guide and focus using electric fields. And unlike protons, which can be liberated by igniting hydrogen gas, the neutron is stubbornly sequestered within the atomic nucleus, making it especially hard to interact with one-on-one.

What's most annoying is that neutrons are steadfastly secretive. Unlike charged particles, neutrons are hard to detect — making it hard to measure how long they live. Pinning down the length of the neutron's life span could help physicists better understand many atomic and cosmic processes, from the nature of forces acting on subatomic particles to the distribution of matter in the moments following the Big Bang. More than 60 years of research has gone into determining the neutron's average lifetime precisely.

But despite all those decades of study, physicists still can't agree on the length of the neutron's life. The best measurements done in the last 20 years differ by more than 10 seconds. And most report the measurement with an error of a few seconds. Without an agreed on value that's also more precise, scientists can't answer key physics questions for which the neutron lifetime matters.

"It's unsound to have measurements that are in such statistical disagreement," says Geoffrey Greene, a physicist at the University of Tennessee, Knoxville and Oak Ridge National Laboratory who has been working on determining the neutron's lifetime for three decades.

Right now, teams with two very different approaches — one working with beams of neutrons and another that uses bottles to trap them — are tweaking their experiments in hopes of determining this elusive property.

Dying to know

Neutrons are usually bound in a nucleus, where they can stay as long as the nucleus remains intact. But neutrons free from nuclear confinement are unstable: The weak nuclear force compels them to break apart and die.

At the end of its life, a neutron turns into a proton, a process known as beta decay. When the proton appears, two more particles fly away: the small, negatively charged electron (the beta particle) and a ghostlike particle known as an antineutrino. This decay process is the same one that occurs when carbon-14, the radioactive isotope used in carbon dating, decays into the stable nitrogen-14.

Typically when people talk about the timescale of radioactive decay, they refer to the half-life. Carbon-14's half-life is 5,730 years, so after 5,730 years the initial amount of that form of the element is reduced by half. But hunters of the neutron lifetime are instead looking for the time that elapses from the moment a free neutron is born to the moment it turns into a proton.

What's tricky is that not all neutrons die at the same age. Neutron decay, like all radioactive decay, is a matter of probabilities. So scientists are looking for the average lifetime.

In an ideal experiment, scientists would have a bunch of free neutrons that could be studied closely. If all these neutrons were born at once, researchers could record how long it took for each individual neutron to turn into a proton. Assuming the sample of neutrons was large enough, averaging those time spans would give a precise average lifetime.

But measuring the neutron lifetime is much more complicated. For one thing, free neutrons have lots of energy and tend to fly around, limiting the neutron-tracking ability of even the best detectors.

The Particle Data Group, an international collaboration that acts as an authority on subatomic particle properties, currently puts the neutron lifetime at 881.5 seconds (14 minutes, 41.5 seconds). This number is an average of the best seven measurements in the last two decades, weighted based on precision. But the values included range from 878.5 to 889.2 seconds. To say something new and interesting about physics, scientists need consistent independent experiments that pin down the neutron lifetime to within a second.

Getting such a value could help scientists test their theories about the raw materials for star formation. Within the first three minutes following the Big Bang, neutrons and protons came together to cook up those ingredients — mostly hydrogen, but also helium and a trace of lithium. The exact ratio of the ingredients created in this coalescence, called Big Bang nucleosynthesis, depends on

STEPHEN EGTS

how fast neutrons die. Without the neutron lifetime, it's hard to test current theories describing the early universe.

What's more, the average neutron lifetime helps reveal how much ordinary matter was generated in the Big Bang. Knowing the amount of ordinary matter is an important factor in determining how much mysterious dark matter lurks in the universe. Quantifying dark matter "is important in understanding how galaxies form and the evolution of the universe," says Rocky Kolb, a cosmologist at the University of Chicago.

Knowing the neutron lifetime would also provide physicists with a better understanding of the weak nuclear force, possibly leading the way to insights beyond the current standard model of particles and forces.

Of bottles and beams

Those seeking the neutron lifetime share a common goal: to better understand what the universe is made of and how all of its constituents interact. But the teams use different strategies. After huge batches of neutrons are created from nuclear reactors or particle-accelerating facilities, one approach determines the portion that die in just a few milliseconds.

At the National Institute of Standards and Technology in Maryland, Greene and colleague Fred Wietfeldt, a physicist from Tulane University in New Orleans, generate a beam of cold neutrons flying at speeds of about 1,000 meters per second. Some of these particles will decay while they are still in the beam. By applying magnetic and electric fields, scientists can shepherd the positively charged remnant protons and count them.

To calculate the average neutron lifetime, scientists also need to know the number of neutrons that were in the beam to begin with, determined by counting reactions between neutrons and a thin piece of lithium in the beam.

In their last set of experiments, published in 2005, Greene and Wietfeldt set the neutron lifetime at 886.3 seconds, give or take more than three seconds.

"What prevented us from getting a precise measurement 10 years ago was associated with counting the neutrons," says NIST researcher Jeffrey Nico, who works with the beam team. "We pushed the state of the art in counting neutrons, but it still wasn't good enough."

Meanwhile, across the globe at the Institut Laue-Langevin facility in Grenoble, France, physicist Anatolii Serebrov and collaborators are using an opposite strategy: Instead of determining the number of protons left behind by neutrons that die, the team is bottling neutrons and counting the particles that survive.

Serebrov, of the Petersburg Nuclear Physics Institute in Russia, and colleagues cool the neutrons to temperatures of 2 millikelvins, just above absolute zero, in order to contain the particles. As the ultracold neutrons are poured into and emptied out of a bottle, they pass through a detector. By tracking the number of neutrons at the beginning and end of an experiment, the team can calculate how many particles have decayed.

"If you have no losses in your bottle besides beta decay, then you know exactly the lifetime," says Peter Geltenbort, who worked with Serebrov at the Institut Laue-Langevin.

But that's a big *if*. Though the bottle is made of metals that reflect neutrons, residual gases or impurities can cause neutrons to be absorbed. Also, bouncing particles can sometimes acquire enough energy to escape out of the bottle's top.

This trap captures protons emitted by neutron decay. Comparing the number of protons after a certain time to the initial number of neutrons helps scientists determine the neutron's lifetime.

In 2005 Serebrov and his colleagues reported that the neutron's lifetime was approximately 878.5 seconds. The team's measurement was precise to within a second. But this number is nearly eight seconds shorter than the time measured by Greene and Wietfeldt, and about three seconds less than the current average reported by the Particle Data Group.

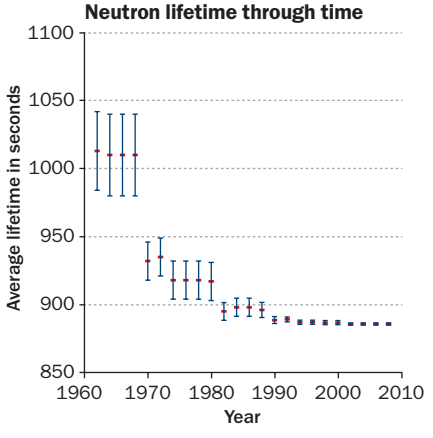
Another precise measurement could help settle the dispute, but not if it doesn't match the beam team's results. "If they disagree, you know that at least one of them is wrong," Wietfeldt says.

For now, the two tribes are committed to perfecting their experiments. Greene says his team has recently recalibrated its system to estimate the number of neutrons in a beam with six times the accuracy. And while Serebrov focuses on updating his existing project, Geltenbort and colleagues in France are working on a magnetic bottling setup. Because neutrons respond to magnetism, scientists think that magnetic fields will keep neutrons well-contained.

Both teams plan on presenting new data precisely pinning down the neutron's lifetime within the next few years — perhaps giving physicists the number they've been waiting for.

"This is the decade of precision cosmology," Kolb says. "Estimates no longer cut it." ■

Honing survival Precision in measuring the neutron lifetime has increased (error bars in blue). But scientists need corroborating measurements to within a second if they want to answer key questions about nature's forces and the early universe.



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NIST

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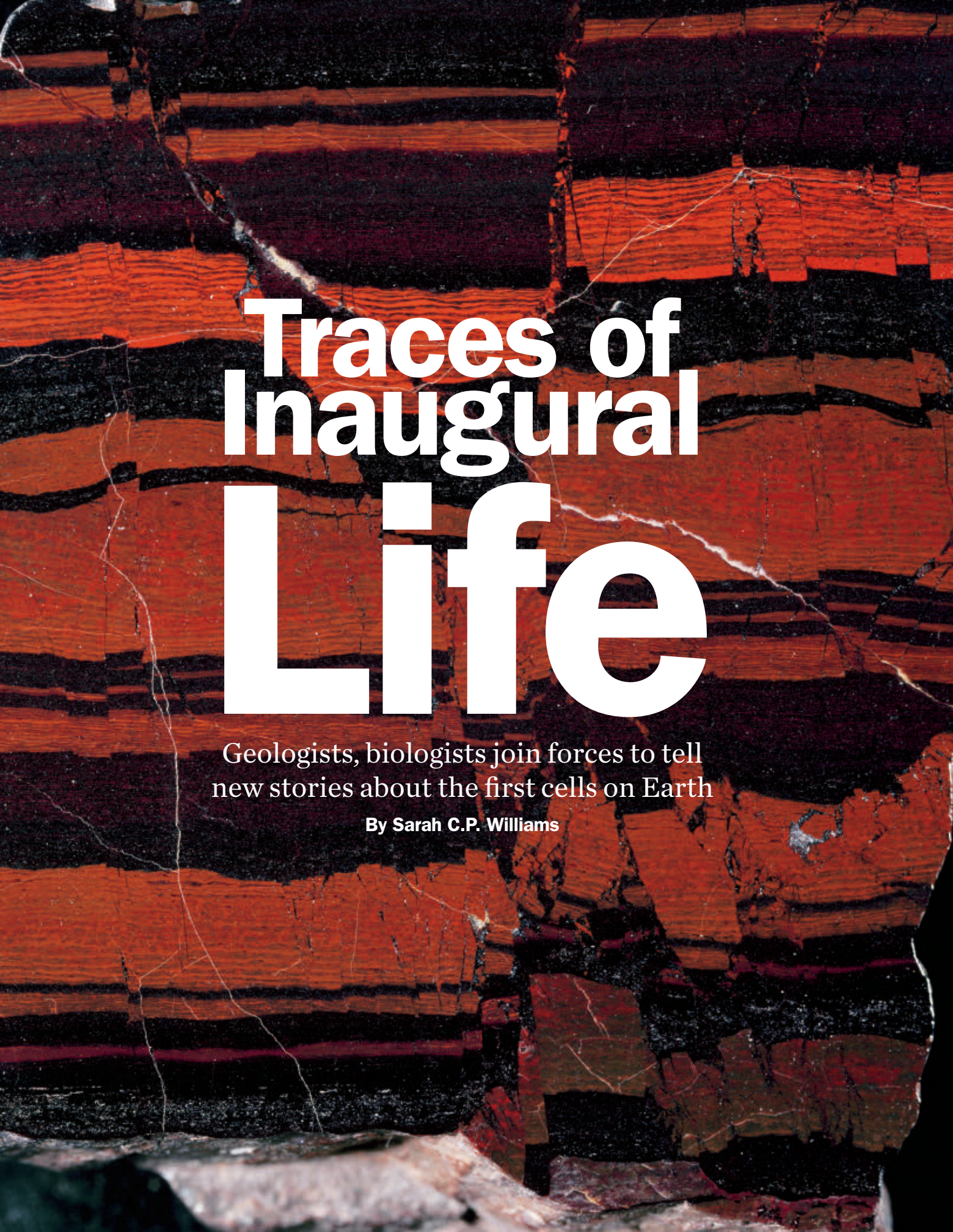
- Stephan Paul. "The puzzle of neutron lifetime." Online at arxiv.org/abs/0902.0169v2



Traces of Inaugural Life

Geologists, biologists join forces to tell new stories about the first cells on Earth

By Sarah C.P. Williams

Earth's first living organisms didn't leave behind footprints or bite marks or bones. These single cells thrived quietly in a tiny pocket somewhere on the planet. For centuries, scientists trying to describe this earliest life have relied on evidence provided by biology, studying what features modern life-forms have in common to deduce the most primitive components of cells. By working backward, biologists have developed proposals describing when and where such simple forms of life could have arisen. But the ideas so far are guesses at best, impossible to prove.

Researchers from a different field — geology — have more recently joined in the effort. With guidance from biologists, geologists are looking to Earth's oldest rocks to uncover traces of life left behind by the very first cells. Geologists are also pointing biologists toward unusual environments where early cells might have gained a foothold. Where the two fields intersect, more concrete scenarios regarding life's formative years are now taking shape.

Life, by definition, alters its surroundings, exchanging energy and chemicals with the world around it. So early cells should have left indelible chemical traces of their existence — clusters of elements that would never have come together without help from a metabolizing organism. Today, materials that could contain chemical signatures of Earth's earliest life are few and far between, mostly buried deep within the planet's interior, occasionally pushed to the surface when volcanoes erupt or mountains form. But geologists are determined to find and analyze these rocks for signs of life.

"The geological record is like a rug in an old house," says Stephen Mojzsis of the University of Colorado Boulder. "Over centuries of people walking over it, it gets completely worn away and all you have is a few colored threads left. But if you look closely enough at those few threads, you might be able — thread by thread — to figure out what the rug once looked like."

Finding the threads left by early life is only part of the challenge. Geologists are also contributing to discussions about where those threads were spun. One story, based on the discovery of a new type of underwater vent, begins deep in the ocean. Another proposal gets its start in vapor-fed ponds, where geologists say the requirements biologists have laid out for life's existence could have been met.

As the collaboration plays out, geologists and biologists are providing a reality check for each other, determining what was possible.

"There's a need for the biologists who are thinking about this to think in terms of real Earth processes and conditions rather than what they can do in a test tube, because clearly there weren't test tubes lying around on early Earth," says geophysicist Norm Sleep of Stanford University. "I consider it my duty to provide a shopping list of early environments to these biologists."

Rocks of life

Four and a half billion years ago, the infant Earth was a hot and volatile place. Shortly after its formation, within 150 million years or so, it is thought to have been hit by a smaller young planet. The collision formed the moon and altered the Earth dramatically.

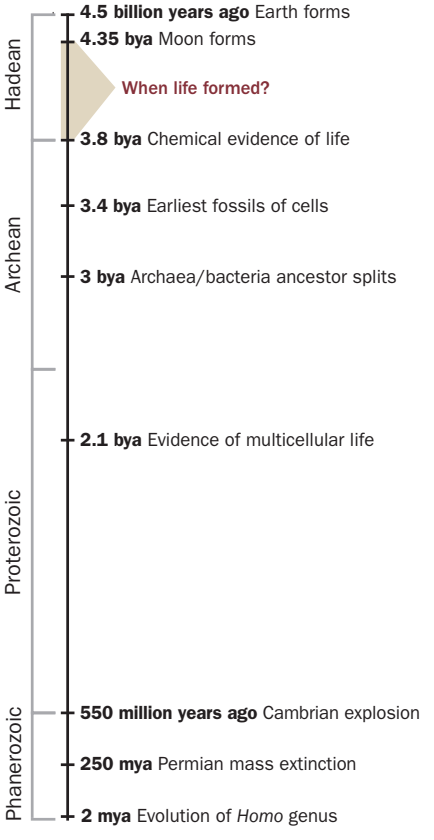
"There are bookends to the possible time for life to emerge on the planet," Mojzsis says. "And one bookend is the formation of the moon — this was such a catastrophic event that it remelted the Earth and reset everything. There's no way any life could have survived this." But as the Earth cooled through this period, called the Hadean eon, it slowly became a more habitable place. By the start of the Archean, 3.8 billion years ago, life was thriving.

Geologists know that life existed then because rocks from the Archean have high concentrations of carbon. Before living organisms were around, most of the carbon on the planet was in the atmosphere. But the chemical reactions used to generate energy by photosynthetic organisms integrate carbon into the solid matter of the planet. So the presence of carbon-rich rocks mean photosynthesis was occurring. And it's not just carbon. Ancient rocks with "banded iron formations" — red layers rich in iron — also indicate photosynthesis; the oxygen released by photosynthesis rusted iron on the planet's surface (*SN: 6/20/09, p. 24*).

"We see this evidence of photosynthesis at 3.8 billion years ago," says Stanford geochemist Dennis Bird. "But photosynthesis is an advanced chemical reaction, so life must have originated some time before that." The trouble, he says, is the further back you go in Earth's history, the less concrete the data.

The picture becomes fuzzier because rocks from the Hadean are hard to come by. Throughout the last 4 billion years, all the rocks and minerals on Earth have been cycling throughout different

Life's first step Scientists suspect that the root of all life on Earth emerged sometime after the cataclysmic event that is believed to have formed the moon, some 4.35 billion years ago. The event would also have reset the Earth environs, opening the way for life.



This banded iron formation reveals the presence of primitive bacteria more than 3 billion years ago. Older rocks may yield even earlier signs of life.

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layers of the planet. Today, Earth's oldest rocks are mostly contained deep within the mantle, a viscous layer of material that begins several kilometers beneath the surface and reaches temperatures of thousands of degrees. Rocks of all different ages and places of origin melt together in the mantle, the planet's geological mixing bowl. By the time the rocks return to the surface thousands or billions of years later — in a volcano or ocean vent — they rarely resemble their old form.

Ancient minerals called zircons hold signatures from the early Earth.

"Basically all the direct evidence that we have from the Hadean is a collection of crystals that you could fit on the tip of a thimble," Sleep says.

These crystals are mostly zircon, a durable mineral that keeps its form even in the hot turmoil of the mantle. Grains of ancient zircon have been found lodged inside other, newer rocks in Western Australia (*SN: 6/18/83, p. 389*). By studying the types and levels of oxygen and titanium ingrained in the zircons' structures, scientists can tell at what temperature the crystals developed and whether they had contact with water. Zircons have even helped clarify the point in Earth's history when continents formed.

Early remnants

Even when geologists discover ancient rocks dated to the Hadean, searching for signs of life within is tricky. Depending on how early cells functioned, and where, they could have left behind drastically different chemical clues. Sleep and Bird have recently conducted a comprehensive analysis of what the geological signs of early life from more than 3.8 billion years ago could be. Now, they want other geologists to keep an eye out for these signatures.

"Petrologists are studying the mantle all the time," Sleep says. "But they're not trained as paleontologists, so they toss away rocks as insignificant that we might find fascinating."

Among the chemicals in rocks that could be key signatures of ancient life: sulfate, iron, uranium, nickel and nitrogen, the scientists propose in a recent paper in the *Annual Review of Earth and Planetary Sciences*. The geologists developed this list by consulting with biologists on what types of metabolisms enabled such organisms to grow and how they could reproduce and respond to their surroundings. Then the geologists used this information to piece together what traces could have been left behind. Such signatures, the team reports, could have survived the turmoil of the rock cycle since the Hadean.

Just the presence of these elements doesn't mean life, but clusters of any one could be a clue.

"We're conditioned to see what we're looking for, and if no one knows what to look for in terms of these signs of life, they won't find them," says evolutionary biologist Bill Martin of Heinrich-Heine-Universität Düsseldorf in Germany. "What I think is really exciting is that we know what to look for now, and we have expectations of finding these biosignatures that could extend back to the Hadean."

Scientists already have a good idea of where to look — Western Australia and the southwest coast of Greenland are famous for being sources of rocks more than 3 billion years old. And some areas of the globe have older material near the surface. Once they get through the slow process of finding the rocks, researchers can help narrow down the date of the origin of life on Earth. The window of possibility still extends almost a billion years.

But the knowledge to be gained goes beyond age. The chemicals left in rocks might reveal how early cells survived, or even point to the environments in which they thrived.

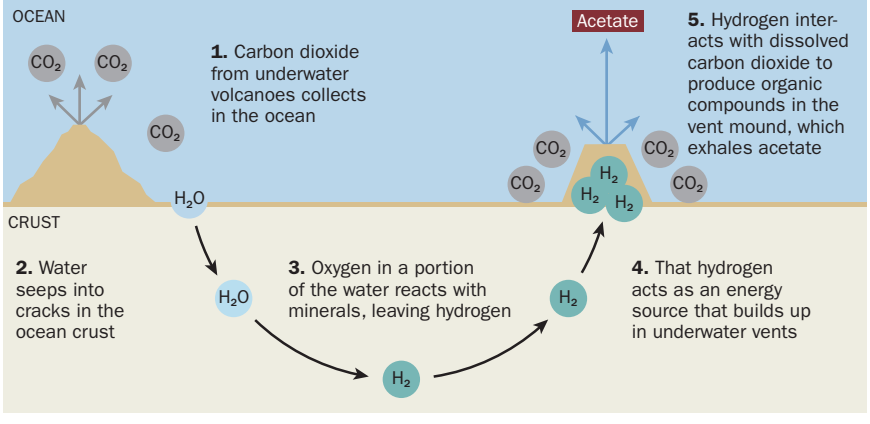
Strategic locale

Most biologists believe early life arose in water, since all life today relies on some form of liquid for molecules to interact. But whether the first cells emerged in salty oceans or freshwater pools is a much-debated question. Geologists can help by cataloging environments that the early Earth hosted and describing the chemistry at play.

A chance discovery in 2000 added evidence to the idea that life began in the ocean. Scientists on a deep-sea expedition discovered a new kind of vent on the ocean floor in the middle of the Atlantic. After seeing the chemical and geological analyses from these Lost City vents, which support many microscopic lifeforms, biologists including Martin realized that such spots could be a prime setting for early life.

While most deep-sea vents are driven by volcanic heat under the ocean floor,

Underwater organics Vents similar to the Lost City vents, discovered in 2000 at the bottom of the Atlantic Ocean, may have had just the right chemistry for the first cells to form. Near the vents, temperatures are around 100° Celsius, the water is alkaline and organics are abundant.



SOURCE: MICHAEL RUSSELL

FROM TOP: DENNISS/WIKIMEDIA COMMONS; E. FELICIANO

and create an acidic environment in the surrounding ocean, the Lost City vents are formed by a reaction between mantle rocks and seawater, leading to an alkaline environment.

The vents spew methane and hydrogen into the water, which react to form limestone chimneys, acetate (a potential energy source for early life) and hydrocarbons (important building blocks for life). What's more, pores in the limestone chimneys suggest a way for chemicals to undergo reactions without floating away.

"These microcompartments serve the function of providing a way for chemicals to be concentrated in a physical way without cellular membranes," explains Martin, who has collaborated with geologists to propose theories on the origins of life at the Lost City vents. Early cells could have lived off the chemical cocktails within the compartments. "Lost City is the most exciting thing that's happened in the past decade in this field," he says.

While today's Lost City vents wouldn't have been around 4 billion years ago, similar ones could have spewed life-sustaining chemicals into the early oceans. It's up to geologists to determine whether such vents existed and up to biologists to figure out whether life could have thrived there.

Armen Mulkidjanian of the Universität Osnabrück in Germany has a different idea about where life began. He studies what features modern single-celled organisms share with each other, a favorite topic among many evolutionary biologists. Two major domains of such organisms exist — bacteria and archaea — and both are thought to have evolved from a common ancestor that existed at least 3.5 billion years ago.

While Earth's first cells were probably more primitive than this ancestor, studying its characteristics may help scientists piece together a picture of even older cells. So far, researchers have found that bacteria and archaea have about 60 genes in common. Thus, scientists deduce, the ancestor, dubbed LUCA (short for Last Universal Common Ancestor), had these same genes.

Vaporous ponds, like those found today at Hot Creek in California, could have provided a potassium-rich setting for early life.

"What we decided to do was to analyze what organic ions are required by each of the proteins coded by these ubiquitous genes," Mulkidjanian says. His team's analysis, reported in *Proceedings of the National Academy of Sciences* earlier this year, revealed that these shared proteins require potassium more than any other element. And sodium, the researchers showed, blocked the function of some of the cellular elements, most of which are involved in the translation of genetic material to proteins.

"We know that original membranes were very leaky. Cells could keep proteins or nucleotides inside, but not potassium," Mulkidjanian says. So this means that LUCA must have been living somewhere with more potassium than sodium; otherwise potassium would have flooded right out of the membrane.

Here's when the biologists consulted with geologists. Researchers familiar with ancient geology agreed that all the evidence from Hadean rocks suggests the oceans back then were rich in sodium. But one place on the ancient Earth, the geologists said, would be replete with potassium: ponds created by vapor from volcanic systems, which the Hadean planet had plenty of.

When magma from volcanoes heats rocks, some water evaporates, pulling certain elements from the rocks and leaving behind others. The resulting vapor can condense back into water and form freshwater ponds, rich not only in potassium but also in zinc and phosphate — also substances that could have driven early cellular processes. The cellular requirements of LUCA proposed by Mulkidjanian's team matched the geological descriptions of these geothermal fields. "That geochemical knowledge is really what fed our biology story," says Mulkidjanian.

Ideas about where life began, whether it was in an ocean or a pond or somewhere else entirely, are still just proposals, hypotheses with bits of evidence. The same is true for existing views about when life emerged and what it looked like. But as geologists and biologists continue to learn from each other, they're turning up new evidence that can strengthen existing scenarios and lead to new ones.

For geologists, the challenge going forward is to find and analyze more ancient rocks to flesh out the picture of the Hadean planet. For biologists, the next task is to combine their theories on early cells with geologists' descriptions of the early Earth.

"We're starting to narrow the gap between microbiology and geochemistry," Martin says.

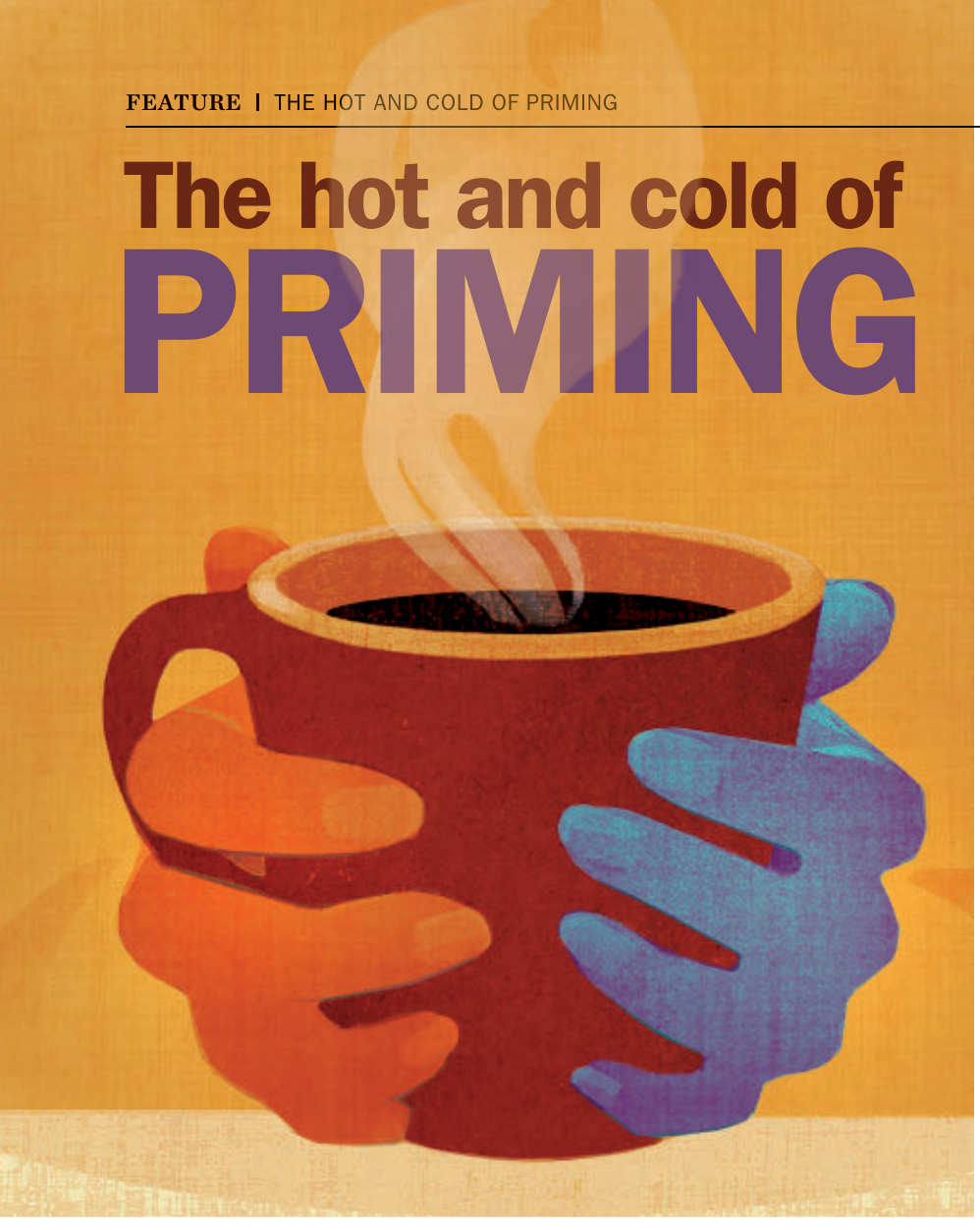
As new zircons are uncovered and chemically favorable environments are explored, the tale of how life began may gain an agreed upon time, a setting and, eventually, a plot. ■

Explore more

■ N.H. Sleep. "The Hadean-Archaean environment." *Cold Spring Harbor Perspectives in Biology*. June 2010.

Sarah C.P. Williams is a freelance science writer based in Hawaii.

The hot and cold of PRIMING



Psychologists are divided on whether unnoticed cues can influence behavior

By Bruce Bower

It's prime time in social psychology for studying primes, a term for cues that go unnoticed but still sway people's attitudes and behavior.

Primes have been reported to influence nearly every facet of social life, at least in lab experiments. Subtle references to old age can cause healthy college students to slow their walking pace without realizing it. Cunningly presented cues about money nudge people to become more self-oriented and less helpful to others. And people holding a hot cup of coffee are more apt to judge strangers as having warm personalities.

Over the last 15 years, many social psychologists have come to regard the triggering of personal tendencies by unnoticed cues as an established phenomenon. Priming may even inspire innovative mental health treatments, some argue.

Yale University psychologist John Bargh likens primes to whistles that only mental butlers can hear. Once roused by primes, these silent inner servants dutifully act on a person's preexisting tendencies and preferences without making a conscious commotion. Many animals reflexively take appropriate actions in response to fleeting smells and sounds associated with predators or potential mates, suggesting an ancient evolutionary heritage for priming, Bargh says. People can pursue actions on their own initiative, but mental butlers strive to ease the burden on the conscious lord of the manor.

Despite the fondness that a lot of social psychologists have for studying primes, long-simmering skepticism about this research has now reached a boiling point. Investigators of decision making, memory and other mental faculties, collectively known as cognitive psychologists, say that bedrock priming effects vanish when independent researchers carefully repeat the experiments. Selective reporting of data in priming papers, a practice that occurs in other areas of psychological research, undermines the statistical strength of many published findings, researchers asserted in January in San Diego at the annual meeting of the Society for Personality and Social Psychology.

One new report suggests that volunteers consciously pick up on what's expected of them in priming trials by reading researchers' body language and other unwitting, nonverbal prompts. A handful of studies, unpublished but posted on a new website, that attempted to minimize direct contact between participants and experimenters find no signs of several previously reported priming effects. Scientific misgivings about priming have apparently strengthened a grassroots movement in psychology to make research more accessible and transparent via the Internet.

Critics consider the power of consciously directed decisions to be more important than priming. Occasional unconscious influences on thoughts and actions are weak and short-lived, this perspective holds. Behavior typically changes slowly and with much effort, explaining why many priming effects that just barely pass statistical muster vanish with further testing.

MICK WIGGINS/GETTY IMAGES, ADAPTED BY T. DUBÉ

"The big idea in social psychology is that social behavior is unconsciously influenced by cues in the environment, but the evidence for that idea needs to be much better," says cognitive psychologist David Shanks of University College London.

Walk this way

Much of the current fuss over priming concerns Bargh-directed experiments described in an influential 1996 paper. College students unscrambled sentences that, for one group, contained words related to stereotypes about the elderly, such as *wrinkle* and *Florida*. Upon finishing, participants who had read old age–related words took about a second longer to walk down an exit hallway than peers who had perused age-neutral words.

A string of unnoticed, stereotypical references to the elderly slyly evoked thoughts of physical deterioration with age, prompting healthy young adults to slow down, Bargh proposed (*SN: 10/30/99, p. 280*).

Cognitive psychologist Stéphane Doyen of Université Libre de Bruxelles in Belgium has long felt that something was out of step with Bargh's findings. A team led by Doyen reproduced Bargh's slow-walk effect, but only when students recruited to lead the experiments were first briefed to expect such responses from participants who read age-related words.

Volunteers primed with elderly stereotypes didn't change their pace when the experiment's leaders had no knowledge or expectations about the trials (or when experimenters were told to expect that primed volunteers would walk faster), the team reported online January 18 in *PLoS ONE*. Taken together, these results suggest that old-age references coaxed students into a leisurely strut only when experimenters provided inadvertent encouragement to slow down, perhaps via facial expressions or body language, Doyen proposes.

Although volunteers reported no awareness of having read words about old age in Bargh's experiment, they may still have been consciously aware of the priming, Doyen says. After testing, primed participants in Doyen's study were shown pictures of four people from different social categories and asked to pick one that could have been related to words used in scrambled sentences. An image of an elderly person was chosen markedly more often than an athlete, an Arab or a physically handicapped individual, suggesting participants were at least somewhat aware that they'd read words about old age.

People may find it difficult to articulate themes associated with words in scrambled sentences even when faintly aware of those themes. "A lot of precautions should be taken to test for unconscious priming effects," Doyen says.

Even simple experimental actions can give away the game to volunteers. Consider evidence that people judge hills to be steeper after donning heavy backpacks. Investigators initially suggested that a weighty prime on the spine makes terrain look tougher to negotiate, so nearby hills take on added slant.

In a new study directed by psychologist Frank Durgin of Swarthmore College in Pennsylvania, an experimenter told some participants not to let wearing a backpack affect their judgments. Estimates of a hill's angle were comparably accurate whether these volunteers toted a pack or not. What's more, many backpack wearers, regardless of what they'd been told, admitted after the trial that they thought the load had been intended to make the hill seem steeper.

Shanks says such findings suggest that recruits for psychology experiments quickly draw conclusions about what's expected and how to behave, regardless of any unintended signals from researchers. That makes it devilishly hard to study social behavior. Durgin's study illustrates the need to account for participants' unspoken assumptions about the purposes of priming trials, Shanks says.

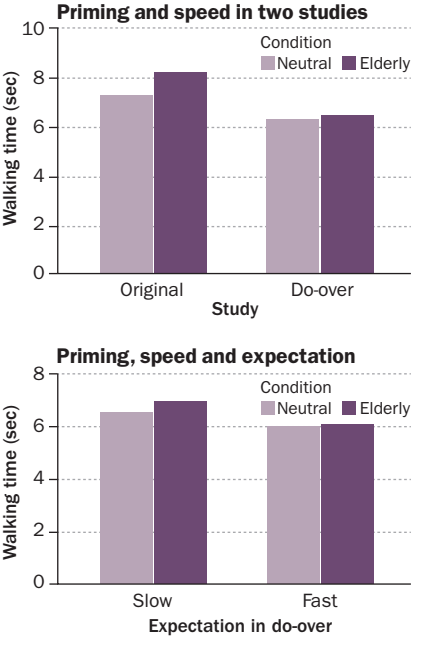
File-drawer rescue

It's a truly steep climb to cart unsuccessful replications of other scientists' studies up Mount Publication. Major journals make no secret of preferring papers that describe novel advances and attract media attention, says psychologist Hal Pashler of the University of California, San Diego. Not surprisingly, failed replications often get filed and forgotten, meaning studies that support priming have gotten more attention than those that don't.

Pashler has conducted five unpublished do-overs of priming studies. None have yielded previously reported effects. Contrary to Bargh, Pashler has found that students walked down a hallway at about the same pace whether or not they had unscrambled sentences containing words associated with old age. Pashler suspects that his ineffectual primes partly resulted from efforts to avoid swaying volunteers' behavior and partly reflect the original study's statistical weakness.

Pashler's investigation remained unknown until January, when a website he cofounded (PsychFileDrawer.org) started posting unpublished replications of psychological studies. Researchers

Do-over data An attempt to replicate a 1996 priming study did not find a difference in how fast volunteers walked after reading words related to old age (top). The do-over, which used infrared sensors to get objective time measurements, did turn up an effect when experimenters were told to expect slow walking (bottom).



SOURCES, FROM TOP: J.A. BARGH *ET AL/J. OF PERSONALITY AND SOCIAL PSYCHOLOGY* 1996; S. DOYEN *ET AL/PLOS ONE* 2012

can upload and compare experimental repeats, discuss their findings and even vote on studies they most want to see conducted a second time. "It would be useful if everyone would post their unpublished results online so we could get a more unbiased picture of the priming data," Pashler says. He predicts that many priming effects will crumble under further scrutiny.

In priming studies, as in much psychological research, researchers try to reject a "null hypothesis" that, say, volunteers' average walking speed will be the same after exposure to age-related and neutral words. If the measured difference between groups is at a 5 percent level of statistical significance, for example, it is generally assumed to mean that in five of 100 instances, evidence favoring rejection of a null hypothesis would actually be a statistical fluke.

At the San Diego meeting, psychologist Joseph Simmons of the University of Pennsylvania in Philadelphia argued that researchers often arbitrarily exclude data considered unreliable, alter experimental conditions that don't work as planned and otherwise fiddle with what goes into a final report. Cherry-picking data in this way masks the statistical weakness of published studies and raises doubts about many reports of statistical significance, he said.

For decades, a string of influential psychologists have recommended disposing of null hypothesis significance testing altogether, calling the approach an unscientific ritual that should be replaced by testing specific predictions. In the February *Theory & Psychology*, psychologist Charles Lambdin of Intel Corp.'s campus at Ronler Acres in Hillsboro, Ore., calls significance testing psychology's "dirty little secret."

A 5 percent significance level merely indicates that chance may not be responsible for slowed walking among readers of elderly references, Lambdin says. But the likelihood of any proposed explanation for the results remains unknown. In Bargh's study, slow walking might be due to priming, subtle coaxing by experimenters, volunteers' guessing the purpose of the study, a combination of all three or something else entirely. A rejected null hypothesis sulks in the corner, saying nothing about the relative merits of any potential reason for its existence.

Subliminally yours

Still, Bargh regards his studies, and the last 30 years of priming research, as solid science. Reams of statistically significant results reflect the mind-changing power of unconscious cues, even if much remains to be learned about how primes work, he says.

As for Doyen's proposal that Bargh's team subtly prompted responses from volunteers, Bargh dismisses it: "We went out of our way to control for experimenter effects in our 1996 studies." Experimenters who dealt with volunteers knew nothing about the study's aims or materials and never saw scrambled sentences, which were handed to participants in sealed envelopes.

Stereotypes about the elderly are stronger in the United States than in Belgium, so it's not clear that age-related words had anything to activate in the minds of Doyen's Brussels-based volunteers, adds psychologist Hans IJzerman of Tilburg University in the Netherlands. IJzerman studies primes but was not involved in either Bargh's or Doyen's investigations.

In addition to priming volunteers with senior stereotypes embedded in scrambled sentences, Bargh's 1996 paper included an experiment aimed at priming underlying assumptions about black people. Previous studies had found that these racial stereotypes include attributing a propensity for hostility to blacks.

White and nonblack minority students working on a computer task reacted more angrily to a minor provocation if images of black people's faces, as opposed to white people's faces, had flashed on the screen during the task. Each face, followed by a pair of crosshatched patterns intended to block awareness of having seen a face, appeared for a fraction of a second. Conscious, hostility-related thoughts and feelings triggered by unconsciously perceived black faces prompted surly behavior, Bargh proposes.

In this case, volunteers weren't aware that they had seen faces of black people at all (unlike slow-walking students who knew they had seen words but were purportedly unaware of how loaded the words were).

Comparable effects from both aware and subliminal priming bolster Bargh's confidence that stereotype references in scrambled sentences truly were modifying people's behavior.

Subliminal primes, such as the flashing faces, offer a way to untangle how priming can sway some volunteers but not others, says psychologist Chris Loersch of the University of Missouri in Columbia. In an upcoming *Social Cognition*, he and psychologist Keith Payne of the University of North Carolina at Chapel Hill report that primes alter behavior only when participants are encouraged by researchers to treat thoughts and feelings activated by a subliminal cue as self-generated.

In an experiment inspired by Bargh's slow walkers, Loersch and Payne measured how rapidly volunteers read experimental instructions on a computer screen

Error error Some number-minded researchers argue for a rethinking of statistical analyses. When researchers alter their setup or cherry-pick data, a significance level (p) of .05 can predict a greater than 5 percent chance of finding evidence for an effect that doesn't exist (as shown below).

Statistics-altering situation	Likelihood of false positive for p<.05
Researchers allow flexibility in analyzing for a second dependent variable, such as measuring both weight loss and fitness in a diet pill trial	9.5%
Researchers collect 20 observations; if the results aren't significant, they go on to collect another 10 observations and rerun the analysis	7.7%
A research team combines the two situations above, analyzing 20 observations for both measures and then 10 more if no effect is seen	14.4%

SOURCE: J.P. SIMMONS *ET AL/PSYCHOLOGICAL SCIENCE* 2011

before and after subliminal presentations of words related to speed or slowness.

During subliminal priming, letter and number strings flashed on the screen just long enough to be noticed. Some volunteers were told that these strings would distract them from any thoughts starting to form. Among these individuals, average reading pace quickened in response to fast primes and decelerated after slow primes. Loersch suggests that participants mistook prime-induced urges to speed up or slow down for their own ideas, believing their thoughts were powerful enough to survive experimental distractions. Taking ownership of primed thoughts prompted behavior consistent with those thoughts — reading instructions either faster or slower.

Reading rates remained unchanged, though, when participants were told that letter and number strings contained powerful, irresistible subliminal messages. In this case, volunteers may have refused to heed urges to speed up or slow down, feeling that those urges were alien notions implanted during the trial. "We may be priming people to trust or distrust what they remember," Loersch says.

Some real-life situations up the chances of mistaking externally influenced thoughts for self-generated ones, he adds. Priming may flourish, for example, when people have to make quick decisions in complex settings.

Doyen takes a dim view of subliminal research. "It's already difficult to obtain priming effects with weakly perceived cues in scrambled sentences," he says. "I doubt subliminal priming effects will stand up to replication."

Warm showers for cold hearts

Whether Doyen and others buy into priming's effects or not, Bargh is poised to move the dispute outside the lab.

Bargh suspects that physical warmth and other health-related cues, delivered by image or text to smartphones or via virtual reality headsets, can supplement treatments for anxiety, depression, eating disorders, addictive behaviors and learning disabilities.

Lonely, rejected guys and gals instinctively seek out physical warmth without realizing what they're doing, Bargh and psychologist Idit Shalev of Ben-Gurion University of the Negev in Beersheba, Israel, reported in the February *Emotion*.

"People maintain emotional equilibrium in mundane ways," Bargh says. "These home remedies can be adapted for mental health treatments."

Bargh has applied to several funding agencies for grants to study possible applications of priming to clinical work. One proposal would examine whether some alcoholics prefer drinking hard liquor because it provides a rush of physical warmth that temporarily lessens loneliness and fires up conviviality. If so, warm packs or other high-temperature cues could be tried as aids in alcoholism recovery programs, Bargh suggests.

So far, his proposals have been turned down by funders. A "wave of negativity" about priming effects may partly account for grant reviewers' coldness toward Bargh's research proposals, remarks psychologist Joseph Cesario of Michigan State University in East Lansing. Cesario, who studies how responses to the same prime vary in different physical settings, says that priming critics are threatened by evidence that complex thinking doesn't require conscious thought.

Shanks admits having felt uncomfortable at first with claims that a few unobtrusive words or images can reshape behavior. Ensuing studies, rife with what he sees as flaws, have only solidified his misgivings. Included are the recent findings on unconscious links between social and physical warmth.

Without independent confirmations, Shanks sees no future for clinical applications of warmth primes. "It's puzzling that so little attention has been devoted to replicating priming results," Shanks says. Until such replications are done, he recommends serving no prime before its time. ■

Repeats and defeats

Attempts to replicate studies of unconscious influences on mind and behavior often don't get published. Some researchers say that publicizing details on such research repeats (some below) would allow a fuller evaluation of priming.

✗ Initially, a report suggested that U.S. volunteers (who are known to talk about time as if it moves horizontally, as in "moving forward") make faster judgments about factual questions after seeing an array of horizontal objects rather than a vertical array. A do-over didn't find the effect.

✓ A 2008 study found that volunteers scored lower on a general knowledge test if, after being prompted to feel close to others, the volunteers focused on the hair color of blond beauty queens. A redo got the same result, suggesting that identifying with "dumb blondes" can undermine thinking — at least among those who buy into the stereotype.

✗ Compared with students who plotted closely situated points on a grid, students who plotted distant points reported weaker emotional ties to family members in one study. A replication attempt that minimized researchers' contacts with participants found that the distance between points didn't drive feelings toward kin.

✗ In an original study, researchers reported that Europeans' scores on a general knowledge test rose after thinking about college professors and dropped after thinking about soccer hooligans. In a replication, test scores remained stable after participants' contemplated either academics or sports ruffians.

Explore more

- For do-overs of psychology studies, visit www.psychfiledrawer.org

Waking the Giant

Bill McGuire

Nearly any time a major natural disaster strikes — an earthquake in Japan, an eruption in Chile — someone tries to link it to climate change.

Usually such claims are bunk. But McGuire, a geologist at University College London, shows that there can be an underlying grain of truth. What happens in the atmosphere, it turns out, doesn't stay in the atmosphere. Climate change can in fact affect the solid Earth and its natural hazards.

Consider the end of the last ice age, some 12,000 years ago. Changes in Earth's orbit, along with rising atmospheric levels of carbon dioxide, conspired to melt great glacial masses. As the ice melted, huge landscapes were suddenly relieved of their overlying burden. The ground rebounded, and stresses shifted within the crust. The result: more earthquakes in Scandinavia and more volcanic eruptions in Iceland.

Today Earth is in the midst of similar kinds of changes. Greenhouse gases spew from power plants, the atmosphere is heating up and ice is melting (though at a far smaller scale, at least so far). Places like Alaska may serve as the proverbial canary in the coal mine, where melting ice leads to more quakes and who knows what else.

McGuire lays out a strong case for the interconnectedness of Earth systems, showing for instance how the destabilization of seafloor methane may cause huge underwater landslides and tsunamis. Yet when it comes to the most crucial question, of how future climate change will affect the planet, even he cannot say. Science is providing scary hints about how fast Earth is changing, but it cannot predict exactly what will transpire.

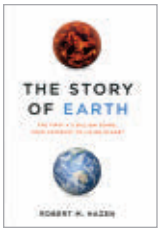
Anyone looking for a guide to the future may need to simply wait until it is here. — *Alexandra Witze*

Oxford Univ., 2012, 320 p., $29.95

The Story of Earth

Robert M. Hazen

Earth's history is a saga of change. The planet has evolved ever since it and its solar system companions coalesced from a massive interstellar cloud of gas and icy dust. What was once a barren lava planet is now a teeming orb where life occupies nearly every conceivable niche on and near its surface.



Cramming billions of years of geological evolution into a single book is a daunting challenge, but it's one that Hazen, a geophysicist, has risen to splendidly. He chronicles the major events and eras in Earth's history, from "The Big Thwack" (a collision with another planet thought to have formed the moon) to the greening of Earth's landscape as life emerged from shallow waters worldwide.

And, Hazen says, the "Boring Billion," an interval from 1.85 billion to 850 million years ago that many scientists have viewed as uneventful in terms of biological or geological evolution, probably wasn't so boring after all. Recent research suggests that supercontinents came together and cracked apart at least twice during this lengthy period.

After thoroughly reviewing Earth's past, Hazen peers into the planet's future. He looks ahead to near-term warming triggered by greenhouse gases and to the desertification of the planet billions of years in the future as the sun brightens and oceans boil away. In the meantime, continents will continue to shift, and microscopic life will scarcely miss a beat. For eons to come — and with or without humans, Hazen notes — Earth will be a living planet of blue oceans, green lands and swirling white clouds. — *Sid Perkins*

Viking, 2012, 320 p., $27.95

Baby-making

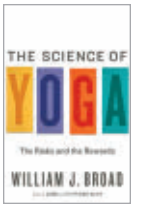
Bart Fauser and Paul Devroey

Two fertility doctors describe modern technologies and the future of assisted reproduction. *Oxford Univ., 2011, 292 p., $29.95*

Taste What You're Missing

Barb Stuckey

Learn why bacon is so delicious and cilantro is not for everyone in this exploration of how the senses of taste, smell, hearing and sight influence the experience of food. *Free Press, 2012, 407 p., $26*



The Science of Yoga

William J. Broad

A review of research shows the demonstrated benefits — and risks — of various yoga practices. *Simon & Schuster, 2012, 298 p., $26*

Before the Lights Go Out

Maggie Koerth-Baker

A journalist explores society's energy options for the future, including technologies both old and new. *Wiley, 2012, 225 p., $27.95*

Snap

Katherine Ramsland

This exploration of the neuroscience behind "aha" moments offers tips for increasing the odds of such spontaneous insights, or "snaps." *Prometheus Books, 2012, 283 p., $25*

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Visions spark debate

In "Visions for all" (*SN: 4/7/12, p. 22*), researchers found that functioning people who "hallucinated" God were high on the "absorption" scale and that 4 percent of people studied reported hallucinations.

This reminded me that 4 percent of the population is grade V hypnotizable. All of these superhypnotizable people rate very high on absorption. [As a psychiatrist,] I had patients like this who had been severely abused as children. These are the ones who developed multiple personalities, or dissociative identity disorder. These patients often had visions of helpful spirits. Since none of your sources seemed to recognize that dissociation in healthy grade V hypnotizable people can show this kind of picture, I thought I would bring it to your attention.

Ralph B. Allison, Paso Robles, Calif.

If I didn't know better, I would say this article, though interesting, seems to have as its goal to reduce God to a hallucination at best and psychosis at worst. There are crucial differences between hallucinations (at least in my experience) and God speaking: Hallucinations occur in times of mental stress, drugs or illness that affect the mind; hallucinations are bizarre, otherworldly auditory and visual sensations; hallucinations do not make moral judgments or render valid insights.

Kenneth V. Hoffman, South Kingstown, R.I.

Neandertal DNA still a mystery

"Icy isolation may have led to new human species" (*SN: 4/7/12, p. 5*) was the best and most concise article about human ancestry that I have ever read. Yet, by focusing on "cold-climate refuges," it neglects one area: the human groups that never left Africa. The only information I have seen is that the modern ancestors of these folks have no trace of Neandertal or Denisovan DNA in their genomes. What do we know about the evolution of humans that remained in warm climates?

Gene Phillip, Great Falls, Va.

Geographical variation among populations today in amounts and types of Neandertal DNA is poorly understood. But look for research on this topic to heat up. — Bruce Bower

A question of magnetism

"Sleeplessness agitates the brain" (*SN: 4/7/12, p. 16*) says, "To look for signs of altered brain function, the team delivered a jolt of magnetic current to the participants' skulls that kicked off an electrical response in the nerve cells." I believe the phrase "jolt of magnetic current" is not accurate. The experimenters used transcranial magnetic stimulation, or TMS, which functions by applying to the skull a rapidly changing magnetic field.

Robert P. Yassanye, Sarasota, Fla.

The reader is correct. — Laura Sanders

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

The Science Life

For more on current art projects at the CERN lab, visit **bit.ly/CERNartblog**

Julius von Bismarck assembles a face made of steel and neon tubes, with a mouth that smiles or frowns in response to the facial expressions of passersby photographed in Lindau, Germany.

Taking the world for a spin

Julius von Bismarck wants to feel like he's the center of the universe. He likes the idea of living on a spinning platform for days, maybe weeks — long enough, he hopes, to trick his mind into believing that he's standing still while the world revolves around him.

The project isn't an exercise in egotism. It's his way of coming to grips with how people used to view their place in the cosmos.

"I've always been fascinated by the idea that humans once thought the Earth was the center of the galaxy," says von Bismarck.

This playful approach to science earned the 28-year-old German artist a place at CERN, Europe's largest physics laboratory and home of the world's biggest atom smasher. In March he began a two-month stay as the institution's first artist in residence, kicking off a program bringing digital arts, dance and performance to the lab. His task, as he sees it, is to build bridges between the bizarre world that particle physicists think about and the familiar world that people experience every day.

One idea that he has come up with is to create a row of lightbulbs dangling from long cords. Tug on the cords, and the lights swing in circles. Each light could play the role of a particle, with the size of the circle and the speed of the lightbulb's motion providing an intuitive sense of the particle's properties.

"As an artist, I can be more free in my approach than a scientist," says von Bismarck, whose grandfather and brother both became physicists. "I can make something that can be experienced and get you closer to the way scientists think."

In a previous piece, von Bismarck toyed with how to visualize a four-dimensional universe. He built a doughnutlike device made of a coiled wire that continuously twists itself inside-out, its contortions representing the motion of time. The contraption, called a self-revolving torus, looked like a Slinky coated with aluminum foil and moved like a Roomba vacuum cleaner.

Von Bismarck's work at CERN — whatever it ultimately becomes — will be displayed at the Ars Electronica festival in Linz, Austria, in the fall. — *Devin Powell*

More art projects

As a child, Julius von Bismarck broke into abandoned military bases to find components for explosives. So it's no surprise that as an adult his art uses technology to explore the world in unconventional ways. For more photos and videos of his projects, go to www.juliusvonbismarck.com.

- **A perpetual storytelling machine** sketches images in patents to trace the evolution of ideas and ingenuity.
- **The "topshot" helmet** (shown below) allows the artist to see himself from above as he walks, thanks to a camera mounted on a balloon.
- **A metal ball** shakes the ground when dropped, demonstrating the power of gravity as understood by Newton.

BOTH: COURTESY OF J. VON BISMARCK

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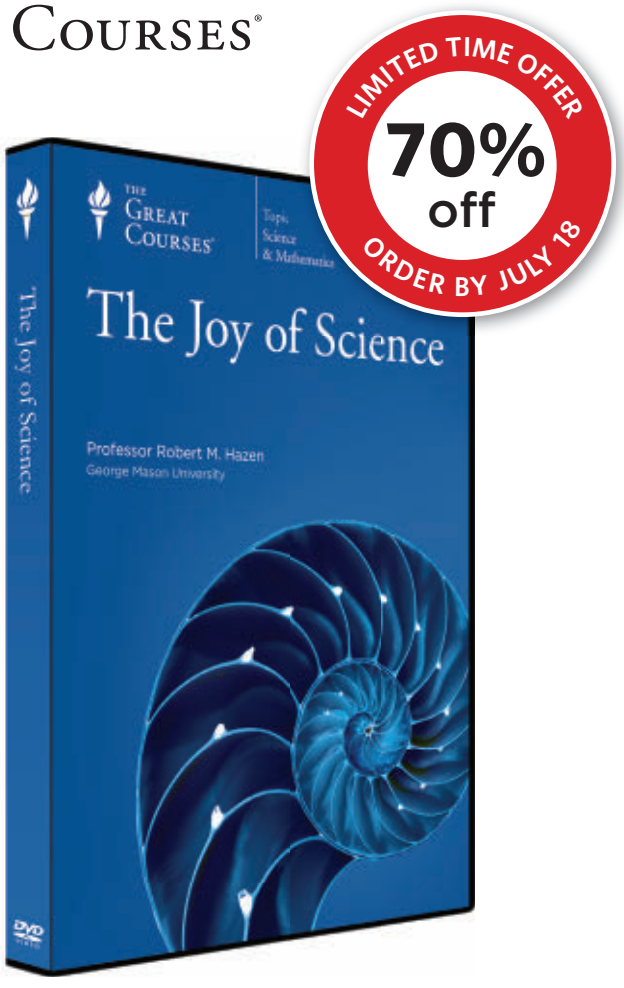

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