SN
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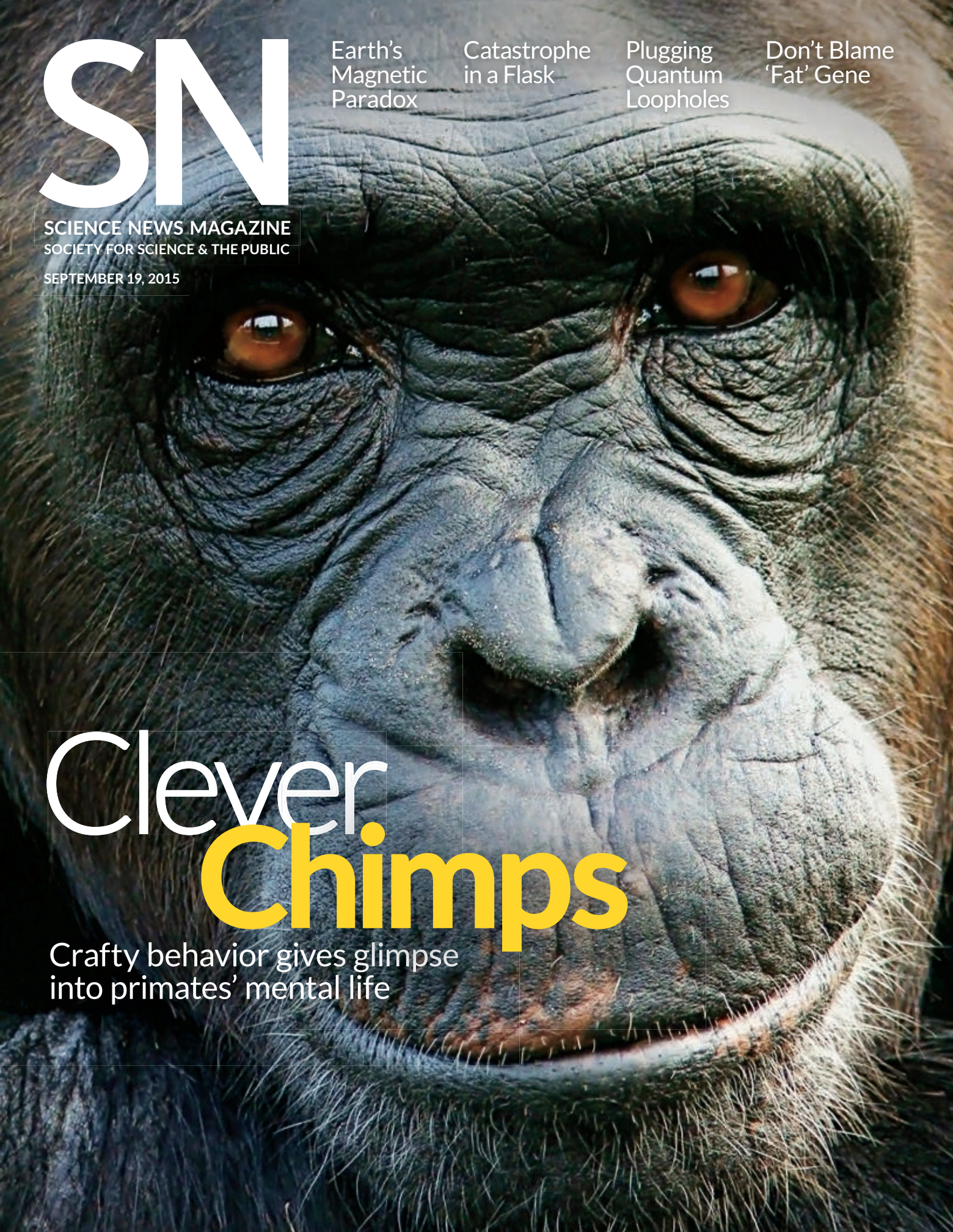
SEPTEMBER 19, 2015

Earth's Magnetic Paradox

Catastrophe in a Flask

Plugging Quantum Loopholes

Don't Blame 'Fat' Gene



Clever Chimps

Crafty behavior gives glimpse into primates' mental life

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Going, Going, Octagon!

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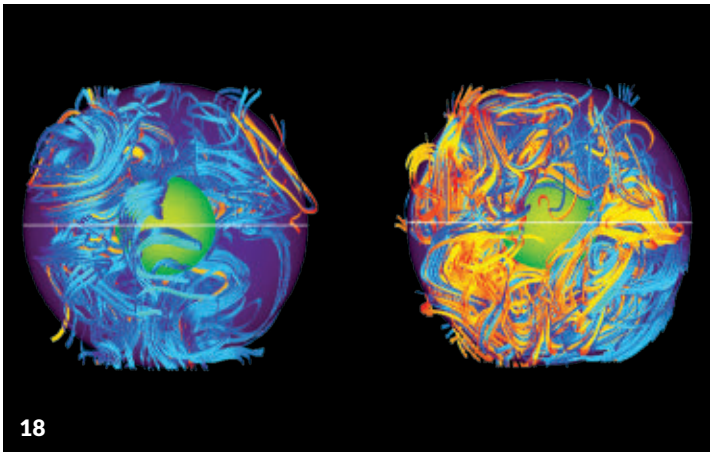
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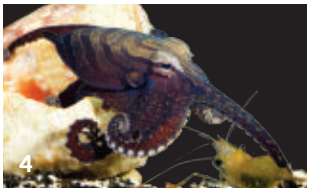
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Departments

COVER A chimp from the Tchimpounga Sanctuary in Republic of the Congo, where researchers tested chimps' interest in cooked food. *Alexandra Rosati*

CLOCKWISE FROM TOP: P. OLSON/JOHNS HOPKINS UNIV.; R. CALDWELL; C. MEYER

When the pieces don't fit, try a new puzzle

Put it in the category of invisible but vital: The magnetic field that envelops the Earth shields life from harmful ions spat out by the sun. Although unseen, it's not undetectable (try a compass); auroras displayed when geomagnetic storms hit the polar regions hint at its presence. Our magnetic field has protected us for eons, its existence recorded in minute crystals hidden in ancient rocks.

Scientists believe that this magnetic field originates in the roiling of iron and dancing of electrons within the metallic soup of the Earth's core. But exactly how that magnetism mechanism works has been a hard question to answer. From decades of study, geophysicists have pieced together a general picture of the process: The cooling of the planet's solid inner core stirs up the liquid iron in the outer core. This movement creates electric currents, which generate magnetic fields.

But that explanation hinges on how that metallic fluid motion, called convection, is powered. Some recent computer simulations, as Thomas Sumner reports on Page 18, suggest that the early Earth could have powered only a weak magnetic field. Yet the rock record suggests a strong field, as would have been needed to protect early life. This paradox has led scientists to perform new experiments, probing the nature of iron at high temperatures and pressures, along with continuing simulations of how matter ought to behave deep in the Earth.

It's a nice example of the excitement that animates scientists when the pieces don't all fit: They have to rethink things and ask whether they are solving the right puzzle. That can inspire creative approaches, and eventually, new answers.

That's similar to the story behind results described by Tina Hesman Saey on Page 6. A gene closely linked to obesity risk does not actually affect fat storage. But a bit of DNA stuck into this gene does. Scientists discovered that this DNA region regulates the activity of two other distant genes involved in determining whether cells develop into energy-storing white fat cells or energy-burning beige fat cells. Asking how the "fat gene" worked turned out to be the wrong question. Maybe in explaining the Earth's magnetic field paradox, scientists will discover a new question with an even more interesting answer. — *Eva Emerson, Editor in Chief*

SANDY SCHAFFER

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Excerpt from the September 18, 1965, issue of *Science News Letter*

50 YEARS AGO

Coolest stars found

The coolest stars yet have been discovered. One is reported to have a surface temperature as low as 800° F.... The other of the two cool stars has a surface temperature of about 1,200°. Both objects are presumed to be true stars, not planets, having interior temperatures of 25 million degrees, high enough for them to be stoked by nuclear fusion.

UPDATE: These two stars, IK Tauri and NML Cygni, turned out to be warmer by roughly 2,000 degrees Celsius (3,600 degrees Fahrenheit). NML Cygni is actually one of the largest known stars; it wouldn't fit within the orbit of Saturn. Today, the coolest known starlike orb is a brown dwarf discovered last year. Its surface is around –30° C (–22° F), making its temperature comparable to a winter day in Antarctica (*SN Online: 4/26/14*). Brown dwarfs, first seen in 1995, occupy a murky ground between planets and full-fledged stars, lacking the mass needed to sustain hydrogen fusion in their cores.

IT'S ALIVE

When octopuses dance beak to beak

Two larger Pacific striped octopuses mate beak-side to beak-side, defying what people thought they knew about octopus intimacy.

The larger Pacific striped octopus hunts shrimp using a strategy worthy of a schoolyard prank. And that's not the only oddity about the species. It's only the second octopus known with females that prolong motherhood, instead of dying after weeks of all-out coddling a single brood.

But what everyone wants to talk about, researchers who study the species have found, is beak-to-beak mating.

Before writhing, wrestling videos of the larger Pacific striped octopus (nicknamed LPSO), biologists knew of two forms of eight-armed sex. Some species mate at a distance, says Roy Caldwell of the University of California, Berkeley. The male extends one arm, always the same one, toward the female and up under her mantle. A travel-ready package of sperm emerges onto his skin and settles into a specialized groove on his mating arm. Waves of arm flexing resembling mammal intestinal motions nudge the packet toward one of two openings to her reproductive tracts.

"It's a messy way of reproducing," Caldwell says. A lot of sperm packets "are wasted and go floating off."

Instead of pouncing, a larger Pacific striped octopus reaches out to a shrimp for a sneak attack.

Distance mating has other challenges. In an Indonesian octopus species, Caldwell's former student Christine Huffard of the Monterey Bay Aquarium Research Institute discovered males hunkered in their dens sending an arm across the seafloor into the den of the female next door. On occasion, such females leave their dens on some octopus errand, dragging the male along by his mating arm.

In some small species, such as blue-ringed octopuses, a male positions himself against a female's mantle while reaching around and underneath with the mating arm. But Caldwell, Huffard and colleagues report August 12 in *PLOS ONE* that LPSOs in the lab routinely coupled with arms spread back, mouth to mouth.

"They actually line up their arms," Caldwell says. He's seen LPSO pairs matched eight to eight. And it looks chancy. There's grappling, and sometimes a female engulfs the male with her arms and web — both moves that octopuses make when they fight. Afterward, males show marks left by female suckers.

LPSOs have subtler moves when offered a shrimp. Unlike other octopuses, the LPSO doesn't just pounce. It eases out one arm slowly, slowly, and then just taps the shrimp on the shoulder. The shrimp startles into flight — often directly into the octopus's arms. — *Susan Milius*

BOTH: R. CALDWELL

Watch a video of octopus mating at **bit.ly/SN_LPSO**

SAY WHAT?

Vomiting device \VAH-miht-eeng dih-VAIS\ n.

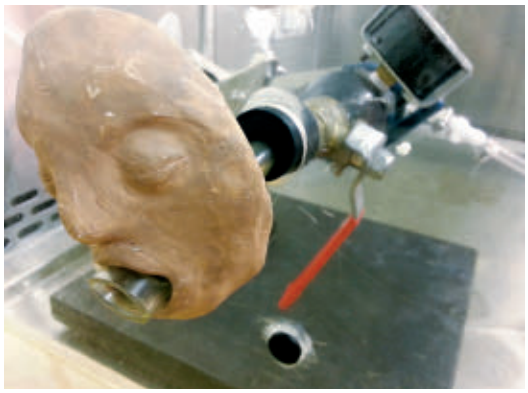
A mechanical system that imitates projectile vomiting.

Researchers in North Carolina use the barfing machine to study how human noroviruses, leading causes of upchucking worldwide, spread through the air.

The vomiting device's tubes, valves, piston and pump imitate a human mouth, throat and stomach at one-quarter size. A clay face mask gives the machine an appropriate expression of misery, but it also provides weight to bend the throat down, simulating the flexed neck of a heaving human.

To see how many viruses a patient might spread while puking, the researchers laced artificial vomit — made from imitation saliva or vanilla instant pudding, depending on the desired thickness — with a noninfectious virus similar to norovirus in shape and size. Using lifelike stomach pressure, the team ejected faux vomit from the device's stomach into a plastic "vomitus containment chamber." Another device tested air from the chamber for airborne viruses.

Every vomiting trial sent viruses into the air, the researchers say August 19 in *PLOS ONE*. Depending on pump pressure and the virus concentration in the throw-up, as few as 36 and as many as over 13,000 virus particles were released by the mechanical spewing. Just 20 norovirus particles can cause infection, so vomiting can probably spread norovirus to more unfortunate victims. — *Sarah Schwartz*



SCIENCE STATS

Carbon cuts could save U.S. farmers billions of dollars

U.S. agriculture could reap big benefits from curbed carbon emissions. Such cuts would reduce the frequency and severity of future crop-parching droughts, saving American farmers billions of dollars annually by 2100, researchers calculate in the July *Weather, Climate and Society*.

Calculating how changes in temperature and rainfall will affect future droughts, economist Brent Boehlert of MIT and colleagues estimate that large-scale climate action would save farmers about $980 million annually by 2050. More modest cuts would net savings of around $390 million annually. The first scenario would keep atmospheric carbon dioxide concentrations below 500 parts per million and the second below 600 ppm, compared with 1,750 ppm without mitigation of greenhouse gas emissions. — *Thomas Sumner*

$2.2 billion

Estimated annual savings to U.S. agriculture by 2100 from aggressive carbon emission reductions

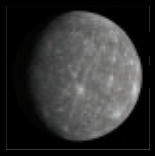
$6–8 billion

Current total damages from droughts in the United States each year on average, an amount greater than from flooding or hurricanes

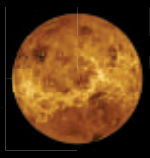
THE LIST

The sad magnetic fields of nearby rocky worlds

A powerful global magnetic field envelops Earth in a cozy blanket of protection against bursts of solar particles (see Page 18). But the solar system's other rocky worlds aren't so lucky.

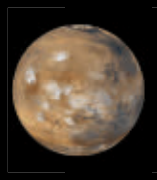


Mercury: Paltry
The most petite planet has an appropriately puny magnetic field, just 1.1 percent as strong as Earth's (*SN Online: 5/7/15*).



Venus: Zilch
Earth's nearest neighbor doesn't generate a planet-wide magnetic field, so the solar wind penetrates and is gradually stripping away the atmosphere.

The moon: Lost
Magnetized lunar rocks hauled back by Apollo astronauts show that, at some point, the ancient moon had a hefty magnetic field. It has since died out (*SN Online: 12/4/14*).



Mars: Collapsed
The Red Planet lacks a global magnetic field today, but magnetized regions of Martian crust point to an ancient magnetic field that eventually fizzled.

Earth's magnetic field deflects charged solar particles toward the planet's poles, generating auroras. This photo was taken from (and shows parts of) the International Space Station.

CLOCKWISE FROM TOP: NASA, JHUAPL, CARNEGIE INSTITUTION FOR SCIENCE; JPL-CALTECH/NASA; NASA; JPL-CALTECH/NASA; NASA; GRACE TUNG-THOMPSON

GENES & CELLS

‘Fat’ gene not to blame for obesity

Nearby bit of noncoding DNA real culprit, researchers say

BY TINA HESMAN SAEY

Researchers have discovered a “genetic switch” that determines whether people burn extra calories or save them as fat.

A genetic variant tightly linked to obesity causes fat-precursor cells to become energy-storing white fat instead of energy-burning beige fat, researchers report online August 19 in the *New England Journal of Medicine*.

Scientists had thought that the variant alters a gene called *FTO* in the brain to increase appetite. The new work shows that *FTO* is not the cause of obesity, says coauthor Manolis Kellis, a computational biologist at MIT and the Broad Institute. But the work may point to a new way to control body fat.

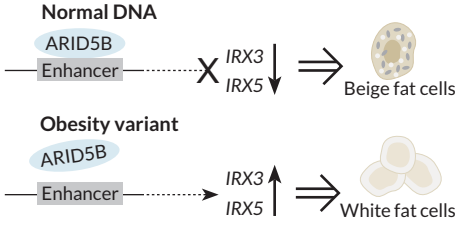
In humans and many other organisms, genes are interrupted by stretches of DNA called introns. Kellis and Melina Claussnitzer of Harvard Medical School and colleagues discovered that a genetic variant linked to increased risk of obesity affects an intron that interrupts the *FTO* gene. The variant does not change the protein produced from the gene or change the gene’s activity. Instead, the variant doubles the activity of two other genes, *IRX3* and *IRX5*, which are involved in determining which kind of fat cells will be produced.

FTO’s intron is an enhancer, a stretch of DNA that controls activity of faraway genes, the researchers discovered. Normally, a protein called ARID5B squats on the enhancer and prevents it from dialing up activity of the fat-determining genes. In the fat cells of people who have the obesity-risk variant, ARID5B can’t do its job, and the *IRX* genes crank up production of energy-storing white fat.

When researchers turned down activity of the *IRX* genes in human fat cells, the cells became energy-burning beige fat cells. Researchers also disrupted the *IRX3* gene in the fat cells of normal-weight mice. Those mice had less than half the body fat of normal mice, even though they ate and exercised as much as other mice did. The mice were also protected from gaining weight on a high-fat diet. Disrupting the *IRX3* gene in a part of the brain called the hypothalamus, which helps control appetite, did not have the same effect. That result indicates that the white fat–beige fat switch works in fat tissue, not in the brain.

More than 40 percent of Europeans carry the obesity-risk variant while only about 5 percent of Africans do, Kellis says. But “every human on the planet has that genetic circuit,” so researchers may be able to manipulate the *IRX* genes to eliminate obesity, he says. “This is perhaps the secret to curing obesity.”

But benefits could be a long way off, Clifford Rosen of the Maine Medical Center Research Institute in Scarborough and Julie Ingelfinger of Massachusetts General Hospital write in an editorial accompanying the paper. “As yet, there is still no simple path to an anti-obesity drug that can be derived from this research,” they write. But scientists might use similar strategies to those in this study to figure out how genetic variants are linked to other diseases. ■



Fat switch Energy-burning beige fat is made when a protein called ARID5B prevents a bit of DNA that acts as an enhancer from turning on two faraway genes (*IRX3* and *IRX5*). A DNA variant associated with obesity stops ARID5B from sitting on the enhancer. That allows *IRX3* and *IRX5* to be more active and turn more cells into energy-storing white fat.
SOURCE: M. CLAUSSNITZER *ET AL*/*NEJM* 2015

LIFE & EVOLUTION

Hummingbirds pump up nectar

New videos spark debate over how tongue slurps up fluid

BY SUSAN MILIUS

A new way of looking at hummingbird tongues sees them as long, skinny pumps.

This view challenges an old notion of how hummingbirds sip — that nectar flows up open grooves in the tongue the way water rises inside thin capillary tubes, says Alejandro Rico-Guevara, a functional morphologist at the University of Connecticut in Storrs. It’s the latest in a lively debate over just how hummingbird tongues work.

The “elastic micropump” theory that Rico-Guevara and his Connecticut colleagues propose relies on the same tendency of water molecules to grip each other that creates capillary rise in an open tube. But Rico-Guevara’s high-speed videos show that hummingbirds in the wild rarely dip open grooves into nectar. Instead, bird bills squash the tongue and its grooves flat. When the tongue tip touches nectar, the grooves spring open, pulling up a column of nectar as they expand. This pulling, or pumping, slurps nectar faster than grooves that had been open all along would, the researchers report in the Aug. 22 *Proceedings of the Royal Society B*.

The skinny, translucent hummingbird tongue, with no muscles in it, has a semicircular groove on each side. The tongue forks into fringed halves at the tip. That tip is not so much a capillary tube as a trap for nectar, Rico-Guevara and colleague Margaret Rubega proposed in 2011. Based on high-speed video, they argued that as the squashed grooves touch nectar and spring open, the fringe helps capture nectar. Proposed as an alternative to capillary rise, “it was going against what everybody believed,” Rico-Guevara says. “It got a lot of attention, but also a lot of skepticism.”

John W.M. Bush, who studies fluid dynamics at MIT, and his colleagues

E. OTWELL

Watch a hummingbird guzzle fluid at **bit.ly/SN_hummingbirdtongue**

A new way of looking at hummingbird tongues suggests that they work like tiny pumps, challenging the familiar idea that nectar rises as if the tongue were an open tube.

countered with computer simulations and their own videos of birds in the lab. The team argued that, regardless of what happens at the tip, capillary suction is important in drawing nectar up the grooves. The tongue is really a "self-assembling capillary siphon," Bush proposed in 2012 with Wonjung Kim, now at Sogang University in Seoul, South Korea, and collaborators.

To make his own study of the grooves, Rico-Guevara with ethologist Kristiina Hurme coaxed 18 hummingbird species in the wild to sip on camera. The birds' tongue grooves mostly stayed closed waiting for nectar. And when tongue met nectar, the fluid moved fast — averaging nearly 1 meter per second as it rose up. Even under ideal conditions, simple capillary rise would draw in nectar much more slowly, only about 36 centimeters per second, the researchers report.

In the course of filming, one accident turned into a "perfect experiment" to compare capillary and pump action, Rico-Guevara says. A bird bumped one side of its tongue against a feeding tube and the tongue's compressed groove opened before touching the nectar. In this instance, nectar did a typical capillary rise — and moved more slowly than nectar in the groove on the opposite side of the tongue that sprang open later.

Study coauthor Tai-Hsi Fan, who studies fluids, developed the concept of the tongue as an elastic micropump. With computer simulations, he predicted such details as nectar uptake speed.

Even in the new grooves-closed model, "I think that capillary force is still at work," Kim says. This force of water molecules gripping each other might explain why the wet, compressed tongue grooves stay closed until the tongue dips into nectar. ■

K. HURME

MATTER & ENERGY

Physicists get info from idle computer

Quantum trick enables success in counterfactual computing

BY ANDREW GRANT

For all that computers can do, they're useless when they're not running. Unless they are quantum computers. Using a rudimentary quantum computer, a team of physicists consistently determined which of two operations the computer would have performed, even though it didn't actually perform them.

The experiment, reported in the Aug. 21 *Physical Review Letters*, delivered an unprecedented 85 percent success rate for what's called counterfactual computation: exploiting quantum mechanics to glean the information a computer would have provided had it run.

Future counterfactual schemes could enable the imaging of objects vulnerable to light, the team says. But some physicists aren't sold on the result, because it's difficult to define the concept of a computer running or not running in the wishy-washy quantum world. At the very least, the study "contributes to the debate of how we understand quantum mechanics and how it compares with our normal ideas of logic," says Matthew Rakher, a condensed matter experimentalist at HRL Laboratories in Malibu, Calif.

The realm of the tiny is both bizarre and exciting because of its uncertainty. A photon, for example, can seemingly take two paths simultaneously to reach a destination, a phenomenon called superposition. In 1993, theoretical physicists showed that if a photon-triggered bomb were placed in one of the paths, a photon passing through would occasionally reveal the presence of the bomb without setting it off. Five years later, theoretical physicist Richard Jozsa, now at the University of Cambridge, replaced the bomb in the thought experiment with a quantum computer. He showed that if the computer was turned on and programmed to perform a calculation, then an experimenter could learn the result without the computer doing anything. But the success rate was limited to 50 percent, no better than guessing.

Quantum physicist Fei Kong of the University of Science and Technology of China and colleagues tried to beat that limit. They programmed a simple quantum computer to run either one of two operations. Each operation assigned a different value to the spin of a nucleus.

Rather than let the computer do its thing, the researchers set up a detour to probe which operation the computer would have performed. They put the nucleus in a superposition of multiple spins, then repeatedly manipulated the spin using radio pulses. A trick known as the quantum Zeno effect (*SN: 11/20/10, p. 20*) prevented the computer from running. After tweaking the nucleus 17 times, the team measured the spin. If the spin had a value of 1, the researchers knew the computer would have run the first operation; if it was 2, the computer would have performed the second operation. The scheme worked 85 percent of the time.

Although a team experimentally demonstrated counterfactual computation in 2006 (*SN: 2/25/06, p. 117*), the new setup far surpasses the theorized 50 percent limit. "That's where this magic turns out to be very exciting," says study coauthor Liang Jiang, a Yale applied physicist. If single photons and nuclear spins can extract information unobtrusively, Jiang says, then perhaps a handful of photons could deliver a complete image of a light-sensitive protein under the microscope.

Jozsa and Rakher are more cautious, noting that physicists are still deciphering the magic of counterfactual computation. ■

HUMANS & SOCIETY

Bones tell of 7,000-year-old massacre

Mass grave fuels debate over demise of early farming culture

About 7,000 years ago, at least 26 people were massacred and dumped in a pit near a farming village in what is now Germany, researchers say. A roughly 8-year-old child's skull found in the pit displays blunt-force injuries.

BY BRUCE BOWER

Central Europe's first farmers cultivated not just crops but also massacres, with some villages nearly wiping out neighboring settlements, researchers say.

Evidence of this ancient warfare appears on human bones found scattered in a ditch exposed by German road workers in 2006, says a team led by anthropologist Christian Meyer of the University of Mainz in Germany. These bones represent at least 26 people who were beaten to death and possibly shot with arrows before being dumped in the ditch, the team reports online August 17 in the *Proceedings of the National Academy of Sciences*. The mass grave lies near remnants of an ancient farming site called Schöneck-Kilianstädten.

A majority of recovered skull pieces display cracks and depressions probably caused by blows from stone tools attached to handles. Two bone arrowheads also lay among the remains. Fractures on many lower leg bones indicate that attackers immobilized and perhaps tortured victims before killing them, Meyer says.

Radiocarbon analyses of bones from four individuals date the mass grave to between roughly 7,200 and 6,850 years ago. Meyer's group suspects that attackers and victims belonged to different farming settlements of the Linear Pottery, or LBK, culture. These farmers inhabited Central Europe from about 7,600 to 6,900 years ago.

Combined with a few previously discovered mass graves in Central Europe (*SN: 1/2/10, p. 10*), the new report underscores "the ferocity, depth and impact of lethal violence in late LBK society," comments archaeologist Ian Armit of the University of Bradford in England.

Bone and tooth features indicate that 13 of the victims were adults: nine men and one adult of undetermined sex who were in their 20s and 30s, two women older than age 40 and an adult whose age and sex are unknown. Of the remaining victims, 12 ranged in age from 6 months to 8 years. Another was 16 to 21 years old.

No remains of young adult women were found at Schöneck-Kilianstädten. Attackers took young women captive rather than killing them, the researchers speculate. Population increases in closely spaced villages plagued by drought-related food shortages may have contributed to this ancient massacre, the researchers hypothesize.

Archaeologist Rick Schulting of the University of Oxford predicts the new report will fuel debate over whether LBK culture rapidly collapsed due to social and political conflicts, droughts or both. Other researchers argue that LBK culture gradually gave way to succeeding agricultural populations. ■

C. MEYER

MATTER & ENERGY

Antimatter looks a lot like matter

Protons, antiprotons have same charge-to-mass ratio

BY ANDREW GRANT

No matter how precise the measurement, matter and antimatter look stubbornly similar.

An ultrasensitive experiment comparing protons with their antimatter counterparts found no difference in the ratios of their charge to mass, researchers report in the Aug. 13 *Nature*. The result is consistent with the standard model of particle physics, which predicts that antiprotons are essentially protons with negative charge — the particles' mass, spin and nearly every other property should be identical. Many physicists would love to discover even minute discrepancies, which could signal the existence of new particles and forces and help reveal why the universe is made of matter rather than antimatter.

Stefan Ulmer, a particle physicist at RIKEN in Wako, Japan, and colleagues analyzed antiprotons and negative hydrogen ions (a proton plus two electrons) one by one inside an instrument called a Penning trap. The trap's electric and magnetic fields forced each particle to zip around in a small circle. By counting the number of revolutions per second and factoring in the strength of the trap's magnetic field, the scientists determined the particle's charge divided by mass. The researchers used the data from the hydrogen ions to calculate the charge-to-mass ratio for protons.

After repeating the experiment thousands of times, the researchers achieved enough precision to say the charge-to-mass ratios of protons and antiprotons are equal to within 69 parts per trillion (but with an opposite sign). "They've done a very clean experiment," says particle physicist Klaus Jungmann of the University of Groningen in the Netherlands.

After failing to find fissures in the standard model, the researchers turned their sights to the general theory of relativity but also came up empty. They found that as particles circled inside the Penning trap, gravity acted on protons and antiprotons with the same strength, just as Einstein's theory predicts.

Ulmer's next goal is to measure the intrinsic magnetism of the antiproton, which, like charge, should be equal but opposite that of the proton (*SN: 6/28/14, p. 15*). "If we detect even a small deviation," he says, "it would have a huge effect on our entire understanding of the laws of nature." ■

LIFE & EVOLUTION

Seeing humans as superpredators

Many hunting, fishing habits may be unsustainable for prey

BY SUSAN MILIUS

To get a glimpse of a superpredator, just look in the mirror. Comparing the hunting habits of various animals reveals humans as Earth's most dangerous, oddball predator — one that targets adult prey in large numbers, a practice that can push populations into decline.

Humans' main prey are reproductive adults, the animals that replenish populations, explains conservation scientist Chris Darimont of the University of Victoria in Canada. He and his colleagues call for people to switch to the hunting patterns of other predators. Such a change would entail targeting the young and taking smaller percentages, the scientists say in the Aug. 21 *Science*.

A shift toward the young would be more sustainable, "consuming the reproductive interest rather than the reproductive capital," says study coauthor Thomas Reimchen, also at Victoria. He acknowledges, though, that changing human habits would not be easy.

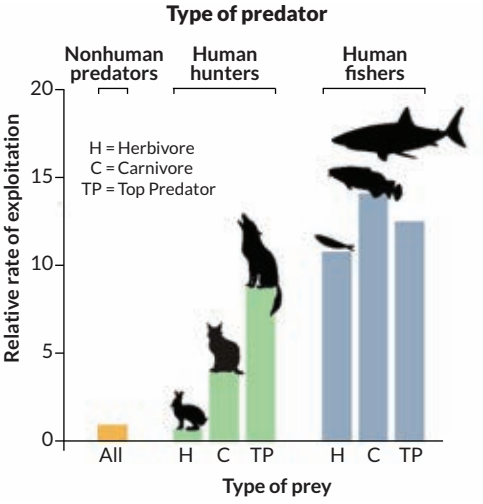
Reimchen has been itching to analyze people as just another predator since 1976, when he was monitoring populations of small fish called threespine sticklebacks in a lake in the Haida Gwaii archipelago off Canada's western coast. Twenty-two predators, including trout and loon, feasted on these fish, yet stickleback population size didn't change much from year to year. These combined predators were eating less than 5 percent of the stickleback mass in the lake, and mostly the youngsters. But not far away in the ocean, Reimchen saw humans catching 40 to 80 percent of adults in several commercial fish populations — a harvest that seemed unlikely to leave these fish populations stable.

About seven years ago, Reimchen finally got his chance to follow up on lopsided fishing rates. He recruited Darimont, also with the Raincoast Conservation Foundation in Sidney, Canada, and two other former students to search out rates of human hunting or fishing recorded for 399 mammals and fishes.

Marine fishers are "the planet's dominant predator of adult prey," Darimont says. Human fishing takes a median of about 14 percent of the total weight of adults out of the sea annually. That's 14 times as high as the median rate of what predatory fish take, the new analysis shows.

In hunts for grazing mammals on land, people kill about 6 percent of adult prey a year, the researchers say. That's roughly what wild carnivores kill. What's unusual about people, though, is their power to turn those other predators into prey. Human predators kill carnivores at about nine times the rate that carnivores kill each other.

On its own, *Homo sapiens* is just a primate without fangs, claws, horns, much running speed or a fabulous sense of smell. But the guns, nets, vehicles, refrigeration and other technologies that people have brought to their hunts have given humans predatory superpowers, Darimont explains.



Bigger bite Human hunters and fishers take a bigger bite out of wild fish and mammal populations (except for terrestrial herbivores) than nonhuman predators do.

Killing animals doesn't always shrink a population over time; more deaths by human hand could just mean fewer caused by other menaces. Yet humans' killing of large carnivores, such as wolves in the Northern Rockies, usually does affect population trends, says behavioral ecologist Scott Creel of Montana State University in Bozeman.

Humans kill plenty of animals besides mammals. Among amphibians, the impact falls mainly on a few of the large-bodied frog species, such as American bullfrogs, "themselves terrific predators," says David Green of the Redpath Museum at McGill University in Montreal. But for birds, at least in the developed world, sport hunting is highly regulated and "unlikely to have much population impact," says David Blockstein of the National Council for Science and the Environment in Washington, D.C.

So for birds and most other land animals, the main threat that humans pose is destruction of habitat. The concept of people as superpredators is useful, Blockstein says. But people are also "superdestroyers." ■

By analyzing humans as just another predator, researchers found a unique pattern of hunting and fishing (fishermen in Alaska hauling in cod, shown) that targets adult animals.

FROM TOP: P. HUEY/*SCIENCE*; NICK RAHAIM/FLICKR (CC BY-NC-SA 2.0)

EARTH & ENVIRONMENT

Volcanism convicted in Permian die-off

Precise dating ties Siberian Traps eruptions to mass extinction

BY THOMAS SUMNER

The biggest catastrophe in the history of life on Earth resulted from one of the most titanic volcanic outpourings on record, new research concludes.

At the close of the Permian period some 252 million years ago, more than 90 percent of all marine species and roughly 75 percent of all land species vanished. New high-precision analysis of ancient lavas places this extinction just after the start of massive volcanic eruptions in what is now Siberia, researchers report online August 28 in *Science Advances*. The finding clinches what paleontologists have long suspected: Volcanic gases prompted environmental changes that made the planet uninhabitable for most life.

The researchers have "found the smoking gun for this extinction event," says geoscientist Richard Ernst of Carleton University in Ottawa.

The Siberian Traps eruptions spewed more than 3 million cubic kilometers of molten rock (*SN: 1/15/11, p. 12*), enough to bury the United States to the height of the Eiffel Tower. Scientists knew this volcanism took place around the time of the Permian extinction but couldn't determine whether the eruptions were the cause of the die-off or just a bystander.

Resolving this issue required precisely dating both the volcanic eruptions and the extinction itself, says Seth Burgess, a geochronologist at the U.S. Geological Survey in Menlo Park, Calif. Burgess and geologist Samuel Bowring of MIT collected rocks from an ancient island chain in China. The rocks contain fossilized evidence of the Permian extinction and ash blasted from nearby volcanoes.

The ash holds zircon crystals, which naturally form with small amounts of uranium that gradually decays into lead. Comparing the relative number of uranium and lead atoms in the zircons provided precise dates for the Permian extinction, the researchers reported last year in the *Proceedings of the National Academy of Sciences*.

The less explosive Siberian Traps eruptions contained few zircons (*SN: 1/10/15, p. 12*). But after scouring the remnants of the lava flows, the pair found and precisely dated 192 crystals and then compared them with the extinction timeline.

Gases from the Siberian Traps eruptions sparked a mass extinction 252 million years ago. Geologists dated the eruptions by analyzing crystals in ancient lavas (shown) in Siberia.

The dates peg the volcanism to around 300,000 years before the extinction and suggest that the eruptions continued for at least 500,000 years afterward. The volcanism probably released huge amounts of carbon dioxide and other volatiles, causing extreme climate change and ocean acidification (*SN Online: 6/14/12*).

"We can now say that this largest preserved magmatic event in Earth's history preceded the onset of mass extinction," Burgess says.

But a big puzzle still remains, says Stanford paleontologist Jonathan Payne. Life took around 5 million years to start recovering from the extinction. "We still don't understand why the Earth system remained unstable for so long after the main pulse of Siberian Trap volcanism appears to have ended," he says. ■

BODY & BRAIN

Altered protein makes mice smart

Genetic tweak points to future treatment for schizophrenia

BY LAURA SANDERS

By tweaking a single gene, scientists have turned average mice into supersmart daredevils. The findings are preliminary but hint at therapies that may one day ease the symptoms of disorders such as schizophrenia, scientists report August 14 in *Neuropsychopharmacology*.

The altered gene provides instructions for a protein called phosphodiesterase-4B, or Pde4B, which has been implicated in schizophrenia. It's too early to say whether Pde4B will be a useful target for drugs that treat these disorders, cautions pharmacologist Ernesto Fedele of the University of Genoa in Italy. Nonetheless, the protein deserves further investigation, he says.

The genetic change interfered with Pde4B's ability to break down a molecular messenger called cAMP. Mice designed to have this disabled form of Pde4B showed a suite of curious behaviors, says coauthor Alexander McGirr of the University of British Columbia in Vancouver. Compared with normal mice, these mice more quickly learned which objects in a cage had been moved to a new location and could better recognize a familiar mouse after 24 hours. "The system is primed and ready to learn, and it doesn't require the same kind of input as a normal mouse," McGirr says.

These mice also spent more time than usual exploring brightly lit spaces, spots that normal mice avoid. But this devil-may-care attitude sometimes made the "smart" mice blind to risky situations: The mice were happy to spend time poking around an area that had been sprinkled with bobcat urine.

Pde4B may play other roles in the brain, McGirr says. And because the protein has jobs in the heart, lungs and immune system as well, it might be difficult to find drugs that have the desired effect on Pde4B in the brain but few side effects elsewhere. ■

SCOTT SIMPER

LIFE & EVOLUTION

Extinction in lab bottle was fluke

Catastrophe wiped out *E. coli* strain, evolution 'replay' shows

BY TINA HESMAN SAEY

Sometimes extinction is just a fluke, a long-term experiment in evolution has shown.

Scientists captured an extinction in a bottle during a study in evolutionary biologist Richard Lenski's lab at Michigan State University in East Lansing. For 27 years, researchers there have been growing 12 flasks of *Escherichia coli*. Those bacteria have been evolving for more than 60,000 generations.

In one of those flasks, some of the bacteria evolved the ability to eat a chemical called citrate (*SN: 1/31/09, p. 26*; *SN: 10/20/12, p. 8*). For more than 10,000 generations, the citrate eaters, called Cit-plus, lived alongside Cit-minus *E. coli* that couldn't digest the chemical. But then sometime between generation 43,500 and 44,000, the Cit-minus bacteria disappeared from the flask, which had food for both. It looked like a clear-cut case of the citrate eaters outcompeting the bacteria that couldn't digest citrate.

Instead, the Cit-minus bacteria's extinction was a "random catastrophe," Lenski and colleagues report online July 19 in a paper posted at bioRxiv.org.

"Even in this highly controlled lab setting, you have major evolutionary events being driven by external shocks to the system," says Carl Bergstrom, an evolutionary biologist at the University of Washington in Seattle. If random chance can cause extinction in the lab, he says, "just think what could happen in a forest or an ocean."

Usually, biologists can only speculate on the cause of an extinction, but Lenski's group can replay evolution. Every 500 bacterial generations, the researchers freeze a sample from the flasks. Samples thawed from this frozen fossil record can be grown again to determine whether evolutionary events play out the same way.

Lenski's team revived samples from generations 40,000 and 43,500, and reran the experiment 20 times each. The scientists thought that after 500 generations, Cit-minus bacteria from generation 43,500 would succumb to the more competitive Cit-plus bacteria. But the noncitrate eaters never went extinct in any of the replay experiments.

The researchers also pitted Cit-minus bacteria against citrate eaters from generations after the extinction. If the citrate eaters had really developed an evolutionary advantage that could kill off the Cit-minus bacteria, the noncitrate eaters wouldn't be able to gain a foothold. But the Cit-minus bacteria were able to hold their own even against Cit-plus bacteria from 6,000 generations after the extinction event.

"Being able to compete an evolved strain against its ancestors is something we can't usually do," Bergstrom says.

Results of the competition replays indicate that the extinction wasn't a matter of the Cit-plus bacteria getting an evolutionary upper hand and driving the Cit-minus bacteria to extinction, the researchers conclude. "We propose, therefore, that the most likely cause of the Cit-minus extinction was a 'random catastrophe,'" the researchers write.

The cause of the catastrophe is unknown. Perhaps soap residue in the flask or water problems may have finished off the noncitrate eaters, the team writes.

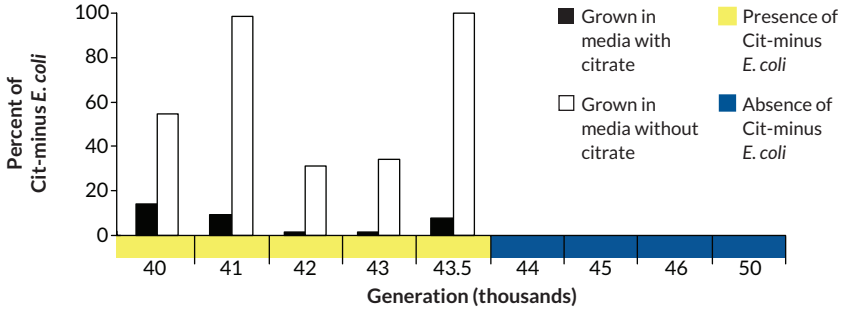
There's almost no chance that the researchers just didn't transfer any of the Cit-minus bacteria to a new flask one day, says Alan Hastings, a population biologist at the University of California, Davis. Lenski and colleagues calculate that there is one chance in $10^{43,700}$ of that happening. "They will never know what event did this," Hastings says. But the results serve as a reminder that "events which may seem insignificant could have very large consequences."

Scientists who study ecology and evolution have debated the role of random chance in determining the fate of species within an ecosystem, says Jonathan Losos, an evolutionary ecologist at Harvard University. Data are lacking on whether "some crazy event can come along and wipe out a species that is doing just fine," he says. "General wisdom is that catastrophic events can finish off a species when it's already in decline." There is no evidence, though, that noncitrate eaters were in decline before they went extinct.

Lenski's team has added a 13th flask to the experiment. This one is an "alternative history" flask that will allow both citrate eaters and noncitrate eaters from generation 43,000 to evolve without the catastrophic event to see what might happen next. ■

Extinction event For thousands of generations, *E. coli* that can't digest citrate (Cit-minus) lived alongside *E. coli* that eat the chemical. When scientists revived frozen *E. coli* samples in media containing citrate, the Cit-minus bacteria were present in low numbers (black bars), but dominated the population when citrate wasn't present (white bars). Sometime between generation 43,500 and generation 44,000, Cit-minus bacteria disappeared from the flask.

SOURCE: C.B. TURNER *ET AL*/BIORXIV.ORG 2015



MATTER & ENERGY

Physicists verify quantum spookiness

Variation on classic test of entanglement closes loopholes

BY ANDREW GRANT

It's official: Quantum mechanics is spooky.

A new experiment provides the best evidence yet that the commonsense concept of locality — that an event on Earth can't immediately influence what happens on Mars, for instance — doesn't apply in the quantum realm.

Researchers have long thought that quantum theory is nonlocal. But airtight experimental confirmation has been difficult to achieve. Now a new paper, posted online August 26 at arXiv.org, closes two loopholes that had cast a smidgen of doubt on previous results from a crucial test.

"Nonlocality is so fundamental and so important for our worldview of quantum mechanics that it's important to achieve such a result," says Nicolas Gisin, a quantum physicist at the University of Geneva. An apparatus similar to the one used in the new experiment could be used to build extremely secure communication networks.

The experiment performed a version of a test proposed by physicist John Bell half a century ago to demonstrate nonlocality in quantum physics. Nonlocality is the hallmark of a phenomenon called entanglement, in which particles — say, a pair of electrons — can be coordinated regardless of the distance between them. An experimenter who determines the spin of an entangled electron immediately knows what the spin of the other electron will be, even though it's essentially spinning in multiple directions simultaneously before it is measured. It's as if entangled particles are parts of one whole: "If you measure one part, the entire system shivers," Gisin says.

Einstein famously decried this "spooky action at a distance." He and other physicists wondered whether a theory more fundamental than quantum mechanics could explain phenomena such as entanglement while preserving locality. In 1964, Bell devised a test that would resolve the dispute. Experimenters would separate entangled particles and independently make any of several measurements on them. Bell showed that there is a limit to the degree those measurement outcomes could match if the world behaves locally.

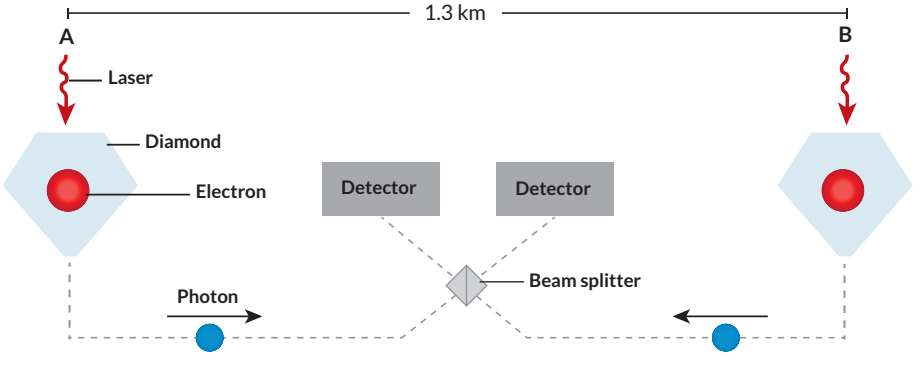
The new Bell test, by quantum physicist Bas Hensen of Delft University of Technology in the Netherlands and colleagues, required two diamond chips that were placed in labs nearly 1.3 kilometers apart. Each chip contained a tiny defect with an electron inside. The researchers zapped the diamonds with lasers, which spurred each chip to emit a photon that was entangled with the electron. Those photons were sent to a third lab (located between the other labs) and fed through a beam splitter. Whenever detectors at the ends of the beam splitter captured two photons at the same time, there was a transfer of entanglement — now the electrons in the two chips were entangled with each other. Then the researchers randomly performed one of two measurements on the electrons' spin. The physicists confirmed that the outcomes of those measurements matched more often than Bell's limit.

> "Nonlocality is so fundamental and so important for our worldview of quantum mechanics that it's important to achieve such a result."
>
> NICOLAS GISIN

While the result supports other tests of Bell's limit over the last four decades, this experiment avoids two pervasive pitfalls. Tests in the 1970s used inefficient detectors that could measure only a small percentage of the entangled particles that passed through them. More recent experiments used nearly perfect detectors, but the entangled particles were close enough together that in principle they could conspire by exchanging light-speed signals. This experiment is the first to overcome both loopholes: The detectors are good, and measurements are made before one electron would have a chance to "communicate" with the other.

Matthew Leifer, a quantum physicist at the Perimeter Institute for Theoretical Physics in Waterloo, Canada, praises the experiment. But, he notes, it took a long time to establish entanglement between electrons — the researchers needed more than nine days to collect 245 data points. He says that a more efficient version would be needed to create secret quantum keys and exchange information securely. ■

Ultimate Bell test A new experiment confirmed quantum spookiness by measuring the spins of entangled electrons inside diamonds. First, lasers spur each diamond to emit a photon. When detectors at a central station simultaneously detect photons, the diamonds' electrons are entangled. Physicists randomly make one of two measurements on each electron and compare the results.



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EARTH & ENVIRONMENT

Katrina's legacy: Refining forecasts

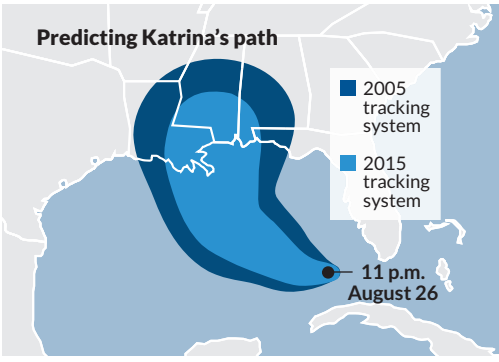
10 years after hurricane, storm warnings have improved

BY THOMAS SUMNER

Ten years ago, the sea and sky rallied to unleash one of the worst natural disasters in U.S. history. During the 2005 Atlantic hurricane season, the most active season on record, 27 named storms — from Arlene to Zeta — swirled into existence. By far, the most destructive was Hurricane Katrina.

Katrina killed nearly 2,000 people and caused an unprecedented $108 billion in damage from the time of its formation over the Atlantic Ocean on August 23, 2005, to its demise eight days later near the Great Lakes.

Yet the disaster also left an enduring — and far more positive — legacy. It has been a driving force for innovations in storm forecasting. Weather gurus say a Katrina-level hurricane will strike the U.S. coast once every 14 years on average. When the next one hits, advances in science and technology will allow earlier and more precise predictions of the storm's path and its surging floodwaters. Forecasters are also working on ways to get a better handle on what triggers a storm's often unpredictable intensification.



Hurricane warpath Meteorologists can predict where a hurricane will strike much more accurately than they could a decade ago. The dark blue shows the potential range of Hurricane Katrina storm paths that meteorologists predicted in 2005, starting in the evening of Friday, August 26. Using new simulations, this range would have been much narrower (light blue). SOURCE: NOAA

These improvements will ultimately save lives, says Kathryn Sullivan, administrator of the National Oceanic and Atmospheric Administration. "We know we still have work to do," she says, but "we're in a much better place now because of the investments we've made over the last decade."

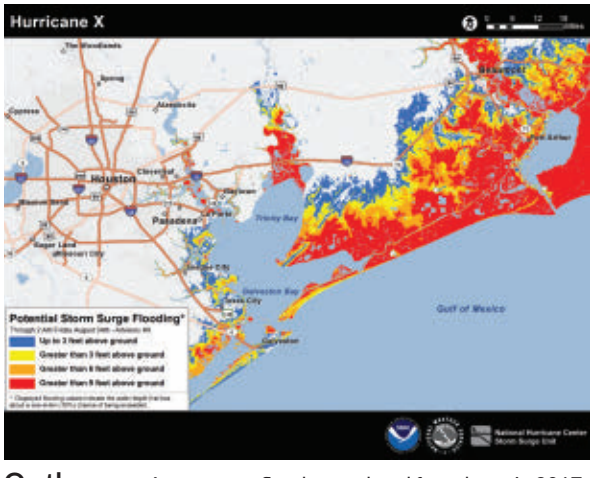
When Katrina was born out of the remnants of a previous storm over the Bahamas, no one suspected that it was just days away from causing massive devastation in Louisiana and Mississippi. The spiraling storm picked up strength and reached hurricane status less than two hours before making its first landfall in southeastern Florida, where it passed directly over the National Hurricane Center in Miami. After losing steam during its cross-Florida jaunt, Katrina revitalized over the warm waters of the Gulf of Mexico. It reached Category 5, the highest designation, a day before slamming into Louisiana, but weakened to a Category 3 before making landfall.

The storm's powerful winds, clocked at over 200 kilometers per hour, shoved seawater inland. This storm surge reached over 8 meters above mean sea level, the highest ever seen in the United States. A levee system constructed to divert storm waters away from New Orleans burst in multiple places, sending floodwaters pouring into residential neighborhoods. At the height of the disaster, about 80 percent of New Orleans was underwater, more than 4 meters deep in places.

Katrina's devastating storm surge highlighted the ineffectiveness of the hurricane category system to adequately convey hazards, says meteorologist Rick Knabb, director of the National Hurricane Center. The Saffir-Simpson Hurricane Wind Scale rates hurricanes based on their peak sustained wind speed. But a hurricane's floods typically cause more damage than its winds do. The widespread destruction of storm surges from relatively weaker storms, such as 2012's Hurricane Sandy, is largely due to an onslaught of seawater. From 1963 to 2012, storm surges caused nearly half of all hurricane fatalities; winds caused about one in 10 deaths, Knabb says.

In 2017, NOAA will launch a new supplemental warning system aimed at communicating the flood risks posed by incoming storms. The prototype mapping system combines multiple storm and flood simulations with detailed land elevation data to precisely predict where and how high above the ground floodwaters will rise. That information can help emergency managers determine which areas to evacuate. This system does not, however, account for breaches or the overflowing of levees, both of which occurred during Katrina.

While the new flood map is still two years out, other improvements are in place now. Over the last 10 years,



On the map A prototype flood map, slated for release in 2017, will provide residents with an accurate warning of where floodwaters will rise. This example shows the storm surge impact of hypothetical Hurricane X striking near Houston. Colored regions represent areas likely to flood, with red signifying places where water could rise more than 2.7 meters (9 feet) above ground level.

FROM TOP: REDMAL/ISTOCKPHOTO, ADAPTED BY E. OTWELL; NHC/NWS/NOAA

hurricane path predictions have become more accurate on every timescale from hours to days.

Advances in computer hurricane forecasting now allow meteorologists to simulate multiple storms simultaneously to account for interactions between weather systems. GOES-R, a weather satellite slated for launch next year, should take these advances even further. The satellite will collect data five times as frequently as current U.S. weather satellites do and provide 60 times the amount of information, says Steve Goodman, senior scientist for the GOES-R program. NOAA hopes these improvements will extend forecasts from five to seven days and provide earlier warnings of gathering storms.

These accurate storm track predictions should result in tighter evacuation zones, easing traffic jams before a hurricane hits, says meteorologist Louis Uccellini, director of the National Weather Service in Silver Spring, Md. Better predictions may also help people take warnings more seriously — fewer would get false alarms to flee, he says.

Despite the improvements, forecasters still have a major blind spot: storm strength. Meteorologists can't explain why storms occasionally strengthen suddenly (*SN Online: 3/20/15*). Huge cloud columns called hot towers appear near the center of some hurricanes just before they rapidly strengthen. With Hurricane Katrina, these hot towers appeared before the storm intensified to a Category 5. Scientists don't know whether these hot towers were the result or cause of hurricane intensification. If they can figure that out, the information could improve intensity forecasts.

While some of these improvements have been used to track typhoons over the Pacific Ocean, major tests of hurricane forecasting improvements in the Atlantic are yet to come. No hurricanes have made landfall along the U.S. coast at Category 3 or above since Hurricane Wilma in 2005 (*SN Online: 4/17/15*). "When each one of these [hurricanes] comes, you find the vulnerabilities in the systems you've designed," says Lt. Gen. Thomas Bostick, commanding general of the U.S. Army Corps of Engineers.

The hurricane drought probably won't end during the current hurricane season, NOAA reported August 6. The agency's Atlantic hurricane outlook calls for a 90 percent chance of a below-normal season — just two or fewer major hurricanes — and a 10 percent chance of an average season, with one to four major hurricanes. That's the highest probability for a below-normal season since NOAA started giving seasonal outlooks in 1998.

Such a quiet season is largely due to the ongoing El Niño, an eastward shift in warm Pacific seawater that disrupts global weather patterns. The current El Niño is on track to be one of the strongest on record, scientists say (*SN Online: 7/16/15*).

Strong El Niño years often precede strong La Niña events, however, which can turbocharge Atlantic hurricane seasons. If the current El Niño gets a blockbuster La Niña sequel, the next big hurricane landfall could be just a year or two away. When it comes, forecasters say, they'll be ready. ■

BODY & BRAIN

E-cigarettes: gateway to real smoking

Teens who vape are more likely to try tobacco than nonusers

BY MEGHAN ROSEN

E-cigarettes may tempt kids into trying tobacco.

Teens who use e-cigarettes are more likely to start smoking cigarettes, cigars and other tobacco products than teens who don't use e-cigarettes, researchers report in the Aug. 18 *JAMA*. The study is the first to draw a clear link between e-cigarette use and later experimentation with tobacco.

"The question of whether e-cigarette use promotes cigarette smoking has now been answered — and the answer is yes," says tobacco control researcher Stanton Glantz of the University of California, San Francisco.

Unlike tobacco products, e-cigarettes can be advertised on TV and radio in the United States and — in some states — sold to minors (*SN: 7/11/15, p. 18*). E-cigarettes don't contain tobacco, but usually deliver hits of nicotine and other chemicals and come in flavors like cotton candy that appeal to kids.

The number of teens who have tried e-cigarettes more than doubled from 2011 to 2012. Last year, Glantz and UC San Francisco colleague Lauren Dutra reported that e-cigarette users are more likely than nonusers to smoke tobacco.

But because that study didn't follow users over time, the researchers couldn't say whether e-cigarette use led people to try tobacco. "We got yelled at because we suggested that e-cigarettes were promoting smoking," Glantz says.

Some scientists have argued that e-cigarettes actually prevent smoking by giving teens a tobacco-free product to choose, says addiction scientist Adam Leventhal of the University of Southern California in Los Angeles.

Leventhal and colleagues asked 2,530 nonsmoking ninth-graders from 10 Los Angeles public high schools about their background, family history and habits. Of those students, 222 had used, or vaped, e-cigarettes. The team repeated the survey after six months and again after a year. Compared with kids who didn't use e-cigarettes at the beginning of ninth grade, those who did were about three times as likely to start smoking tobacco products during the year.

The findings "blow away one of the head-in-the-sand arguments that a lot of the e-cigarette advocates have been making," Glantz says.

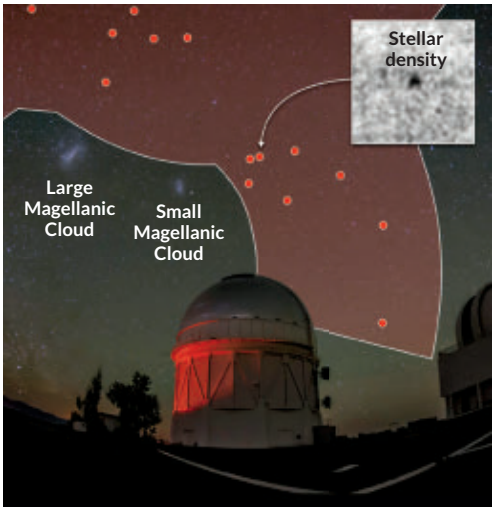
Leventhal plans to continue following the study's participants to find out if teens who use e-cigarettes are more likely than nonusers not just to experiment with tobacco but also to become hooked on it. ■

ATOM & COSMOS

Eight more galaxies found orbiting the Milky Way

The neighborhood around our galaxy is getting a little crowded. Eight more satellite galaxies have been found buzzing around the Milky Way, researchers report online August 16 at arXiv.org. This brings the number of known Milky Way cohorts to nearly 50 when combined with nine other satellites discovered earlier this year (*SN: 4/4/15, p. 6*).

Our galactic groupies are pint-size — the smallest contains just 161 stars — and sit between about 80,000 and 700,000 light-years from Earth. These teeny tagalongs are almost entirely made of dark matter, which makes them excellent laboratories for studying the elusive substance that holds galaxies together. — *Christopher Crockett*



Seventeen satellite galaxies (some marked with red dots in the sky above an observatory in Chile) have been found around the Milky Way this year, including eight just announced. These galaxies are often too faint for images, so scientists use maps of star density (inset) instead.

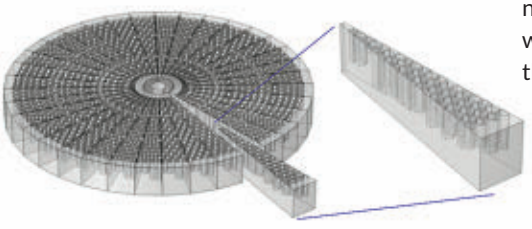
MATTER & ENERGY

3-D–printed device cracks cocktail party problem

A 3-D–printed plastic disk can help pick out a voice from a crowd, a task that's easy for people but not for technology (*SN Online: 4/18/12*). The device could lead to improved voice recognition and hearing aids, researchers report in the Aug. 25 *Proceedings of the National Academy of Sciences*.

To solve what scientists call the cocktail party problem, Duke University electrical engineer Steven Cummer and colleagues built a pizza pie–sized disk (illustrated below) that was divided into 36 wedges and imprinted with centimeters-high hexagonal cells. The heights of the cells varied in each wedge so that incoming sound waves would propagate differently depending on their frequency.

The researchers placed the disk in an echo-free room and installed three speakers that blared random words at the same time. After a microphone at the disk's center recorded the sound waves that had traveled inward, a computer algorithm successfully identified what was said and from where. — *Andrew Grant*



BODY & BRAIN

Hints emerge of how the brain visualizes dreams

Nerve cells that help us see the world stay on the clock during sleep, too. The spooky eye movements associated with REM sleep — and the ensuing nerve cell behavior — may help people "see" their dream world, scientists report August 11 in *Nature Communications*.

The results come from a study conducted on people who had electrodes implanted deep into their brains as a treatment for epilepsy. Those electrodes eavesdropped on individual nerve cells, or neurons, in the medial temporal lobe, a brain area known to help make sense of visual information. When people moved their eyes while awake, single neurons in the MTL showed distinct behavior, becoming sluggish just before rapid eye movements and springing into action just afterward. The neurons behaved similarly during REM sleep, a stage of sleep that often comes with vivid dreams.

Because participants weren't asked about the quality of their dreams, researchers can't yet say how the neurons' behavior might relate to dream imagery. — *Laura Sanders*

GENES & CELLS

Copied genes help explain octopus intelligence

Octopuses and mammals may come by their smarts in a similar way.

The California two-spot octopus (*Octopus bimaculoides*) has nervous system development genes similar to those found in intelligent vertebrates like humans, researchers report in the Aug. 13 *Nature*. The first complete analysis of the octopus's genome reveals genetic reorganizations that separate the brainy, complex animal from its simpler relatives.

The octopus's genome largely contains the same basic material as other mollusks, report Daniel Rokhsar, an evolutionary biologist at the University of California, Berkeley and the Okinawa Institute of Science and Technology Graduate University in Japan, and colleagues. But specific groups of octopus genes have been duplicated and rearranged.

One highly copied group contains genes with instructions for making proteins called protocadherins. Having a greater variety of these proteins, which play a role in nervous system development, enables the construction of more complex neural networks, Rokhsar says. While limpets and oysters have about 20 protocadherin genes, the octopus has 168, the researchers found. Mammals also produce a large variety of protocadherins but use fewer genes to do so.

The findings suggest that although octopuses and vertebrates both evolved diversity in these proteins, they did so through different mechanisms, says Jan Strugnell, an evolutionary biologist at La Trobe University in Melbourne, Australia. — *Sarah Schwartz*

FROM TOP: DARK ENERGY SURVEY COLLABORATION; Y. XIE *ET AL*/*PNAS* 2015

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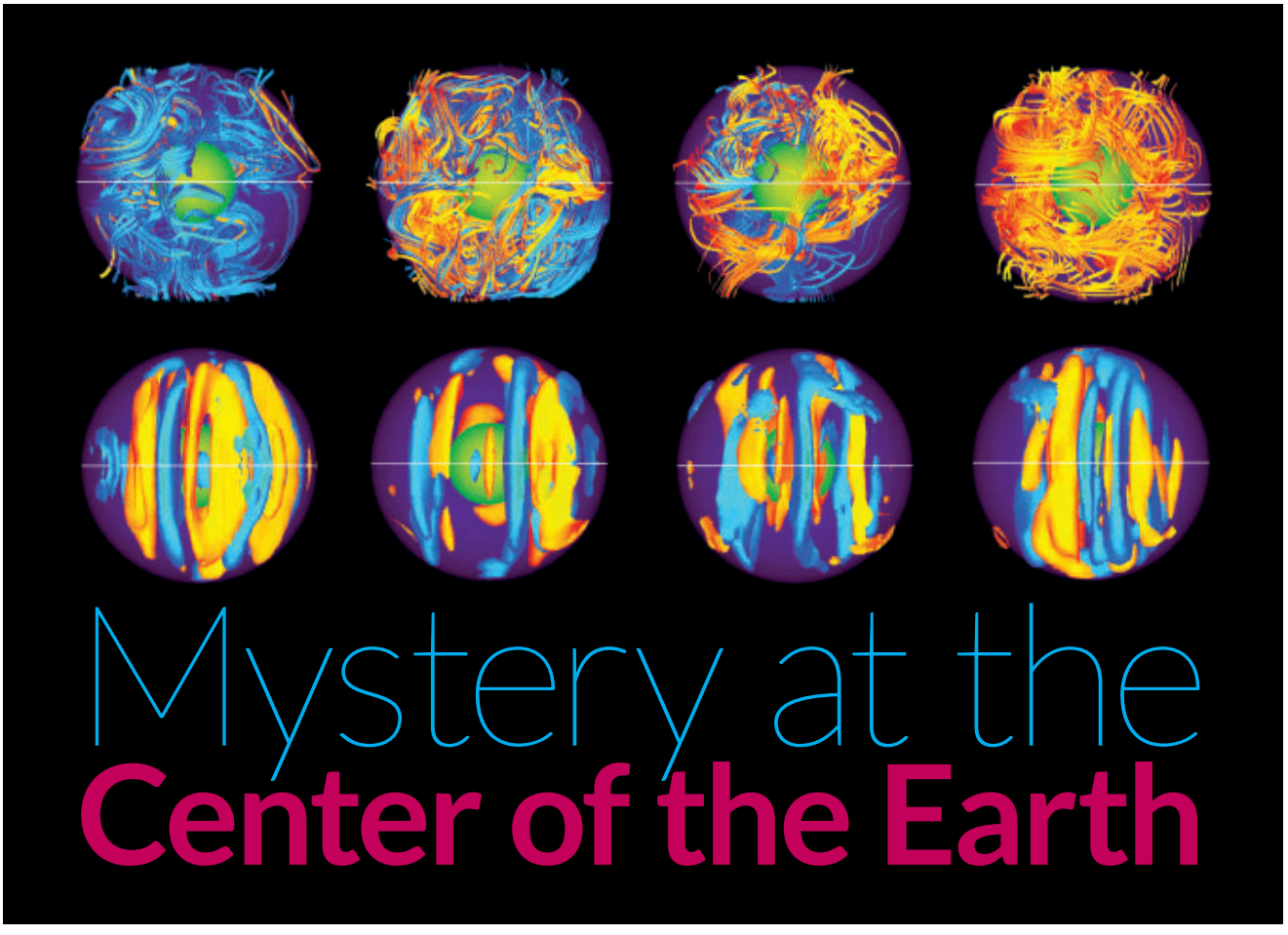


Mystery at the Center of the Earth

New research attempts to unravel the paradoxical past of the planet's magnetic field

By Thomas Sumner

Earth's depths are a hellish place. More than 5,000 kilometers belowground, the iron-rich core scorches at temperatures comparable to the sun's surface and crushes at pressures akin to the weight of 20 blue whales balanced on a postage stamp.

This extreme environment helps generate Earth's magnetic field, the planetwide force that makes life on the surface possible. When the sun occasionally belches a blast of electrically charged particles at Earth, the magnetic field redirects the incoming bombardment. Without this magnetic defense, solar storms would fry any unsuspecting life-forms on the surface and gradually strip away Earth's atmosphere (see Page 5).

For decades, scientists debated and fine-tuned their understanding of Earth's magnetism. Heat flowing through the liquid outer core helps slosh the molten iron, generating a magnetic field, the general consensus holds. In the last few years, however, new investigations of Earth's magnetic bodyguard have thrown a wrench into any sense of common ground. In 2012, scientists proposed that iron in the planet's core conducts heat more readily than previously thought. That would imply less mixing in the outer core and a young Earth with only a meager magnetic field, if any at all. Yet ancient rocks reveal magnetic records of an early, powerful magnetic field protecting the planet billions of years ago.

In January, supercomputer simulations offered a possible resolution to this paradox. Simulating how electrons ricochet around iron atoms at the extremes of temperature and pressure found in Earth's core suggested that iron's heat conductivity could actually be low enough to allow a strong magnetic field during Earth's youth. For a few brief weeks, researchers thought the mystery might be solved. In recent months, however, actual experiments using diamonds and lasers to recreate the intense conditions of the planet's core raise doubts

In a computer simulation, magnetic field lines (top row) twist and curl around the Earth's liquid outer core. This magnetism results from swirling, or convecting, liquid iron (bottom row). The simulation mimics the process of a polarity reversal in which Earth's north and south magnetic poles swap. Such reversals, a sign of a strong magnetic field generator, are seen going back hundreds of millions of years in planetary history.

P. OLSON/JOHNS HOPKINS UNIV.

that the paradox will be resolved so easily.

While the rising and falling conductivity predictions may seem like scientists running in circles, it suggests that a solution could be close, says Peter Driscoll, a geophysicist at the Carnegie Institution for Science in Washington, D.C.

"The community is never going to converge toward a solution until people start pushing from both directions," he says.

Freezing over hell

Earth's core is a giant heat-powered engine fueled mainly by energy left over from cosmic collisions, such as the one that formed the moon about 4.5 billion years ago. As the planet gradually cools off, this primordial heat flows through the liquid outer layers that surround the solid inner core. Some of the thermal energy transfers freely from atom to atom via conduction. The material remains stationary while the heat flows through it, like a cast iron skillet warming on a stovetop. When the heat flowing through a material exceeds what the material can handle through conduction, warmer patches can rise like the heated air in a hot air balloon, creating convection. In convection, the material itself moves.

This convection swirls the molten iron in the outer core. The sloshing liquid serves as a dynamo (*SN: 5/18/13, p. 26*). Within an existing magnetic field, a dynamo acts as an electrical generator to induce an electrical current in the flowing iron. This action produces its own magnetism, which strengthens and sustains the original field. If more heat flows by conduction rather than by iron-stirring convection, the dynamo weakens and the magnetic field wanes.

Five years ago, scientists thought that the iron in Earth's outer core transported a significant fraction of its heat through convection. In 2012, rather abruptly, everything changed. Several research groups independently proposed that more heat in the core moved via conduction, at a rate of about 150 to 250 watts per meter per kelvin. (The conductivity represents how many watts of thermal energy would pass through a 1-meter cube with a 1 kelvin temperature difference between two opposite sides.) That conductivity was about three times the value, 46 to 63 W/(m•K), scientists had previously used. With such a high conductivity, thermal convection in the core would be weak, if present at all. The magnetic field was in trouble.

"That's just an alarming statement to make," Driscoll says. "It's rare to see a jump effectively overnight by a factor of three." A robust magnetic field driven by thermal convection alone suddenly seemed unlikely.

Lucky for most forms of modern life, thermal convection isn't the only way to drive a dynamo. As Earth cooled, the iron in its core began to freeze from the inside out. The solid inner core currently grows by as much as 6,000 metric tons every second. Lighter elements such as oxygen and sulfur mixed in with the solidifying iron are expelled into the outer core. The buoyancy of the ousted elements helps churn the outer core and keep the dynamo running. So far, only about 4 percent of the core has frozen, leaving plenty of energy to keep the magnetic field going for potentially billions of years.

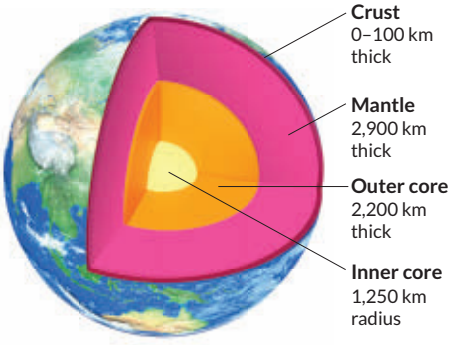
While the magnetic field's future is accounted for, its past still poses a problem. The 2012 conductivity estimates suggest that the inner core started freezing only within about the last 1 billion years. Before then, the sluggish thermal convection in the core could have generated only a weak magnetic field.

Yet the rock record shows otherwise. In July, geophysicist John Tarduno of the University of Rochester in New York and colleagues presented in *Science* the oldest record of Earth's magnetic field. By measuring magnetic impurities embedded inside ancient Australian crystals, the researchers demonstrated that a relatively powerful magnetic field varying between roughly 12 to 100 percent of its present-day strength enveloped Earth from about 4.2 billion to 3.3 billion years ago.

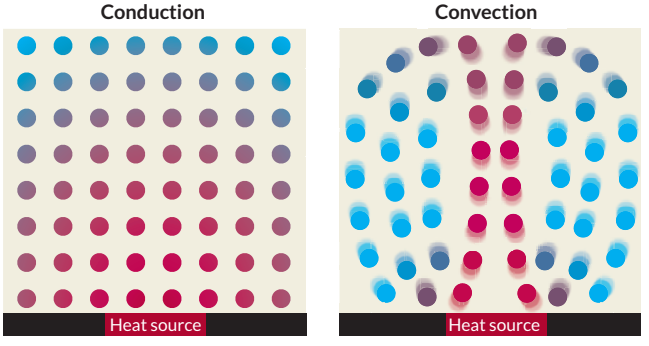
Earth's magnetic history since those early days is similarly confusing. Geophysicists expect that the field strength suddenly increased when lighter elements leaving the inner core began stirring the dynamo in a new way. "You have this new power source," says Peter Olson, a geophysicist at Johns Hopkins University. "You're plugging the dynamo into a 240-volt socket instead of a 120-volt socket — you should see that effect." But no such jump exists in the data, he says. In a 2013 paper in *Science*, Olson gave these dynamo dilemmas a name: the new core paradox. The mainstream theory and history of

Gooey center Below Earth's exterior lies the semimolten mantle, which makes up 84 percent of the planet's volume. Beneath the mantle is the iron-rich core. Once entirely liquid, the core is freezing from the inside out, creating a growing solid inner core.

SOURCE: USGS



Warm up Heat flows through Earth's liquid outer core by both conduction and convection. During conduction (left), heat (red) hops between stationary atoms. In convection (right), hot patches rise like molten globs in a lava lamp and cool patches (blue) fall. The movement churns iron in the liquid outer core and helps generate the planet's magnetic field.



FROM TOP: STOCKERNUMBER2/SHUTTERSTOCK, ADAPTED BY E. OTWELL; E. OTWELL

Earth's magnetic field just didn't match up, he wrote.

The 2012 papers that spawned the paradox were not the last word on the conductivity of Earth's core, however. Temperatures in the planet's heart can reach 6,000° Celsius and pressures can exceed 3 million times the atmospheric pressure at sea level. Without a real-life *Journey to the Center of the Earth*, there's no way to gather direct measurements. And scientists currently can't make accurate conductivity measurements for such extreme conditions in the lab. Instead, experiments typically take place at lower temperatures, below around 1,700°. The results from these more moderate conditions are then extrapolated to the conditions found in the core.

This extrapolation could introduce ambiguity because it assumes that iron doesn't significantly change its behavior between experimental and core conditions. But it just might. Earlier this year, researchers announced that the higher conductivity estimates may have overlooked something in the gap between relatively modest experimental conditions and the harsh environment in Earth's core — something that could possibly resolve the new core paradox.

Electron pinball

Understanding the conductivity of iron requires a deep knowledge of how electrons zip and whiz around iron atoms. In metals such as iron, free-moving electrons ferry electric charge and thermal energy. How readily iron conducts electricity and heat depends on how easily these electrons can travel.

At the temperatures and pressures found on Earth's surface, most of the resistance to the moving electrons is thought to come from the iron atoms themselves. Electrons collide with vibrating iron atoms, restricting the flow of electricity and heat. The iron in the core, however, acts very differently. Pressure in the core squeezes iron to more than 1.6 times its normal density, and the abundant heat gives electrons a speed boost.

Instead of trying to replicate core conditions in a lab, geophysicists Ronald Cohen and Peng Zhang of the Carnegie Institution for Science and colleagues created a detailed digital simulation of the iron in Earth's core. While previous versions used a simplified view of how electrons can interact, Cohen's team precisely tracked each individual electron's activities.

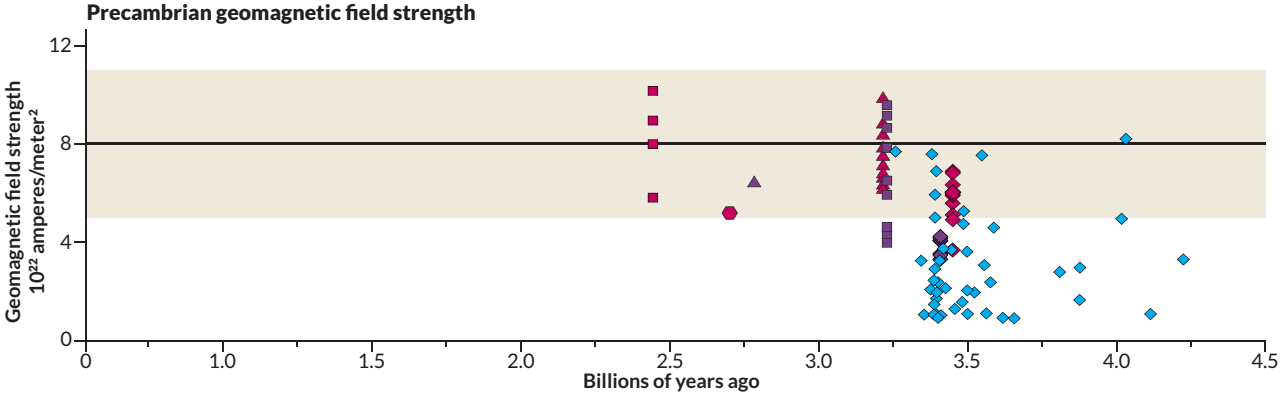
"We pulled out the big guns and accounted for every possible interaction," says Cohen. "We're doing the same type of calculation they do for predicting properties in high-energy physics at the Large Hadron Collider."

The team's simulation starts with a bundle of hundreds of iron atoms at the temperatures and pressures found in Earth's core. The computer program crunches all the quantum forces acting between each iron atom and electron before nudging every particle slightly forward in time. This process repeats over and over again until these snapshots create a video of how the electrons move around. The sheer number of simulated particles and the complex interactions between them are incredibly time consuming to calculate. Even with supercomputers, the simulation can't actually compute the exact conductivity. The researchers instead repeat the experiment again and again until the program can estimate the conductivity of iron with a low enough amount of uncertainty.

At the temperatures reached during earlier lab experiments, Cohen's simulation agreed with the previous higher predictions of iron's conductivity. Above around 1,700°, however, an overlooked interaction took center stage. In addition to electrons scattering off of vibrating iron atoms, the thermally energized electrons crossed paths more often and started colliding with each other. At core conditions, this electron-electron scattering became just as important as the electron-iron scattering. This addition essentially doubled the resistivity, which cut the thermal conductivity to about 105 W/(m•K), roughly half the 2012 estimates, the researchers reported in the January 29 *Nature*.

"Geophysicists can use our numbers and make the geophysics work," Cohen says. "They can explain the history of Earth's dynamo the way they want to and have been doing for some years."

The new conductivity estimate can indeed make the dynamo work, Olson and colleagues reported in the June issue of



Powerful protector In July, an analysis of ancient rocks suggested that a strong magnetic field has protected Earth for at least 4.2 billion years. The new magnetic measurements (blue diamonds) join a number of other studies that demonstrate that the planet's magnetic field has remained consistently strong throughout Earth's history. Tan shading represents the range of the modern magnetic field strength.

SOURCE: J. TARDUNO/UNIV. OF ROCHESTER

E. OTWELL

Physics of the Earth and Planetary Interiors. Plugging the new number into a simulation of heat flow through Earth's interior resulted in a convection-driven dynamo before the inner core formed. In this scenario, the magnetic field would still strengthen alongside the formation of the inner core. This magnetic boost, however, would be smaller, thanks to the boost in thermal convection, and could blend in with the natural variations in the magnetic field strength, says Aleksey Smirnov, a geophysicist at Michigan Technological University in Houghton.

Many geophysicists were cautiously optimistic that the new, lower thermal conductivity value could help undo some of the thorny problems that had arisen in recent years. The new conductivity was still only theoretical, however. It needs experimental results to confirm the presence of electron-electron scattering at higher temperatures. But so far, that's been hard to do.

Physicists reproduce the extreme conditions of Earth's interior by squeezing iron samples between two gem-quality diamonds.

Under pressure

Re-creating the intense conditions of Earth's core requires finesse and a bit of bling. In his lab at the Tokyo Institute of Technology, high-pressure mineral physicist Kei Hirose and colleagues put the squeeze on disks of pure iron using a diamond vise. The iron samples are tiny — only around 20 micrometers in diameter and 10 micrometers thick, about a tenth the thickness of a sheet of copier paper. These small dimensions help the researchers evenly compress and heat the samples to something akin to the extreme conditions in the center of the Earth.

The iron goes between the tips of two 0.2-carat diamonds, which are unlikely to crack or warp under the extreme forces required during the experiments. Hirose likens the shape of the diamonds to Mount Fuji, each roughly cone-shaped with a tiny flat peak where the sample sits. The researchers gradually squeeze the two diamonds together for around 30 minutes until the iron is under corelike pressures. A carefully aimed infrared laser then heats up the sample to several thousand degrees. At last the sample is ready for examination.

Because the electrons in iron move both electric charge and heat, Hirose and colleagues can measure the electric conductivity and from that, infer the thermal conductivity. The researchers attach electrodes, typically made of gold or platinum, to the iron and run a current through the sample. The drop in the voltage across the sample lets the researchers know how strongly the iron resists the flow of electrons.

Recently Hirose's team conducted experiments above the approximately 1,700° threshold at which Cohen's group predicted electron collisions would become important. The experiments showed no evidence of electron-electron scattering, Hirose says. In fact, the experiments threaten to make the paradox even worse. The work suggested iron could be even more conductive as temperature climbs, and therefore less likely to convect, than previously thought.

In 2013, Hirose and colleagues predicted such a trend in *Physics of the Earth and Planetary Interiors*, suggesting that iron eventually reaches a point where the average distance an electron travels before bumping into an atom is comparable to the distance between each iron atom. At this point, with fewer remaining obstacles to bump into, the resistance to the movement of electrons will plateau even as temperatures continue to rise, they argue.

"Well, then we're back to the paradox for now, it seems," Smirnov said after hearing about the Hirose group's new findings.

Even with such high thermal conductivity values, the new core paradox may still be solvable, Driscoll said in May at a meeting of the American Geophysical Union and other organizations. A large enough heat flow through Earth's interior can generate convection even when conductivity is high, he says.

Extra heat could come from the decay of radioactive elements, he proposes. In April, researchers reported in *Nature* that the core could contain a significant amount of radioactive uranium and thorium. Driscoll calculates that even a relatively small amount of radioactivity in the modern core would translate into a sizable boost to the ancient magnetic field. If just a small amount of radioactivity warms the core today, that would mean that billions of years ago plenty of radioactive atoms would have been around to help fuel the heat flow, he explains.

"There are other knobs you can turn to get yourself out of the problem," Driscoll says.

Cohen, for his part, remains confident that electron-electron scattering causes lower core conductivity. "We've gone back and rechecked the robustness of our results, and it seems very strong," he says. He points out that experiments replicating the conditions in Earth's core can be finicky. It's possible Hirose and colleagues actually reached a lower temperature than they reported. Upcoming experiments by other research groups could still swing the pendulum one way or the other, he says.

For now, the riddle surrounding Earth's core and magnetic field will remain, as scientists debate what exactly is going on thousands of kilometers beneath the planet's surface. "I'm sure there's going to be a lot of back and forth over the next few years," Olson says. "But this is a good problem to have. This is the type of thing that gets people off their butts and motivates them to do more work." ■

Explore more

- Peter Olson. "The geodynamo's unique longevity." *Physics Today*. November 2013.

K. HIROSE/TOKYO INSTIT. OF TECHNOLOGY

Fired-Up Apes

Chimps show their smarts and fuel an evolutionary debate

By Bruce Bower

A male Fongoli chimp pokes a tool into a termite mound to get a protein-rich insect snack.

MINT IMAGES - FRANS LANTING/GETTY IMAGES

Wildfires dart through tall grass and tree stands at Fongoli, Senegal, during a roughly seven-month dry season. Chimpanzees living in this West African savanna coolly monitor the approaching fires from perches in trees or from ravines. As flames near, the apes retreat just enough to stay safe, sometimes climbing a tree or scurrying into nearby woods.

Because they predict how and where wildfires will move, Fongoli chimps don't get burned, says anthropologist Jill Pruetz of Iowa State University in Ames. It's not a simple task—flame height, fire intensity, wind direction and other factors demand consideration.

Researchers have long used chimp behavior as a window on how ancient hominids lived. Grasping how fire behaves under different conditions represents a mental stepping stone that human ancestors must have reached before learning to control and start fires, Pruetz and Thomas LaDuke of East Stroudsburg University in Pennsylvania proposed in the *American Journal of Physical Anthropology* in 2010. Members of the *Homo* genus, an evolutionary category that includes present-day humans, may have made campfires 1 million years ago or more (*SN: 5/5/12, p. 18*).

Since the Fongoli report appeared, research into chimp thinking and behavior has heated up. New investigations indicate that these apes possess sophisticated knowledge about food, fire and tools. Chimps don't roast marshmallows around campfires, but they may appreciate that certain foods taste better when heated. Chimps also take a more varied, equal-opportunity approach to hunting than previously thought. And some chimps are surprisingly dexterous in their tool use, wielding twigs with a repertoire of hand grips to break open soil tunnels where tasty termites reside.

Chimps (*Pan troglodytes*) and their sister species, bonobos (*Pan paniscus*), are humans' closest living relatives. Scientists suspect a common ancestor of people, chimps and bonobos lived in Africa 5 million to 7 million years ago. Genetic evidence suggests that chimps and bonobos split from a common ancestor about 2 million years ago.

Chimps have received the bulk of researchers' attention, largely because chimps outnumber bonobos in the wild. Also, bonobos inhabit a politically volatile part of Central Africa.

Some hominid researchers dismiss the assumption that today's chimps or bonobos can illuminate ancient hominid behavior. But scientists who study chimps remain undeterred. If chimp communities are capable of generating distinctive cultural traditions (*SN: 6/16/12, p. 18*), mental life must run deep among these apes.

"Chimps are incredibly complex animals," says Harvard University psychologist Alexandra Rosati. "It's hard to know all that they are capable of doing and thinking, even after observing them for months or years in the wild."

Chimps have exceeded researchers' expectations for more than 50 years. Starting in the 1960s, Jane Goodall documented, to her surprise, how chimps in East Africa's Gombe Stream National Park hunted monkeys for meat and used twigs to extract termites from mounds in the ground. She witnessed fierce male power struggles, killings of neighboring group members and intimate bonds that formed between females and their young. A half century later, researchers inspired by Goodall conduct field and laboratory work aimed at better understanding what makes chimps, and perhaps what made ancient hominids, tick.

Get cooking

Consider that wild chimps, including Fongoli's flame-trackers, may know more about fire and heat than they let on.

Wild-born chimps living in a sanctuary in the Republic of the Congo understand that raw food can be cooked, and they appear to prefer cooked over raw, Rosati and Harvard psychologist Felix Warneken reported in the June 22 *Proceedings of the Royal Society B*.

"Chimps will even save food if they think it will be cooked later," Rosati says.

True, chimps have little motivation to cook, because their menu in the wild largely consists of fruits and leaves with only occasional small prey, Rosati says. Plus cooking usually draws a crowd, creating opportunities for food theft.

But chimps seem to know that some foods taste better heated.

Rosati and Warneken probed the hankering for cooked food in a group of 29 chimps. The researchers found that the chimps usually chose to eat sweet potato slices that were briefly roasted for 1.5 minutes in a dry pan rather than raw slices.

In one experiment, each of 16 chimps had 10 chances, or trials, to choose to wait one minute for three cooked potato slices or take one raw slice right away. The chimps waited for cooked slices in 84 percent of trials. Given the chance to wait for three raw slices, they did so in only 60 percent of trials.

A third experiment exposed chimps to a round-bottomed container that turned raw into cooked slices and a cylindrical container that left raw slices unchanged. The animals quickly learned to select the cooking device over its alternative to obtain potato slices. After watching a researcher place potatoes into both containers, a group of chimps chose potatoes from the cooking device and ate them in nearly 88 percent of trials. Chimps even put a new food, carrot slices, in the cooking device more often than in the other container.

Chimps rarely placed inedible wood chips in the round-bottomed container, Rosati says, suggesting that they understood that the vessel was for cooking food. In a series of trials, chimps carried raw potato slices across the testing room to place them in the cooking device more than half the time rather than eating raw slices right away (*SN Online: 6/2/15*). Finally, five of 13 chimps consistently saved raw potato slices for several minutes until an experimenter showed up with the cooking device.

An understanding that certain foods taste better after exposure to fire and heat may go back millions of years to a common ancestor of people and chimps, Rosati proposes. Knowing about naturally roasted fare, early fire-tamers got cooking right away, in her view. That was a big deal, because increased energy available from cooked foods would have fueled brain expansion in *Homo* species over the last 2 million years, as Harvard anthropologist Richard Wrangham has argued.

Wait for it

Researchers have mixed reactions to the possibility of cooking-savvy chimps.

If chimps understand what it means to cook food, including meat, "I wouldn't be surprised," says biological anthropologist Craig Stanford of the University of Southern California in Los Angeles. Captive chimps prefer cooked meat if they grow up eating it. And wild chimps have been observed collecting and eating charred seeds and nuts from areas recently engulfed by wildfires.

Anthropologist Julie Lesnik of Wayne State University in Detroit has a different interpretation of Rosati and Warneken's experiments. Her

Some like it hot

In a series of experiments, chimps living in an African sanctuary preferred cooked over raw sweet potatoes. Some chimps even saved slices in anticipation of having access to the cooking vessel. Numbers below reflect percent of trials in which chimps took action.

SOURCE: F. WARNEKEN AND A. ROSATI/*PROC. R. SOC. B* 2015

Percent of trials:

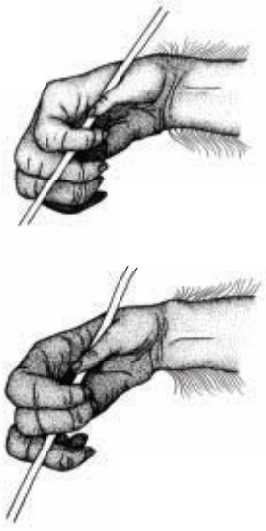
84 percent
Chimps waited for cooked potatoes

77 percent
Chimps placed raw potato in cooker

61 percent
Chimps carried raw food to cooker

10 percent
Chimps placed wood chips in cooker

7 percent
Chimps carried raw food to device that didn't cook



Holding patterns
In one wild community, chimps wield sticks with various grips to open termite mounds. The pencil-like grips shown here are often used to clear away loosened soil after penetrating termite tunnels with a more forceful grip.
SOURCE: J. LESNIK *ET AL/AM. J. PHYS. ANTHROPOL.* 2015

takeaway from the studies: Chimps notice which distinctively shaped container yields better-tasting food. "I'm not convinced we wouldn't see similar results with baboons, dogs or pigs tested in the same way," Lesnik says.

Psychologist Michael Beran of Georgia State University in Atlanta agrees. Further trials should test if chimps understand that certain foods, such as banana slices, taste worse after a spell in the cooking device, he says.

Chimps' ability to show patience in pursuit of more or better food, cooked or not, has also proved hard to pin down, Beran says. In the new cooking study, for instance, animals pointed to indicate whether they wanted to receive one raw potato slice right away or three raw or cooked pieces after waiting one minute. Those who chose to wait for more had no access to food until a minute was up, and therefore had no opportunity to change their minds. That type of pointing test has been used for several decades to study self-control in primates, birds and other creatures.

But many animals, including chimps, tend to point at the larger of two piles of food simply because it's bigger, Beran says. To explore that possibility, Beran and his colleagues tweaked the standard pointing task. After pointing at a smaller amount of food — say, four pieces of cereal instead of 12 pieces — an animal immediately gets the smaller stash. If an animal points at the larger amount, an experimenter puts those cereal pieces within reach one at a time. Food accumulation stops when anything gets eaten.

Chimps show impressive self-control on this task, although some are more patient than others, Beran and colleagues reported last year in *Animal Cognition*. The researchers studied 19 chimps, ages 18 to 44, living in groups at two primate research centers.

Some animals almost always chose 12 delayed rather than four immediate cereal pieces or grape slices. Even when pieces of food were presented every 20 seconds — a long time to wait when staring at available grub — 14 of 19 chimps regularly held out for a larger snack than they would have gotten right away.

Chimps, and perhaps other apes, control their impulses and anticipate future rewards better than other nonhuman primates, Beran suspects. In 2013, he and his colleagues reported that 18 capuchin monkeys tested on the self-control task frequently pointed at the bigger food amount but typically failed to wait long enough to collect more food than was available right away.

Self-control, combined with powerful memories of past experiences and familiar landmarks, enables wild chimps to follow a plan. They've been known, for example, to retrieve nuts from nut-bearing trees and collect nut-cracking stones from rock-strewn areas, Beran says. The chimps will then take those items to places with flat boulders that can be used as natural anvils for breaking nuts open.

People call on self-control to achieve goals more distant than chimps can imagine, Beran says. Humans would store nuts and nut-cracking stones near boulder sites for future use, an option chimps don't consider. Still, on a sliding scale of temptation control, chimps lie closer to humans than to capuchins, Beran suspects. Whether ancient hominids resembled modern chimps in this crucial ability is unknown, he says.

Female hunters

In the wild, as in Beran's lab, grabbing a bite demands patience. Male chimps at Gombe and other forest sites can spend hours scaling and swinging through trees when hunting speedy colobus monkeys. Once the prey is caught and killed, patience flies out the window. Hunters eat much of the meat on the spot. They save small portions to dole out to females in exchange for sex.

Researchers have often thought of hunting as an infrequent, male-only affair among chimps. That assumption may apply to forest-dwelling chimps whose main prey are monkeys, but Fongoli's savanna chimps practice a different, more inclusive form of hunting, Pruetz says.

At Fongoli, many community members, and especially females, jab pointed sticks into holes in trees where palm-sized primates called bush babies sleep during the day, she and her colleagues reported April 15 in *Royal Society Open Science*. The goal: immobilize a hidden bush baby, drag it out of its nest, kill it and eat it.

Fongoli chimps taper branch ends with their teeth before heading out to flush small bush babies out of their tree nests and grab them (*SN: 3/3/07, p. 131*). Pruetz's team tracked this behavior from 2005 through 2014. Although females made up 43 percent of the Fongoli chimp community during that time, they hunted bush babies with sticks 175 times, compared with 130 such hunts by males. Female chimps averaged 10.6 hunts each, versus 6.8 hunts by each male chimp.

More than 4 million years ago, hominids may have participated in similar types of small-mammal hunts, Pruetz speculates. East African

ALESSANDRA KELLEY

landscapes at that time resembled Fongoli's savanna and could have supported hunters of both sexes, she says.

Whatever early hominids were up to, Pruetz rightly emphasizes chimps' ingenuity in using tools to find food, Stanford says. While studying chimps in Gombe's thick jungles, Stanford twice observed chimps poke sticks into holes on the sides of trees until woodpeckers flew out. The apes then used their sticks to break woodpecker eggs nestled inside. Yolks were scooped out and eaten.

Fongoli is not the only place where females use tools more frequently than males, Stanford adds. Researchers already knew that female chimps elsewhere take a special interest in termite fishing. In this practice, chimps jab twigs into large mounds where termites nest. Termites near the surface go into protective mode and bite the twigs. Chimps yank out their probes and lick off mouthfuls of protein-rich insects.

Grip masters

In a densely forested part of the Republic of the Congo called the Goualougo Triangle, chimps take termite fishing to another level. Insect-seekers deftly manipulate twigs with various hand grips. Goualougo chimps sometimes switch from one grip to another to break through hard sediment that seals openings to termite tunnels, Lesnik and her colleagues reported in the *American Journal of Physical Anthropology* in June.

Lesnik's team used remote, motion-sensitive video cameras to monitor chimp activity at 10 Goualougo termite nests from 2003 to 2007. Recordings yielded 157 instances of termite fishing in which the researchers could see chimps' hand grips. At least 13 chimps were taped in the act.

Chimps often pushed through sealed openings of termite tunnels with a sturdy twig held in both hands or with four fingers of one hand tightly wrapped around the twig. Additional grips included pinching a twig between the thumb and the side of the index finger and bracing a twig between thumb and index finger so it could be held between any two other fingers. Those grips are somewhat similar to how people hold pencils.

After forcing open a termite tunnel, chimps typically inserted a smaller twig to clean out the passage and collect termites.

On 31 occasions, the scientists observed chimps switching grips while breaking into a termite nest. Adjustments usually involved going from a two-handed to a one-handed grip. Chimps switched away from pencil-like grips only three of 51 times they were observed. Those one-handed grips combined power and dexterity, enabling precise movements in tight spaces, Lesnik says.

If Goualougo chimps go to such great lengths to munch termites, it's likely that ancient hominids did as well, Lesnik suggests. Evidence from hominid sites in South Africa that date to more than 1 million years ago supports that idea. Lesnik and several other researchers have reported that animal bones from those sites display microscopic damage consistent with being used as tools for digging into termite mounds and punching through sediment-covering termite tunnels.

"Chimps can set a benchmark of what early hominids were capable of doing, including making tools for termite foraging," Lesnik says. Ancient hominids may have gripped those tools much like chimps do, she says.

Ardi and bonobos

Until recently, little was known about whether early hominids looked or acted like chimps today.

Then a team of paleoanthropologists discovered and studied the 4.4-million-year-old partial skeleton of an adult female hominid dubbed Ardi (*SN: 1/16/10, p. 22*). Remains of more than 100 individuals from Ardi's species, *Ardipithecus ramidus*, confirm that these early hominids were not built like modern chimps or humans, Tim White of the University of California, Berkeley, and his colleagues concluded in the April 21 *Proceedings of the National Academy of Sciences*.

Ardi's surprising physical appearance topples the long-standing assumption that the earliest hominids, and the last common ancestor of present-day people and chimps, were relatively chimplike, the researchers contend.

Ardi walked upright rather than on her knuckles, as chimps do, White's group says. She moved slowly in trees and rarely hung from branches or climbed with chimps' speed. Her features suggest that chimps evolved a distinctive set of characteristics after their ancestors split from a common ancestor with hominids around 7 million years ago, the paleoanthropologists argue. Chimps are interesting in their own right but are unreliable guides to the lives and habits of Ardi or any other ancient hominids, White's team concludes.

Looking at the same fossils, most

Tool time Chimps often employ natural objects as tools. Less is known about the propensity of bonobos, such as this infant, to become tool users. Recent studies, however, indicate they have the ability to do so.

JAMES HOPKIRK/FLICKR (CC BY-NC-SA 2.0)

Not a chimp Some researchers say that the shapes of certain skeletal parts — including the skull base, teeth and feet — show that 4.4-million-year-old *Ardipithecus ramidus* (center) was fundamentally different from both chimps (*P. troglodytes*) and humans (*H. sapiens*). That would mean, some say, that chimps provide no insights into ancient hominid behavior. Chimp investigators disagree.

chimp researchers disagree. *A. ramidus* was an apelike hominid, they say, that climbed trees well and probably ate a varied diet that would appeal to chimps, including fruit, nuts and seeds. That makes chimps a good, if imperfect, source for thinking about how she may have behaved, Stanford says.

Like Ardi's extinct species, present-day bonobos are wild cards for ape researchers aiming to reconstruct ancient hominid behavior. "Humans are as closely related genetically to bonobos as to chimps, so we need much more research on bonobos," Rosati says.

For now, investigators see some general differences between bonobos and chimps. Bonobos often resolve conflicts through sex, while chimps frequently fight. Bonobo females form strong bonds and wield more power over daily affairs than female chimps do. Unlike chimps, bonobos rarely use tools in the wild.

Chimps are predisposed to use sticks, stones and other objects as tools, says anthropologist Kathelijne Koops of the University of Zurich. Bonobos show little interest in turning inanimate objects into tools, Koops and her colleagues reported June 16 in *Scientific Reports*.

Chimps in Uganda and bonobos in the Democratic Republic of the Congo had comparable access to stones, twigs and other potential foraging implements, according to Koops' research. But only chimps used these resources as tools to procure food. And only young chimps showed a keen interest in playing with leaves and other forest knickknacks.

Curiously, though, captive bonobos become ardent tool users when prompted by experimenters, reports a team led by anthropologist Itai Roffman of the University of Haifa in Israel. At a German zoo and a U.S. sanctuary with grasslands and a large forest, 11 of 15 bonobos used researcher-provided branches, stones and deer antlers as tools to retrieve food that had either been buried underground, placed in hard containers or inserted in holes drilled in animal bones, Roffman's group reported in the September *American Journal of Physical Anthropology*. The animals were shown where food had been placed and then left to their own devices.

Using wild chimps as guides, Koops speculates that early hominids inherited a chimplike tendency to find playthings early in life as a prelude to using tools later on. Bonobos are also good models for exploring how ancient hominids transformed natural objects into tools, Roffman and his colleagues conclude.

Whether or not Ardi's species shared anything in common with chimps, Jane Goodall's scientific heirs have much work left to do. As Fongoli's fire monitors and Goualougo's grip masters suggest, chimps and bonobos probably live more complex lives than anyone has imagined. ■

Explore more

- Jane Goodall. *Jane Goodall: 50 Years at Gombe*. Stewart, Tabori & Chang, 2010.
- Felix Warneken and Alexandra Rosati. "Cognitive capacities for cooking in chimpanzees." *Proceedings of the Royal Society B*. June 22, 2015.
- Itai Roffman *et al.* "Preparation and use of varied natural tools for extractive foraging by bonobos." *American Journal of Physical Anthropology*. September 2015.

Watch a video of tool-using chimps at **bit.ly/SN_chimpsmarts**

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To eavesdrop on the universe, the Green Bank Telescope requires a quiet location with little interference from human-made radio signals.

EXPERIENCES

Where scientists listen to the stars

Long before we reached Green Bank, W.Va., the gleaming white dish of a massive radio telescope stood out against the lush green vegetation of a remote valley four hours southwest of Washington, D.C. By then, the car radio received only static, and our cellphones hadn't gotten a signal in hours. To get even closer to the Robert C. Byrd Green Bank Telescope — the world's largest movable land object — we were required to turn off those useless phones and our digital cameras.

"The big battle we have here is to prevent any interference from getting to our telescope," says Steve White, leader of the telescope's microwave engineering group.

Many objects in the universe, such as quasars and clouds of hydrogen gas, give off radio waves, but they are weak and easily overwhelmed by human-made radio signals. That is why the telescope is in such a remote spot with strict rules about electronic equipment that could interfere with signals. Several rooms in the facility, including the telescope's control room, are encased in copper mesh, creating big Faraday cages that prevent stray signals from escaping toward the telescope's detectors. Even the microwave in the public café has shielding (*SN: 5/16/15, p. 5*). "We don't want to self-interfere," White says.

Standing taller than the Statue of Liberty, the telescope is the highlight of the facility's hour-long bus tour. The instrument's dish is bigger than a football field, but it's nearly impossible to get a sense of just how big it is until the bus drops us at the fence surrounding it. We can then see the 2,004 aluminum panels that make up the huge dish, each one about the size of a queen mattress and individually adjustable to ensure the telescope's accuracy. From our driver, we learn about recent discoveries, such as a white dwarf star so cold it had crystallized into an Earth-sized diamond. The tour also includes tales of annoying radio interference, including when the U.S. Fish and Wildlife Service released radio-tagged flying squirrels in the area.

The telescope's science is not cheap. While touring the facility's high-tech labs, White showed us custom-made gold-plated pieces inside the telescope's detectors and talked about the sophisticated computer programs that focus the dish. "We're trying to point something the size of a battleship with the accuracy of a wristwatch," he says. But it's only through such efforts that we can search for mysteries of the universe that we can't even see.

— Sarah Zielinski

Green Bank Telescope

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GREEN BANK, W.VA.

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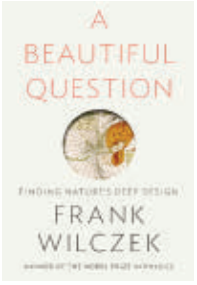

A Beautiful Question
Frank Wilczek
PENGUIN PRESS, $29.95

BOOKSHELF

Nobel laureate finds beauty in science and science in beauty

Frank Wilczek knows how to focus a book. *A Beautiful Question* applies the lessons of modern physics to one query: "Does the world embody beautiful ideas?" Or, "Is the world a work of art?"

His answer is yes. The exploration of the question makes the book worthwhile.

Wilczek, winner of a Nobel Prize for work on fundamental particles and forces, applies an encyclopedic grasp of modern physical science to illustrate how science's description of nature coincides with humankind's multifaceted views of beauty. Take music. Its power to evoke emotions and soothe the mind seems far beyond science. Yet the math describing music's acoustic vibrations is closely related to formulas describing atoms. Something deep seems to connect the physical world's foundations with the human mind's perception of harmony. Mathematics somehow seals that connection.

Even ancient thinkers had suspected that mathematical principles infuse both artistic expression and the foundation of the physical world. Pythagoras related the math of musical harmony to the "music of the spheres" and said "all things are number." Plato insisted that the physical world imperfectly embodies a primordial mathematical beauty.

As Wilczek shows, modern physics has verified and deepened the math-beauty link. Newton's laws, Maxwell's equations, quantum physics and relativity theory have succeeded by relating mathematical harmony to physical reality. Today's "Core Theory" of nature's particles and forces (known generally as the "standard model"), for instance, is rooted in mathematical symmetries. And symmetry is "one of the hallmarks of nature's artistic style," Wilczek writes.

In exploring these notions, Wilczek surveys humankind's current understanding of physical existence. He relates atoms and their parts, light and color, space and time, even the whole universe to the human conception of beauty.

It would be difficult for anyone who follows the exploration of Wilczek's question to the end to dispute his answer. There is beauty embodied in the world. There is beauty in art, in music, in literature. And in nature's equations. The beauty of those equations merges with the beauty of literature in Wilczek's book. It's a work of art. — *Tom Siegfried*

Editor's Note: Wilczek is on the board of trustees of Society for Science & the Public, which publishes Science News.

The Diet Myth
Tim Spector
OVERLOOK PRESS, $28.95

BOOKSHELF

Microbes make the meal, new diet book proposes

For 10 days, Tom Spector lived off McDonald's. He had chicken nuggets or Big Macs for meals and McFlurries for dessert. Tom, a 22-year-old student, was re-creating a version of the diet made famous in the film *Supersize Me*. But Tom's plan had a twist: Before and after the diet, he gave his dad some poop.

Tom's father, Tim, wanted to see how the bacteria in Tom's intestines dealt with junk food. Tim Spector, a genetic epidemiologist at Kings College London, thinks that the billions of bacteria in our guts may help explain health problems including obesity and allergies.

In *The Diet Myth*, Spector makes a convincing case. His son's McDonald's diet whittled down microbial diversity, which has been linked to health. The diet also swapped out friendly, diarrhea-preventing bacteria for ones that trigger inflammation. Spector backs this personal story with a mountain of evidence and cuts through diet myths like butter.

Dairy products, for instance, have gotten a bad rap. High-fat milk, yogurt and cheese actually seem to be good for you, Spector argues. But stick to cheddar, Gouda and other aged cheeses, he advises, or blue-veined varieties such as Roquefort. These cheeses are microbe metropolises and may keep people healthy, studies in humans have shown.

From Atkins to *The China Study* to a French fad called *le forking* (followers eat only with a fork), Spector dumps decades of diet trends into a sieve to see what shakes out.

There's not a whole lot there, he finds. Spector skewers popular heath crazes: Multivitamins? Worthless. Superfoods? A marketing con. The Paleo diet? Majorly flawed.

And a diet that works for one person won't necessarily work for a neighbor — or even a twin. Spector would know. He's the architect of the U.K. twins registry, a collection of data from 12,000 twins. He draws on twins' stories to dispel the myth that peoples' bodies deal with food in the same way. "They don't," he writes. "We are all different."

One huge factor influencing individuals' health and weight, he argues, is our microbes. Like Michael Pollan's 2009 bestseller *In Defense of Food*, *The Diet Myth* challenges widely held ideas about food and eating. Spector even riffs on Pollan's famous advice to eat what your ancestors ate: "Don't eat anything your great-grandmother's microbes wouldn't recognize as food."

To take care of your body, Spector suggests, take care of your microbes. That means mixing up your diet, he says. Variety is key. Try to avoid antibiotics. And one thing most diet books can agree on: Lay off the McDonald's. — *Meghan Rosen*

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Science Talent Search seeks title sponsor

Society for Science & the Public is looking to partner with a new title sponsor for the Science Talent Search, the nation's oldest and most prestigious high school science competition. The new sponsor will assume sole title sponsorship beginning in 2017.

The Science Talent Search has been celebrating the best and brightest young scientific minds in the United States for 75 years. It has only become available for a title sponsor twice since its inception in 1942. The competition receives more than 1,800 applications each year from high school seniors across the country, all vying to be among the nation's top 300 honored young scientists. Forty finalists are selected to compete in a week-long competition in Washington, D.C.

"The Science Talent Search is the nation's talent pipeline for future scientists, innovators, entrepreneurs and leaders. This one-of-a-kind program recognizes and inspires the brightest young minds in America," says Maya Ajmera, president and CEO of the Society and a 1985 Science Talent Search alumna. "We are thrilled for the opportunity to welcome a new sponsor as a partner. They will play an integral role in informing, educating and inspiring students across the nation, while reaping the benefits associated with this extraordinary competition."

Student entrants to the Science Talent Search submit original research in critically important scientific fields of study and are judged by leading experts in their fields. Often, the students' research addresses some of the world's most pressing challenges, and past entries have included promising cancer research and technological advancements. Unique among high school competitions in the United States and globally, the Science Talent Search focuses on identifying the next generation of scientists and engineers who will provide critical leadership in shaping the future of research and development for our nation and the world.

Together with its sponsor, the Society rewards the achievements of the top 300 Science Talent Search students and their schools each year to encourage continued commitment to science, technology, engineering and math research and education. In 2015, prizes totaled more than $1.6 million, including three top awards of $150,000.

Sponsors have found that the competition has not only enhanced their corporate reputation among influential parties, but it has also given them the opportunity to raise awareness of their commitment to education and innovation. For example, Science Talent Search finalists and representatives of the Society and the sponsor organization visit politicians on Capitol Hill each year. Student finalists have met with 10 U.S. presidents, including John F. Kennedy, Ronald Reagan and Barack Obama.

Program alumni include recipients of the world's most coveted science and math honors, including four National Medals of Science, three Breakthrough Prizes, 12 MacArthur Foundation Fellowships, two Fields Medals and eight Nobel prizes. Distinguished Science Talent Search alumni include Society trustees Mary Sue Coleman (retired president of the University of Michigan), Tom Leighton (cofounder and CEO of Akamai Technologies), Paul J. Maddon (founder and vice chairman of Progenics Pharmaceuticals), Frank Wilczek (winner of the 2004 Nobel Prize in physics) and George Yancopoulos (founding scientist, president and chief scientific officer of Regeneron Laboratories).

Westinghouse was the title sponsor of the Science Talent Search for more than 50 years, and Intel has served as the title sponsor since 1998.

Visit **bit.ly/SSP_STSsponsor** to learn more about the Science Talent Search sponsorship.

The Science Talent Search has a long history of celebrating young researchers. Finalists pose with President Kennedy and Vice President Johnson in 1961 (top) and President Obama in 2009 (bottom).

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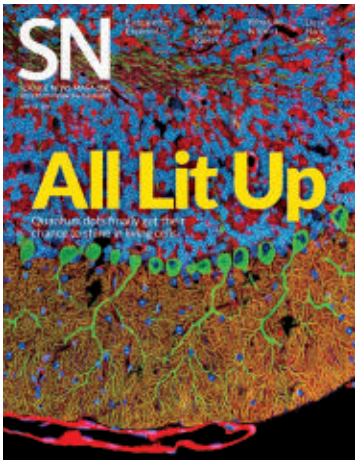

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Limiting life

Dying early may provide an evolutionary advantage. New simulations that pitted short-lived organisms against immortals found that mortals leave more resources behind for future generations, ***Andrew Grant*** *reported in "Evolution may favor limited life span" (*SN: 7/11/15, p. 6*).*

"How would the childbearing propensity of immortals change compared to mortals, and how would that affect the outcome of the simulation?" asked reader **Mike Van Horn**.

In general, immortals in the simulation evolved to have a much lower reproduction rate than mortals, says study coauthor **Yaneer Bar-Yam** of the New England Complex Systems Institute in Cambridge, Mass. By limiting the number of offspring, immortals prevented overpopulation and loss of resources. Mortals, on the other hand, reduced their number of offspring by limiting life spans. Mortals seemed to have the better strategy, since they won out over immortals in the long run.

Tracking ancient humans

*In "Trackers decipher ancient footprints" (*SN: 7/11/15, p. 8*),* ***Bruce Bower*** *described how a trio of Namibian hunters used their experience to offer insights into the behavior of Stone Age humans.*

"I loved this article, but it disappointed me as well, as it highlighted the arrogance that sometimes comes with science," wrote **Steve Schlosser** in an e-mail. "On the one hand, we have individuals whose lives depend on their ability to interpret foot- (and hoof-) prints. Given their environment, their skill is surely the difference between hunger and satisfaction, safety and danger. Then we have the researchers, who discount the trackers' skills by saying that people 20,000 years ago were anatomically different than people are today. Instead of embracing their skills and the insight they can contribute, experts in the field dismiss their knowledge. I'd like to drop these guys in the Namibian desert and see how well they could survive."

Virtual tornado warning

A rotating updraft within this 20-kilometer-high thunderstorm sired a violent tornado. The twister, which looks quite small (bottom, right-center) compared with the rest of the towering storm, packed winds at over 320 kilometers per hour and left behind a long trail of devastation. Or it would have, had the storm been real.

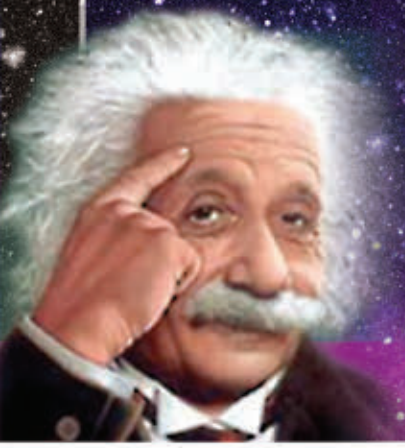
This realistic visualization of a supercell thunderstorm was honored at the Extreme Science and Engineering Discovery Environment conference in St. Louis in July. The underlying computer simulation, which calculates how pressure, moisture and heat conspire to create megastorms, is the first to successfully reproduce a long-lived EF5 tornado, the most severe designation of twister. The simulation could help explain why some tornadoes linger for hours after forming, says cocreator Leigh Orf, an atmospheric scientist at the University of Wisconsin–Madison.

Orf's team spawned the virtual storm in conditions resembling those that bred an EF5 tornado near El Reno, Okla., on May 24, 2011. The simulation revealed that descending pockets of cool air, which form when raindrops evaporate, hit the ground and curl upward, creating vortices. The storm sucks in these vortices, which keep the tornado spinning.

Storm chasers may be able to verify that these vortices swirl near real tornadoes, Orf says. — *Thomas Sumner*

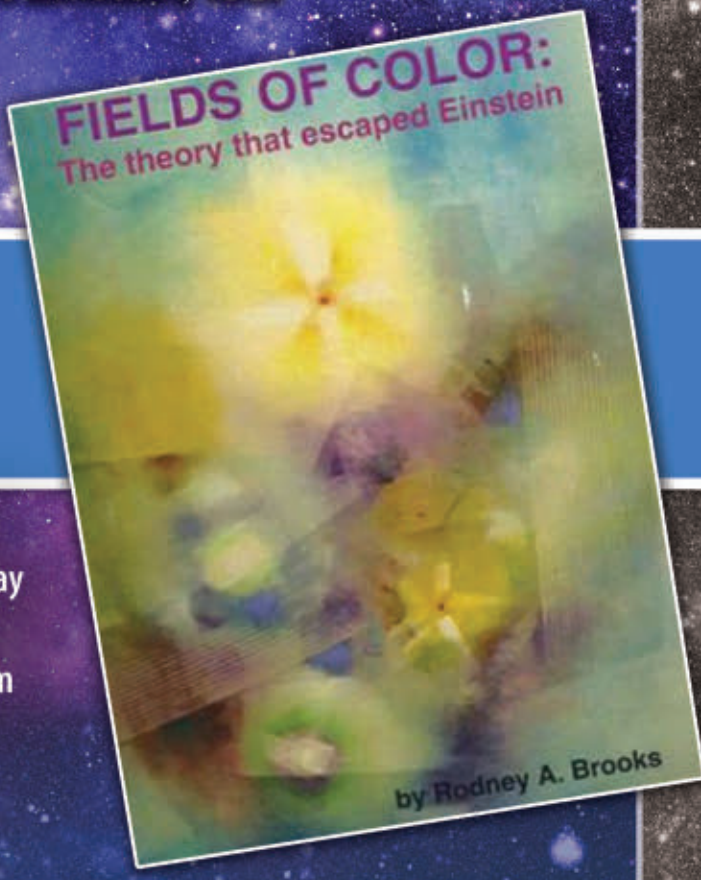
DAVID BOCK

Watch the virtual thunderstorm swirl at **bit.ly/SN_tornado**



"If you can't explain it simply,
you don't understand it well enough"

-Albert Einstein, 1951



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Phoenix Rising From the Ashes

Arresting beauty emerges from nature's fury as Helenite explodes upon the jewelry world.

When Mount St. Helens erupted and shook Washington State to its core, an ash column rose to an altitude of about 16 miles in less than 15 minutes with a vigorous emission of ash continuing for the next nine hours. Ultimately, an estimated 540 million tons of ash drifted up to 2,200 square miles settling over seven states. You could say Mount St. Helens caused quite the stir.

But it was a surprising find discovered in the aftermath of the eruption that had locals talking long after the volcanic dust settled. Workers using a gas torch while doing salvage work discovered that the heat of the torch was melting the volcanic ash into a lustrous green substance. And there, amid the ancient ashes created from a mountain that first erupted in 10,000 BCE, Helenite was born.

Phoenix from the ashes, Helenite explodes upon the jewelry world...

The story got out and captured the attention of jewelers worldwide. It was a scramble to secure the magical ash from Mount St. Helens and perfect the heating process to achieve brilliant green stones that rival even the emerald in terms of color, refractive index and clarity. The world has never seen anything like Helenite.

Now, you can own this newest addition to the fine jewelry scene. We've acquired the world's finest quality Helenite and had it cut and faceted by skilled craftsmen into a gorgeous pendant erupting with vibrant color and fire. This is green like you've never seen it.

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