SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
SEPTEMBER 5, 2015

Futuristic Forensics

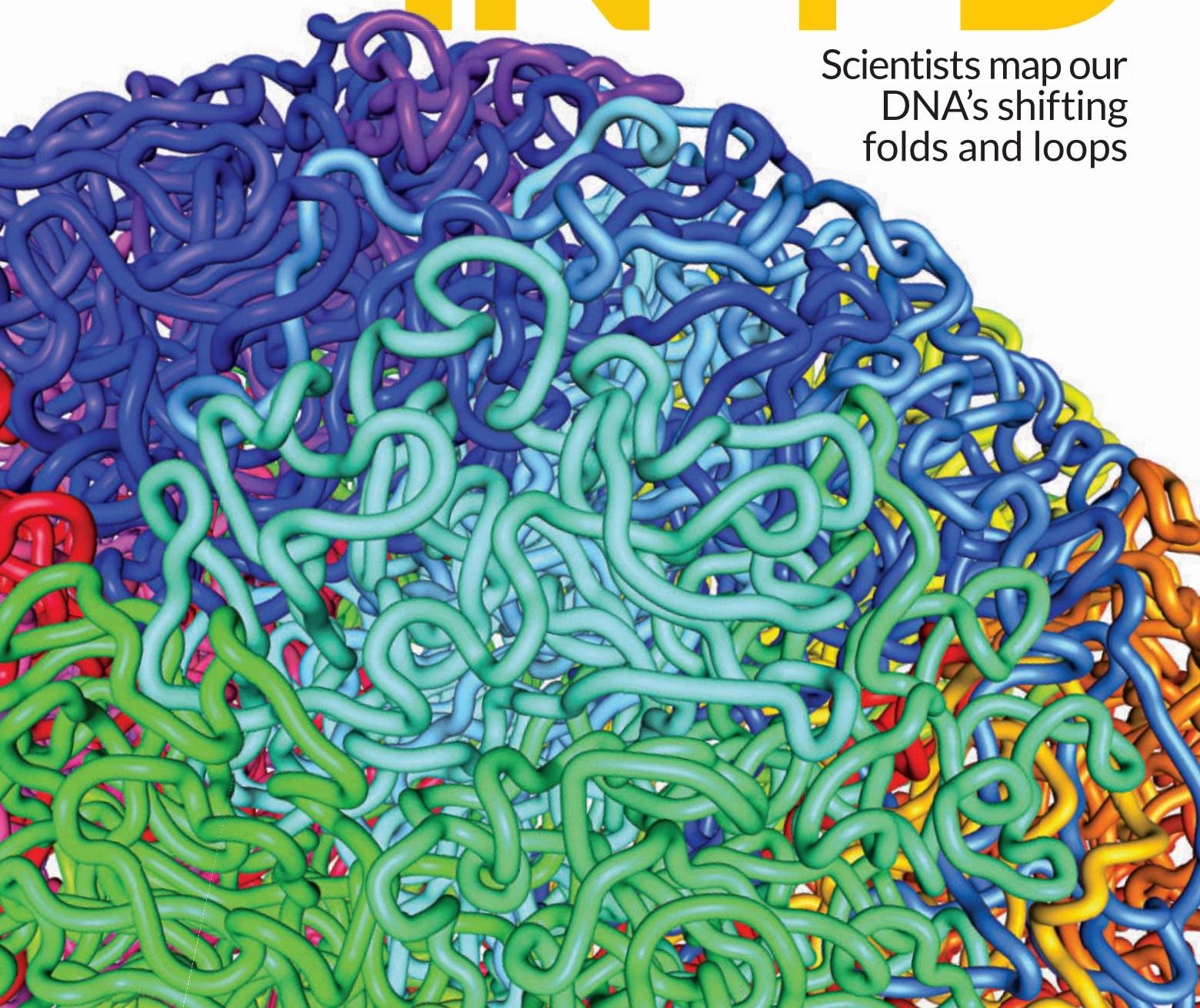
Ebola Vaccine Success

Recalibrating the Kilogram

Earth's Mini Moons

THE GENOME IN 4-D

Scientists map our DNA's shifting folds and loops



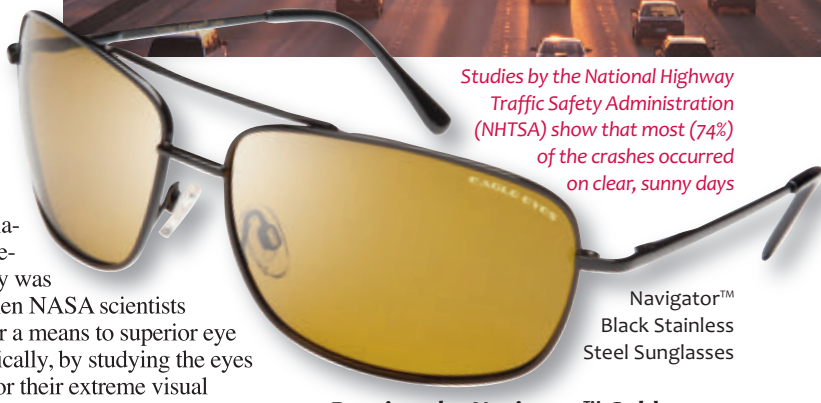
Urgent: Special Summer Driving Notice

To some, sunglasses are a fashion accessory…

But When Driving, These Sunglasses May Save Your Life!

Drivers' Alert: Driving can expose you to more dangerous glare than any sunny day at the beach can… do you know how to protect yourself?

Studies by the National Highway Traffic Safety Administration (NHTSA) show that most (74%) of the crashes occurred on clear, sunny days



Navigator™ Black Stainless Steel Sunglasses

The sun rises and sets at peak travel periods, during the early morning and afternoon rush hours and many drivers find themselves temporarily blinded while driving directly into the glare of the sun. Deadly accidents are regularly caused by such blinding glare with danger arising from reflected light off another vehicle, the pavement, or even from waxed and oily windshields that can make matters worse. Early morning dew can exacerbate this situation. Yet, motorists struggle on despite being blinded by the sun's glare that can cause countless accidents every year.

Not all sunglasses are created equal.
Protecting your eyes is serious business. With all the fancy fashion frames out there it can be easy to overlook what really matters—the lenses. So we did our research and looked to the very best in optic innovation and technology.

Sometimes it does take a rocket scientist. A NASA rocket scientist.
Conventional sunglasses can blur your vision by exposing your eyes to harmful UV rays, blue light, and reflective glare. They can also darken useful vision-enhancing light. But now, independent research conducted by scientists from NASA's Jet Propulsion Laboratory has brought forth ground-breaking technology to help protect human eyesight from the harmful effects of solar radiation light. This superior lens technology was first discovered when NASA scientists looked to nature for a means to superior eye protection—specifically, by studying the eyes of eagles, known for their extreme visual acuity. This discovery resulted in what is now known as Eagle Eyes®.

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Features

News


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Departments

COVER In every cell nucleus, chromatin folds into clusters of interacting DNA loops. *Adrian Sanborn, Miriam Huntley, Erez Lieberman Aiden*

CLOCKWISE FROM TOP: CORINNE BOTZ; GODDARD SPACE FLIGHT CENTER CONCEPTUAL IMAGE LAB/NASA; M.K. HOJO

DNA architecture, novel forensics offer new clues

It's one thing to catalog each chemical unit of DNA that makes up the human genome. It's another thing entirely to understand how that genetic material is folded up inside a living cell — and then decoded, manipulated and used.

Achieving that understanding is the task of the architectural scholars of molecular biology, scientists who describe the loops and other yogic postures that DNA displays inside the cramped space of a cell's nucleus. This architecture has important implications for function, perhaps by arranging the genetic furniture to enable one cell to operate as a liver cell and another to work as a skin cell. But even this 3-D appreciation of the genome is limited, as science writing intern Sarah Schwartz writes on Page 18. Researchers must also contemplate a fourth dimension: genome morphing over time.

Scientists are now drawing up plans to map the 4-D genome, Schwartz reports. Besides acquiring deeper understanding of this fascinating bit of biology, the project will provide clues to how misfolding of the genome can lead to disease and what role it may play in aging.

Forensic scientists are searching for better clues as well, although their interest is in more reliable identification of crime suspects. On Page 22, Meghan Rosen reports on some of the limits of well-known methods, such as fingerprint analysis, and how scientists are seeking to improve them. Rosen also describes new ways that detectives might solve whodunits with aid from the burgeoning field of microbial forensics. Along with our hair and finger marks, we may leave behind idiosyncratic collections of microbes, which may one day help rule out suspects. Body odors may also inform both the search for and prosecution of criminals, researchers say. That's assuming that scientists can establish just how different each individual is in terms of odor and microbes so these clues can be used as reliably as DNA evidence to identify someone.

Going from theory to practice is always rife with problems, be it shifting from the sequence of DNA's letters to observing its dynamic machinations in a cell or from a potential identity marker in the lab to a piece of courtroom evidence. But the journey offers what any good mystery should: a chance for surprising discoveries. — *Eva Emerson, Editor in Chief*

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SANDY SCHAFFER

Finally… an adult brief that keeps you dry all night!

Special Introductory Price!

Night Proofs™ Briefs are virtually leak proof, comfortable and so absorbent you'll sleep through the night without needing a change.

It's a problem no one likes to talk about, but over 25 million Americans suffer from urinary incontinence. For those people, the problem is embarrassing, uncomfortable and can lead to a variety of other health issues such as skin irritation. Now there's an adult diaper that fully absorbs the liquid and pulls it away from the skin leaving little opportunity for skin irritation, or other incontinence-related problems. Plus for many, a good night's sleep uninterrupted, leak-free is the best news of all. Adult diapers have been on the market for years, but because most are sold to hospitals, where frequent changing is not an issue, they simply have not been designed to last through the night. Night Proofs™ Briefs are–and they do!

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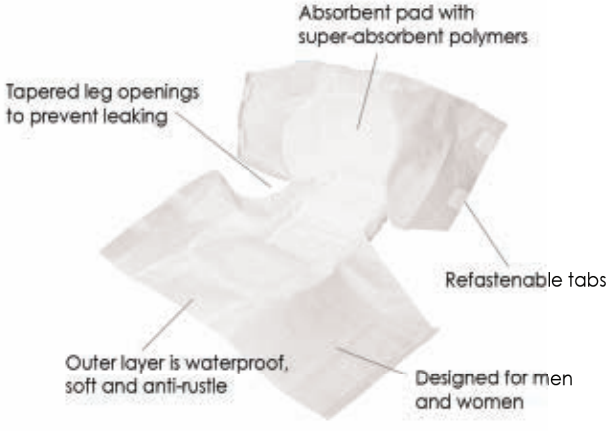
Take a Night Proofs™ Briefs and pour eight full 12-oz glasses of water into it. The water will be fully absorbed and the surface of the lining will remain dry. (If you attempt this test with other adult diapers, you better try it over the sink!)



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Excerpt from the September 4, 1965, issue of *Science News Letter*

50 YEARS AGO

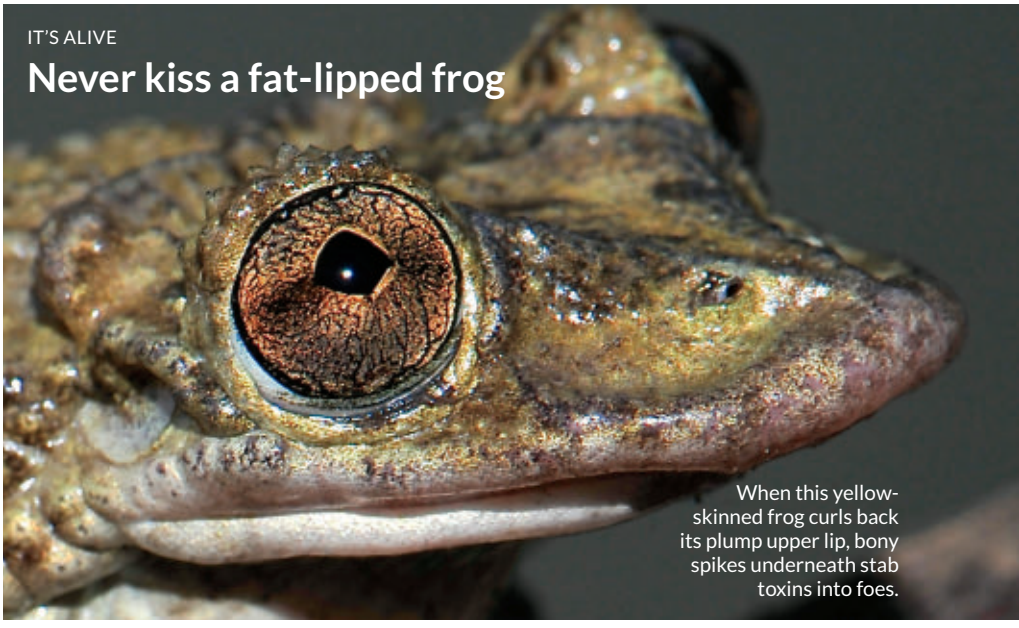
Swedes feed paper bills to pump to get gas

A master automat for controlling several different gasoline pumps at once allows a driver to fill his own tank after hours by putting paper money in the slot.... A photoelectric scanner rejects false notes or those of wrong denomination.... Coin-operated gas automats have been used in Sweden for some time but have been found less practical, especially for long-distance drivers, because of the number of coins needed to fill a nearly empty tank.

UPDATE: Bill readers like this early version proliferated in the late 1960s and '70s. But so did ways to trick them. For decades, thieves could use photocopied counterfeits whose iron levels matched those of legit bills, fooling magnetic sensors inside vending machines. By the late '90s, bill readers began wielding sophisticated optical sensors to scan bills for fluorescent dyes, special threads or watermarks. The machines often reject wrinkled bills because their optical patterns get distorted.

IT'S ALIVE

Never kiss a fat-lipped frog



When this yellow-skinned frog curls back its plump upper lip, bony spikes underneath stab toxins into foes.

Carlos Jared discovered the first known venomous frog by accident. And it took him a long time to connect his pain with tree frogs that head-butted his hand.

Jared, of the Butantan Institute in São Paulo, got his first hint of true venom when collecting yellow-skinned frogs (*Corythomantis greeningi*) among cacti and scrubby trees in Brazil's dry Caatinga region. For hours after grabbing the

An active galaxy called a blazar, illustrated here, emits a jet of high-energy particles toward Earth.

SAY WHAT?

Blazar \BLEHY-zahr\ n.

An unusually luminous galaxy that fires off a jet of high-energy matter and radiation toward Earth.

Blazars have been spotted throughout the sky, but researchers don't know how their jets form. Scientists suspect that gas piles up near a galaxy's central black hole, where it heats up and gets flung away at nearly the speed of light. Astronomers are studying the blazar PKS 1830-211. It is about 11 billion light-years away, but the gravity of at least one nearer galaxy acts as a lens, enabling scientists to examine the distant blazar's energetic outbursts.

The source of high-energy gamma rays from PKS 1830-211 is a confined area about the size of the solar system, University of Geneva astrophysicist Andrii Neronov and colleagues report in the August *Nature Physics*. The finding shows that whatever is driving blazar jets operates right near the central black hole, which can weigh in at millions or billions of times the mass of the sun. —*Andrew Grant*

FROM TOP: C. JARED/BUTANTAN INSTITUTE; GODDARD SPACE FLIGHT CENTER CONCEPTUAL IMAGE LAB/NASA

frogs, intense pain radiated up his arm for no obvious reason.

He knew frogs have no fangs to deliver toxin. Many frog species can poison an animal that touches them, but true venomous animals actively deliver toxins.

Jared realized that head-butting delivers venom only after he saw the frogs' upper lips under a microscope. Bone spikes erupted near venom glands that looked "giant," he says. As a frog's lips curl back, glands dribble toxins onto the spikes and the frog presses them against foes.

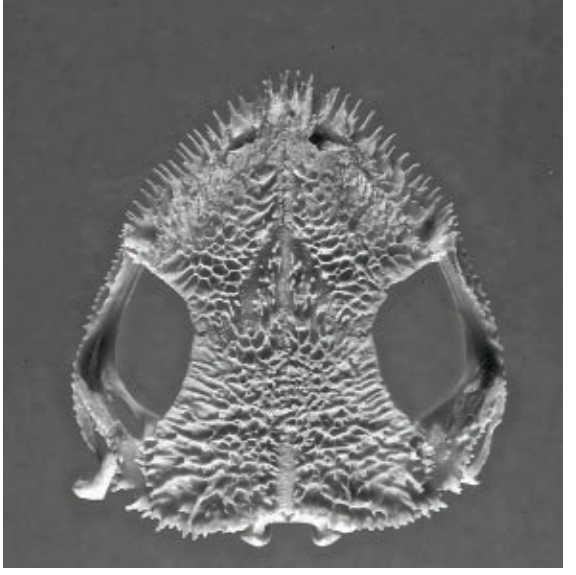
Gram for gram, the frog venom is almost twice as potent as typical venom of the feared *Bothrops* pit vipers, Jared, Edmund Brodie Jr. of Utah State University in Logan and their colleagues report in the Aug. 17 *Current Biology*.

The researchers also report a second spiky-skulled venomous frog, *Aparasphenodon brunoi*, which is a forest species not very closely related to yellow-skinned frogs. It head-butts toxins 25 times as powerful as typical pit viper venom, a phenomenon luckily not discovered by handling.

Accidents are how most venomous animals first come to scientific notice, Brodie says. Early in his career, he discovered details of fire salamander venom by tickling a new specimen with a piece of grass. He was showing students how toxins ooze from the creature's skin and "it sprayed me right in the eye," he says. "I was immediately blinded."

"I ran to the sink and ran water in my eye for about 20 minutes," he says. "The toxin isn't water soluble, so it didn't help much. It was extraordinarily painful," he notes in matter-of-fact tones, adding, "The first time you observe something like that, you're not sure it's temporary blindness." Thankfully, it was.

Venomous amphibians may be more common than people expect, Brodie says. "It's not Kermit anymore." *—Susan Milius*



An edging of bony spikes along the front turns the skull of a yellow-skinned frog into a weapon for venomous head-butts.

THE –EST

Oldest sperm

Worm sperm have staying power. Embedded in a fossilized cocoon, mineralized sperm from what may have been a leechlike worm have stuck around for about 50 million years. The ancient sperm fossils predate the previous record holders — amber-preserved sperm from tiny insects called springtails and petrified sperm from mussel shrimps — by at least 10 million years.

Researchers discovered the cocoon-entombed worm sperm by sifting through sediments from an Antarctic island. The cells' drill bit–shaped heads and grainy texture resemble the sperm of Branchiobdellida, a group of squiggly worms that crawl on freshwater crayfish today.

Sperm are fragile, so preservation happens rarely. Cocoons may offer an untapped resource for finding soft and delicate cells, and even tiny organisms, researchers suggest July 15 in *Biology Letters*. *—Meghan Rosen*

SCIENCE STATS

Giant pandas live in the slow lane

Like LED lightbulbs, giant pandas are energy-saving superstars.

The bamboo-loving bears use only about 38 percent as much energy as other land mammals of similar size, researchers report in the July 10 *Science*. They calculated daily energy use by analyzing the blood, poop and urine of five captive pandas and three wild ones. The bears are more like giant reptiles, the study found.

Giant pandas cut back on energy consumption by acting like couch potatoes. They move less than other bears, and when they do move, they go in slo-mo. What's more, energy-draining organs such as the brain, liver and kidneys are relatively smaller in pandas than in other placental mammals.

The findings help explain how giant pandas can survive on a low-cal, nutrient-poor diet of hard-to-digest bamboo. *—Meghan Rosen*

38
percent
Amount of energy burned by pandas compared with similarly sized land mammals

15.5
meters per hour
Average speed of wild foraging pandas

CLOCKWISE FROM TOP: C. JARED/BUTANTAN INSTITUTE; GLOBALP/ISTOCKPHOTO; B. BOMFLEUR *ET AL*/*BIOLOGY LETTERS* 2015

BODY & BRAIN

Ebola vaccine effective in Guinea trial

Immediate shot after possible exposure protected against virus

A study of more than 7,000 people in Guinea shows that an Ebola vaccine guards against the virus.

BY NATHAN SEPPA

The first large test of an Ebola vaccine in the field shows strong protection against the lethal virus. With the epidemic in West Africa now in retreat, the shot might hasten disease elimination in Guinea, which still had new cases cropping up as of mid-August.

"This is a huge advance in the Ebola field," says Thomas Geisbert, an immunologist at the University of Texas Medical Branch in Galveston. "It's been 10 years, but we're finally getting it into people." In 2005, Geisbert, virologist Heinz Feldmann of the National Institute of Allergy and Infectious Diseases and colleagues developed the vaccine (*SN: 7/16/05, p. 45*), which uses a live virus called vesicular stomatitis that causes only mild infection in humans. The vaccine contains an Ebola glycoprotein that cannot cause disease but does trigger immunity.

An international team of researchers tested the vaccine in Guinea this year using a "ring-vaccination" strategy. When an Ebola case was diagnosed, the patient's close contacts and a cluster of people living in the area were randomly assigned to one of two groups: People in one group received the vaccine's single shot immediately; the others after a 21-day delay. The scientists established 90 such clusters, vaccinating 7,651 adults, about half in each group.

Among people who got the delayed vaccination, 16 contracted Ebola. In the prompt-vaccination clusters, none did, the researchers report online August 3 in the *Lancet*. The scientists counted only Ebola cases that showed up 10 days or more after people entered the study to rule out preexisting cases.

Based on the results, the experimental vaccine will continue to be used throughout the country, as requested by the Guinean government. But it will be given without delay in clusters around new infections, the researchers report. Scientists will continue to collect data on vaccine effectiveness and safety.

The trial may also have had an impact on the epidemic. Public health measures have been the main weapon against the West African outbreak, but they haven't fully stamped it out. The vaccine, dispensed from April 1 through July 20, has contributed to the fight in Guinea, says study coauthor John-Arne Røttingen, director of the Division of Infectious Disease Control at the Norwegian Institute of Public Health in Oslo. "It really is a countermeasure that should help get us to zero."

27,988
Number of Ebola cases since the outbreak in began in March 2014

11,299
Number of deaths from Ebola since the outbreak began

The trial's approach might prove useful in future outbreaks, says Mark Feinberg, chief of public health and science at Merck in West Point, Pa., the pharmaceutical company that manufactures the vaccine. "Before this outbreak, there wasn't a path successfully navigated for how to evaluate the efficacy of a vaccine in the middle of an outbreak," he says.

Until recently, about 20 new cases per week had been cropping up in West Africa. But in the week ending August 9, only two cases arose in Guinea and one in Sierra Leone, the World Health Organization reports. In all, there have been 27,988 cases of Ebola and 11,299 deaths since the outbreak began in the region some 18 months ago.

A lot more work is required before the vaccine can get regulatory approval, Feinberg says. Researchers need to ascertain how well it works in specific groups, such as children and the elderly, and regulators need to establish that batch after batch of the vaccine is produced uniformly and is safe for use in the field, he says.

Ideally, in the initial stages of an epidemic, the vaccine would go to people at the front lines, including health workers, Geisbert says. "In the future, if you have an outbreak, I could see a multipronged approach." In addition to standard public health measures, he says, "you could vaccinate health care workers before they get there — before they're sent into the hot zone." If the vaccine receives regulatory approval, it could ultimately "be used in the context of fighting outbreaks," he says. ■

GENES & CELLS

Ancestral humans had more DNA

Genetic cuts and copies show evolutionary kinships

BY TINA HESMAN SAEY

A new atlas of human genetic diversity indicates what human ancestors' DNA looked like before people migrated out of Africa.

Ancestral humans carried 40.7 million more DNA base pairs than people do today, researchers report online August 6 in *Science*. That's enough DNA to build a small chromosome, says study coauthor Evan Eichler, an evolutionary geneticist at the University of Washington in Seattle.

Human ancestors in Africa jettisoned 15.8 million of those DNA base pairs — information-carrying building blocks of DNA often referred to by the letters A, T, G and C — before dispersing around the globe, the researchers discovered. As people left Africa and spread to other continents, they dropped more chunks of DNA. Eichler and colleagues have followed these genetic bread crumbs to map relationships among 125 human groups worldwide.

People didn't just lose DNA. They also gained some. Compared with great apes, people have 728 extra pieces of DNA created when portions of the human genetic instruction book, the genome, were copied. Everyone has at least three copies of those duplicated bits, although the exact number varies from person to person.

Previous maps of human genetic diversity have usually not marked the yawning chasms left by deletions or the new territory created by duplications. Most have focused on individual DNA base pair changes, often called single nucleotide polymorphisms, or SNPs. But all the SNPs together comprise only 1.1 percent of the genome. Duplications and deletions, collectively known as copy number variants, have shaped more than 7 percent of the human genome.

Because duplications and deletions involve larger swaths of DNA than SNPs do, their influence on human evolution may also be bigger. Both duplications and deletions have been implicated in shaping human characteristics, such as big brains (*SN: 3/21/15, p. 16*; *SN: 4/9/11, p. 15*).

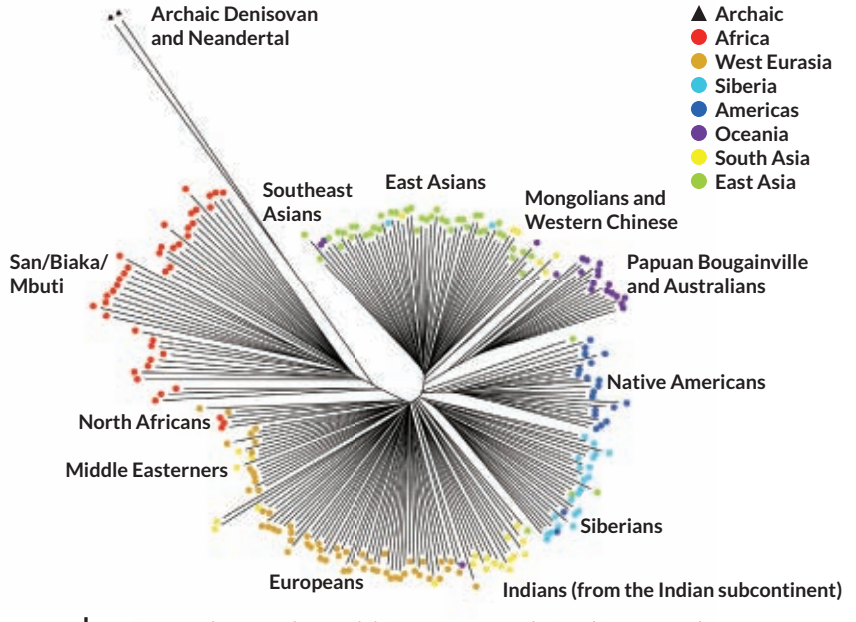
But researchers "can't answer the question yet of whether what makes us human is in what was lost or what was duplicated," says David Liberles, a computational evolutionary biologist at Temple University in Philadelphia.

Eichler's choice is clear. "Duplications rock," he says. "They affect more base pairs in the human genome than any other type of variation." Duplications make up 4.4 percent of the genome, while deletions affect 2.77 percent. And duplications tend to involve genes, while deletions often fall in spaces between genes, the researchers found.

His team flagged many duplications as possible medical and evolutionary points of interest. For instance, some groups of people have up to six copies of *CLPS* genes, which encode pancreatic enzymes that may help reduce blood sugar levels. Some African groups carry duplications of genes that may protect against sleeping sickness caused by trypanosome parasites.

Papua New Guineans inherited a very large duplication of about 225,000 base pairs from Denisovans, an extinct group of hominids related to Neandertals. The colossal hunk of DNA contains two genes for microRNAs, small molecules that help regulate protein production. Eichler and colleagues calculate that the original duplication happened about 440,000 years ago in Denisovans. It was passed to Papuans and some other Melanesians about 40,000 years ago when their ancestors interbred with Denisovans. Now, about 80 percent of Papuans carry the duplication. Eichler speculates that it may have given Papuan ancestors some still unknown evolutionary advantage.

While the researchers make a compelling case that duplications and deletions play an important role in evolution, the team has provided little evidence that copy number variants really determine trait differences between groups, says Edward Hollox, a human geneticist at the University of Leicester in England. "It's almost a paper saying, 'Look, isn't this interesting?' But why it's interesting they haven't quite gotten to the bottom of." Still, Hollox says, the map will point other researchers to parts of the genome where evolution may have left its mark. ■



Common loss Researchers used DNA deletions to trace relationships among human groups by region. Longer lines indicate that the group has more deletions unique to it.

P. SUDMANT *ET AL*/*SCIENCE* 2015

ATOM & COSMOS

Struggle to find origin of Earth's water

Flawed methods impede quest to trace source of primordial ice

BY CHRISTOPHER CROCKETT

When it comes to wringing out the origins of Earth's water, planetary scientist Karen Meech has some bad news. Not only do scientists have bad intel on where water-bearing bodies in the solar system formed, but our own oceans may also be sending them down the wrong path.

"It looks like a complete mess," said Meech, of the University of Hawaii at Manoa, who gave a state-of-the-water address August 4.

There are two big problems, she said. The bulk of Earth's water, hidden deep underground, has a different composition from that of ocean water. Yet scientists use seawater to compare the makeup of Earth's water against that of icy asteroids and comets. Also, the chemical marker that researchers rely on to track water might not even be that useful, Meech said.

When Earth formed, it didn't have water, so it needed help from farther out, where water ice collected on asteroids and comets (*SN: 5/16/15, p. 18*). To trace Earth's water to its source, researchers use a chemical marker known as the D/H ratio. The ratio measures water's relative amounts of hydrogen and deuterium (a slightly heavier version of hydrogen). Deuterium shows up more frequently at lower temperatures, so the D/H ratio should be useful for figuring out how far from the sun Earth's water came.

If only it were that simple.

The disk of gas and dust that encircled the young sun was a turbulent place with planet-building material getting sloshed around. As a result, the D/H ratio bounces all over the place as one moves farther from the sun, recent computer simulations show. And no two calculations agree on what the D/H ratio was at any particular distance from the sun.

"If you get a measurement for a comet, you don't really know where that comet formed," said William Irvine, a planetary scientist at the University of Massachusetts Amherst.

To remove the ambiguity, Meech argues, researchers need more than one fingerprint for water. Ratios of nitrogen and oxygen isotopes also change with distance from the sun. Measuring many ratios for many comets and matching them up with simulations could give scientists a better chance of locating where the water bearers formed, Meech said.

But these measurements are impossible for current telescopes to make except when looking at the nearest, brightest comets. So while waiting for new instruments, researchers may want to spend more time looking down instead of up and asking how well we know Earth's water.

"Turns out we may be wrong on that side, too," Meech said.

Scientists don't really know how much water is locked away in the Earth. Estimates vary: anywhere from 1.5 times as much water as is found in the oceans to 11 times or more. "If most of the water is inside Earth," Meech asked, "does it make sense to compare anything to Earth's ocean water?"

Irvine agreed: "If the geophysicists are right, and there's a lot of water in the interior...that certainly makes things difficult."

Meech and colleagues are hunting for primordial sources of water on Earth. They think they've found one near a hot spot, where molten rock from the mantle wells up into volcanoes.

What they find is troubling: Deep water has a different D/H ratio from seawater, so researchers are probably using the wrong ratio. Scientists need to nail that down before comparing Earth's D/H ratio with that of asteroids and comets.

Knowing which specific populations of asteroids or comets brought water to Earth might seem picky, but getting it right ripples out to science's understanding of how water arrives on planets throughout the galaxy. ■

MEETING NOTE

Map of Ceres' surface shows surprises

Clumps of craters on Ceres hint at a surprising past for the dwarf planet. Whether that past involves hidden ice deposits, a devastating whack by another space rock or something else entirely is uncertain.

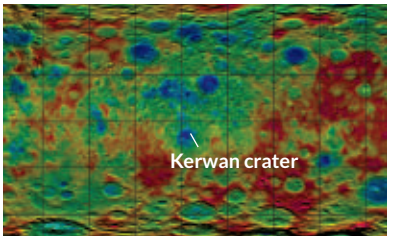
"There is clearly something funky going on," Simone Marchi of the Southwest Research Institute in Boulder, Colo., reported August 3.

Some regions of Ceres have more craters than others. Maps created by the Dawn spacecraft, in orbit around Ceres since March (*SN: 4/4/15, p. 9*), show that areas with the fewest craters overlap regions surrounding the three largest craters, two of which are nearly 300 kilometers across.

The terrain in and around one of these craters, dubbed Kerwan, is quite smooth and flat, Marchi said. This landscape appears to be no older than 1 billion years. "That's relatively fresh and young by geological standards," he said. Ceres, after all, has been around for about 4.6 billion years.

Shifting pockets of subsurface ice could put more spring into the overlying terrain, eroding the oldest craters. If the ice turns to vapor, the ground might collapse and smooth over. Or perhaps Ceres suffered a cataclysmic blow that swept clean some of its terrain.

—Christopher Crockett



The dwarf planet Ceres has an uneven distribution of craters (redder colors show higher elevations) and includes craters, such as Kerwan, that span nearly 300 kilometers.

JPL-CALTECH/NASA, UCLA, MPS, DLR, IDA

ATOM & COSMOS

Mini moons may zip around Earth

One found so far, but more small asteroids probably exist

BY CHRISTOPHER CROCKETT

Earth probably has groupies. A revolving door of tiny space rocks, or "mini moons," might flit around our planet, and Robert Jedicke is determined to find them.

"Only one is known," Jedicke said August 3. "It's not fictional."

With just one temporary tagalong in hand, though, researchers have relied on computer simulations to learn about these visitors from the asteroid belt between Mars and Jupiter. The one discovered in 2006 — roughly 3 meters wide (enormous by presumed mini moon standards) — orbited Earth for about a year. These elusive satellites are tantalizing targets for scoping out asteroids (*SN: 8/23/14, p. 22*) without having to go too far from home.

If only researchers could find more.

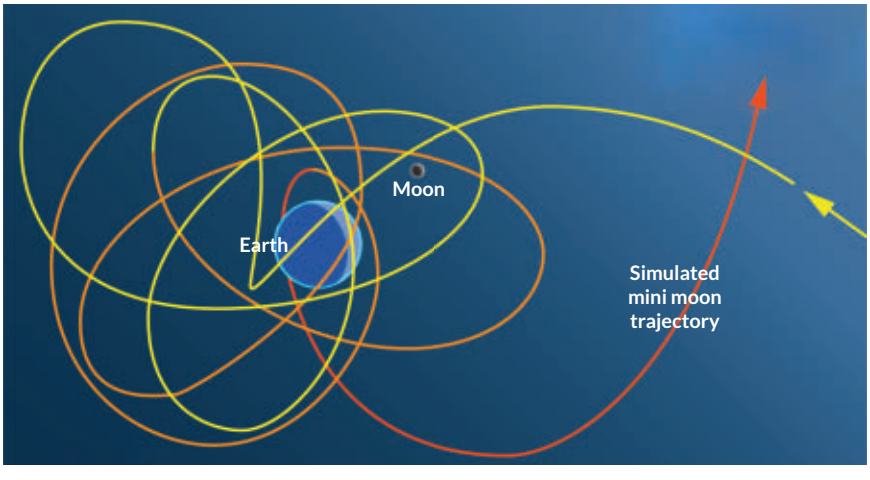
Typically no larger than a washing machine, mini moons are temporarily caught by Earth's gravity. Simulations indicate that the average mini moon hangs around for just nine months. Our planet may attract two roughly meter-sized moons at any one time, said Jedicke, a planetary scientist the University of Hawaii at Manoa. Beach ball–sized mini moons buzz around Earth by the dozen, like a swarm of interplanetary gnats, while dump truck–sized asteroids swing by once every 50 years or so.

These are just theoretical predictions, said Steve Chesley, a planetary scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "But [the mini moons] have to be there, otherwise it would be quite startling." Since a steady stream of space rocks drift from the asteroid belt toward the sun, Earth is bound to snag some of them. These moons are so tiny, however, that without a lot of time on a very large telescope, most remain hidden.

Jedicke has time reserved next year on the Subaru Telescope in Hawaii. With five nights on this 8-meter-wide telescope, there's an 80 percent chance of finding one mini moon, he said.

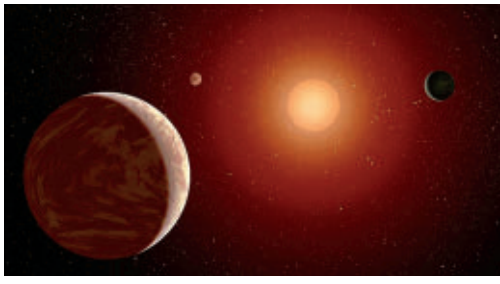
A more dedicated search will have to wait until the Large Synoptic Survey Telescope comes online in Chile early next decade. The LSST will scan the entire southern sky once every three days. Every year, it could find dozens of mini moons as small as half a meter across, Jedicke said.

Mini moons will make great targets for space missions, Chesley notes. "Anytime you want to launch your rocket and go to one of these things," he says, "you can do it because they're always going to be there." ■



A mini moon (yellow trajectory) sidles up to Earth and dances along one possible complex trajectory before leaving several months later (red trajectory). The Earth and the moon are not shown to scale.

FROM TOP: JPL-CALTECH/NASA; K. TERAMURA/UH IFA



MEETING NOTE

Faint red stars can build water worlds drip by drip

The stars likely to have the most habitable planets may also have the hardest time importing water to these worlds, planetary scientist Gijs Mulders reported August 5.

Faint, red orbs known as M dwarfs make up about 80 percent of the Milky Way's stars. But these dwarf stars tend not to build the giant planets like Jupiter that can fling icy asteroids at dry worlds (M dwarf planetary system illustrated above), as is thought to have happened to Earth. Computer simulations, however, show that lots of small boulders working together within a planet nursery can assume Jupiter's and Saturn's role by relocating ice that helps build livable locales.

"Even though water delivery is less efficient," said Mulders, of the University of Arizona, "for a fraction of these stars, it still takes place."

Depending on how much water the typical asteroid carries and how far it has to travel before running into a potentially habitable planet, up to 20 percent of warm rocky worlds around M dwarfs could end up with an ocean, Mulders said. These same simulations put the chances of an Earthlike ocean showing up in a solar system like ours at nearly 100 percent.

The sheer number of M dwarfs makes up for their water-trekking challenges. Pick a warm, rocky, wet world at random, and it probably comes from one of these small red suns. — *Christopher Crockett*

GENES & CELLS

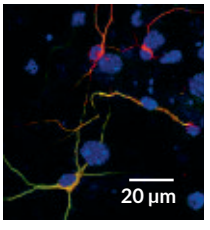
Skin cells transformed into nerve cells

Druglike molecules provide simple reprogramming method

BY MEGHAN ROSEN

In a feat of biological wizardry worthy of Harry Potter, scientists have transformed skin cells into nerve cells — no magic wand required.

Just a handful of chemicals can conjure up nerve cells that look and act like the real thing, Chinese researchers report in two studies in the Aug. 6 *Cell Stem Cell*. Even skin cells from Alzheimer's patients can morph into seemingly healthy neurons, one of the new studies shows. The other reports a similar feat using mouse cells. Scientists have transformed skin cells into nerve cells before, but not as simply.



Adult human skin cells transform into neurons (blue circles with colorful tendrils) a week after being dosed with seven druglike molecules.

"It's a big deal," says Marius Wernig, a stem cell biologist at Stanford University. "I was surprised that it was actually possible." If the technique, which uses small, druglike molecules, can change skin cells into something as dramatically different as nerve cells, Wernig says, scientists could potentially concoct any type of cell.

One day, scientists may even be able to package a few chemicals in a pill and give it to brain-damaged patients to replace busted neurons, says Gang Pei, a coauthor of the human study and a cell biologist at the Chinese Academy of Sciences and Tongji University in Shanghai.

"That's the dream scenario," he says.

Scientists have spent years working on ways to use human cells in therapies for injuries and diseases. Healthy cells transplanted into patients could potentially repair tissue damaged in strokes or heart attacks or be used to treat Alzheimer's disease or diabetes. Finding good sources of cells isn't easy, though. Embryonic cells are adaptable, but research on them raises ethical issues. And adult cells aren't nearly as versatile.

Still, in the last decade, scientists have had some success. Dosing adult cells with a genetic cocktail forces them to crank out proteins called transcription factors that can snap cells back to an embryonic-like state. Scientists can then reprogram the cells into new ones. In 2010, using the gene-based method, Wernig and colleagues figured out how to convert mouse skin cells directly into nerve cells (*SN: 2/27/10, p. 5*).

But the method has some drawbacks. Scientists use viruses to sneak genes into cells' DNA, but no one knows exactly where the genes will squeeze in. These extra bits of DNA could muck up important parts of a cell's genome. What's more, Wernig says, "people are very worried that these viruses could be reactivated."

Because of these fears, "people have been searching for ways to reprogram cells without using transcription factors," says Philipp Koch, a neurobiologist at the University of Bonn in Germany. Scientists have swapped out transcription factors for druglike molecules, using them to convert adult cells into stem cells (*SN Online: 7/18/13*). But until now, no one had used the method to make nerve cells directly from skin.

Pei and colleagues added a mixture of such molecules to human skin cells from healthy people and Alzheimer's patients. Just seven days later, about 20 percent of the cells began to turn into nerve cells. They started sprouting characteristic branching tendrils and even developed the ability to send electrical signals.

The work is proof-of-concept, Pei says, but researchers could theoretically transplant neurons made from a patients' own skin cells into the body or use the neurons to test new therapies in the lab. Doctors could then offer a more personalized treatment approach, where patients get the therapy that worked best on their cells. ■

BODY & BRAIN

A little resveratrol goes a long way

Low dose of red wine chemical protected mice against cancer

BY TINA HESMAN SAEY

Less can be more.

Low doses of resveratrol, a chemical found in red grapes and some other foods, were better than higher doses at stimulating cancer-fighting processes, researchers report in the July 29 *Science Translational Medicine*. Mice with a genetic predisposition for colon cancer also developed fewer tumors on a low dose of the chemical than they did on a higher dose. The effect was noticeable when the mice ate a high-fat diet.

Researchers have long known that chemicals' actions can vary widely at different doses (*SN: 1/20/07, p. 40*). But those findings haven't percolated into most clinical studies of drugs or dietary nutrients, says John Pezzuto, a pharmaceutical scientist at Long Island University in New York. Researchers typically determine the maximum dose that people or animals can tolerate, then prescribe a slightly lower dose, he says.

"The assumption is that the higher the dose you can use without causing toxicity, the better," Pezzuto says. But the new study suggests that "the best dose may not be the highest dose."

Resveratrol is best known as a life-extending chemical, at least in lab organisms. Some work has hinted that that power comes from deterring cancer (*SN: 8/2/08, p. 14*). Karen Brown, a cancer researcher at the University of Leicester in England, and colleagues tested whether the amount of resveratrol people could get from their diets could prevent cancer.

The researchers gave patients undergoing bowel surgery either 5 milligrams or 1 gram of resveratrol daily for a week before the operation. Five milligrams is at the high end of what people might get from foods or red wine, Brown says. Resveratrol was in muscles and intestinal

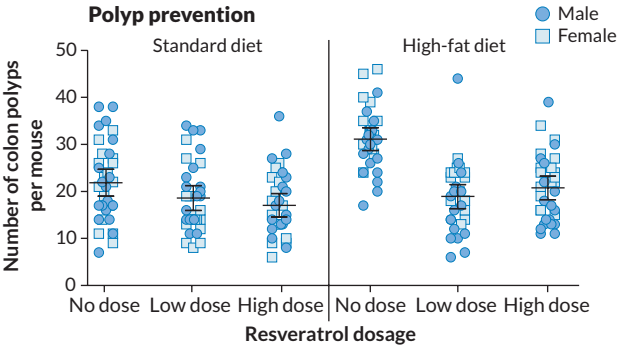
W. HU ET AL/CELL STEM CELL 2015

tissues of people taking either amount, indicating that even at a lower dose, the chemical can get where it needs to go.

The team also worked with mice that have a mutation that causes colon cancer. High doses of resveratrol reduced the number of precancerous colon polyps by 22 percent in mice eating a standard diet but didn't stop tumors from developing. Low doses had no effect.

But the results changed when mice were fed a high-fat diet. Mice given a high dose of resveratrol (14 milligrams per kilogram of body weight) developed a third fewer polyps and a quarter fewer tumors than mice that didn't get the chemical. Low-dose mice (0.07 milligrams per kilogram of body weight) fared even better: They had 40 percent fewer polyps and 52 percent fewer tumors.

Such low doses — less than the 5 milligrams given to people — weren't expected to have any effects, so the result is an important surprise, Pezzuto says. But he's skeptical that the result shows a big advantage for low doses. "Statistically, they are showing an effect, but in my view there's not that much difference," he says. Still, "it would be better to use a low dose if you don't have to use a high dose."



Diet-dependent effect Resveratrol in doses similar to those found in foods reduced the number of precancerous polyps in mice on a high-fat diet. Low doses of the chemical worked better than high doses in mice on the fatty diet (right), but had no effect on polyps in mice fed a standard diet (left).
SOURCE: H. CAI *ET AL*/*SCIENCE TRANSLATIONAL MEDICINE* 2015

In mice and people, low resveratrol doses were also better at stimulating biological processes that may prevent cancer. Higher doses had the opposite effect. Perhaps too much resveratrol triggers others processes that inhibit its beneficial actions, Brown speculates.

These dosage implications may extend to other nutrients reported to fight cancer, the researchers write. Beta-carotene, vitamins C and E, and the nutrient selenium have all failed in clinical trials of their cancer-fighting abilities, mystifying scientists about why such promising chemicals don't live up to expectations. After all, Brown says, "these compounds come to our attention from epidemiological studies that show that populations that consume foods containing these compounds have a lower incidence of cancer."

Her results suggest the failure may have been in giving too much of a good thing, she says. ■

EARTH & ENVIRONMENT

Desert dig uncovers big carbon cache

Aquifers may keep huge amount of CO_2 out of the atmosphere

BY THOMAS SUMNER

The wet undersides of deserts may stash up to a trillion metric tons of climate-altering carbon, more than stored in all land-based plants, a new study suggests.

Human activities such as burning fossil fuels spew carbon dioxide into the atmosphere. Scientists, however, can't account for where as much as 30 percent of this CO_2 ends up.

"We've found a carbon sink in the most unlikely place," says Yan Li, an ecologist at the Chinese Academy of Sciences in Urumqi. Up to a fifth of this missing carbon may end up beneath irrigated deserts, Li and colleagues propose in the July 28 *Geophysical Research Letters*. In arid regions, water from irrigation can flush carbon into underground aquifers, reducing atmospheric CO_2 concentrations and combating greenhouse gas warming, the researchers report.

In the last decade, several studies have measured deserts absorbing unexpectedly large amounts of CO_2. But these findings were controversial because deserts lack the plant life needed to pull in a lot of carbon via photosynthesis, Li says. No one could explain where the carbon went.

Li and colleagues hunted for this vanished carbon around northwest China's Tarim Basin. The researchers collected 170 groundwater samples, plus samples from nearby streams and irrigation channels that feed the farms that straddle the desert's perimeter.

Farmers in arid climates typically overwater crops to flush out salt from the soil. As the water passes through the salty soil, the amount of dissolved carbon in the water more than doubles, the researchers found. Salty, alkaline water can hold more carbon than pure water. Some water makes its way into aquifers, locking away carbon that would normally escape back into the atmosphere. This process boosts the annual amount of CO_2 absorbed by each square meter of desert from 1.34 grams or less to 20 grams or more, akin to the amount of CO_2 absorbed by forests, the researchers estimate. If this process occurs elsewhere, desert aquifers may rank among the top three largest active carbon sinks on land, Li says.

Dating of groundwater samples showed an uptick in carbon collection starting 2,000 years ago, when farming in the area increased. Water usually stays trapped in desert aquifers and is too salty for drinking or irrigation. The carbon will remain underground indefinitely, Li says.

Relatively young carbon isn't definitive proof that desert irrigation is a carbon sink, says biogeochemist Akihiro Koyama of Algoma University in Sault Ste. Marie, Canada. The new carbon may push the old out through an unknown outlet, causing no net effect on the atmosphere. ■

LIFE & EVOLUTION

Caterpillar treats and tricks insects

Brain-altering secretions make ants defend butterfly larva

BY SUSAN MILIUS

Beware the caterpillar offering a juicy treat. Sips tweak ant brain chemistry, lulling the insects into neglecting their own colony in favor of hanging around the source of the marvelous droplets.

Effects on the brain help *Narathura japonica* caterpillars recruit a corps of ant bodyguards, says chemical ecologist Masaru Hojo of Kobe University in Japan. In lab tests, ants sipping these secretions scurried around less on their own initiative than normal ants do. Yet the low-key ants burst into frenzies of defensive aggression when the caterpillar showed alarm. Analyses of ant brains suggest that the caterpillar droplets change the concentrations of the chemical messenger dopamine in the brain. That change may turn passersby into protectors, Hojo and his colleagues report in the Aug. 31 *Current Biology*.

Neglecting their colony tasks, ants hang around — and defend — a *Narathura japonica* caterpillar that oozes droplets spiked with substances that alter ant brain chemistry.

What might look at first like a simple exchange of drinks for defense could turn out to be a trickier manipulation, Hojo suggests. This apparent mutualism could be more like parasitism.

N. japonica caterpillars release a slightly sticky liquid when ants palpate the right spots on the caterpillar's abdomen. Biologists knew the secretions offered some nutrition to ants, but Hojo and his colleagues wondered whether the allure was stronger. Watching ants in the wild, Hojo noted that ants accustomed to droplet feeding don't seem to return to their colonies much, if at all. "They forget about colony tasks," he says.

Lab tests showed that caterpillar-doped *Pristomyrmex punctatus* ants run around less in general, but they erupt into action when caterpillars raise their tentacle organs. These fleshy fingers stretch up when a spider, parasitoid wasp or other danger looms. When Hojo provoked lab caterpillars to raise their tentacles, ants that had not fed on caterpillar droplets mostly ignored the action. But ants that had been lapping secretions for at least three days rushed around excitedly as they do in a crisis. Ants make formidable fighters and can tackle predators that caterpillars can't.

Tests showed that brains of habitual secretion drinkers are lower in dopamine than are brains of unexposed ants. Researchers then used the drug reserpine to block normal ant brains from transporting dopamine. The ants became less active, like ants that lick caterpillars.

The dopamine scenario for manipulating ants sounds possible to neuroscientist Serge Birman of ESPCI Paris Tech. Dopamine deficiency in fruit flies reduces their tendency to run around, he and his colleagues reported in 2011. ■

M.K. HOJO

BODY & BRAIN

Fish oil may ward off schizophrenia

Promising results still need verification in larger study

BY LAURA SANDERS

Taking fish oil capsules for just three months can stave off psychosis for years, a small study finds. If confirmed in larger studies, the results suggest that the common dietary supplement may actually prevent schizophrenia.

Such enduring benefits would be extraordinary, says psychiatrist Jeffrey Lieberman of Columbia University Medical Center in New York City. "It's almost too good to be true," he says. "I still want to see replication before I'm ready to say we have a new standard of care."

In 2010, Paul Amminger of the University of Melbourne in Australia and colleagues reported a tantalizing result: For a small group of young people at high risk of developing schizophrenia, three months of taking 1.2 grams a day of omega-3 fatty acids reduced the risk of psychotic disorders for a year. The researchers' new study, published August 11 in *Nature Communications*, suggests that for many of those people, protection lasted for nearly seven years.

On average, the participants were 16 years old when the study began. During the nearly seven-year follow-up, four of 41 participants who took fish oil developed psychosis, marked by more than a week of hallucinations, delusions and altered thinking. Over the same time period, 16 of the 40 participants who received a placebo became psychotic.

Schizophrenia often emerges in early adulthood — suggesting that treatments might be particularly effective just before that window. It's not clear how the fish oil works, but Amminger thinks that the benefits may come from the omega-3s' inflammation-fighting properties. Some studies have tied schizophrenia to inflammation.

The researchers are now conducting a larger, international study of 304 people, and early results are mixed. After a year, there were no differences in the incidence of psychosis between people who took fish oil and those who took a placebo. Amminger says that noncompliance may be to blame. When the researchers factored in who had actually taken the drug, the results were positive, he says. A different clinical trial based in the United States and Canada is looking at omega-3s' effect on psychosis in 127 young people, with results expected in 2016. ■

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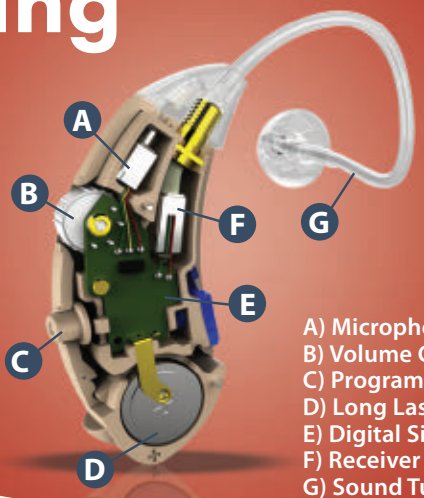

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Studies Show: Hearing Aids MAY HELP Prevent DEMENTIA.

A study by Dr. Frank Lin at the John Hopkins University, found that patients with only mild hearing loss were two times more likely to develop dementia. Fortunately, hearing aids help address hearing loss and may help prevent cognitive health due to hearing loss.

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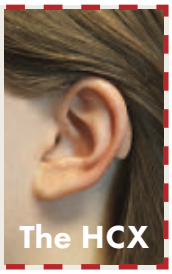

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EARTH & ENVIRONMENT

Nepal quake unleashed long shakes

Low-frequency vibrations to blame for damage in April event

BY THOMAS SUMNER

The April 25 Nepal earthquake killed more than 8,000 people and caused several billion dollars in damage, but new research suggests the toll could have been a lot worse.

GPS readings taken during the quake indicate that most of the tremors vibrated through the ground as long shakes rather than quick pulses. That largely spared the low-lying buildings that make up much of Nepal's capital, Kathmandu, geophysicists report online August 6 in *Science*. Those same low-frequency rumbles, though, toppled Kathmandu's handful of larger buildings.

Understanding why the fault produced a quake at such low frequencies could help seismologists better identify future seismic hazards, says Jean-Philippe Avouac of the University of Cambridge. "This could be some good news not only for this major fault, but also potentially for similar faults around the world."

Nepal sits over a tectonic boundary where the Indian Plate slips under the Eurasian Plate. At places, the two plates snag together, building stress that abruptly releases as an earthquake (*SN: 5/16/15, p. 12*).

Avouac and colleagues monitored April's quake using a network of 35 GPS stations that measured ground movements five times per second. The earthquake shook most intensely at 0.25 hertz, or one full wave every four seconds, with only moderate shaking above 1 hertz, or one or more complete waves per second.

A building is most vulnerable when shaking near its resonance frequency, a range where even small outside forces can result in big vibrations in the structure. Because taller structures have lower resonance frequencies, the April quake's low-frequency rumbles caused larger buildings to sway and crumble while sparing smaller ones, the researchers found.

The low frequencies resulted from the smooth and relatively long duration of the tectonic slipping that initiated the quake, the researchers propose. The low-frequency waves then echoed across the region and produced protracted shaking.

Determining where future low-frequency quakes will strike could save lives by identifying which building types are most vulnerable to collapse, says Kristin Morell, a geologist at the University of Victoria in Canada. ■

MATTER & ENERGY

New twist on entanglement

Link between photon pairs preserved over long distance

BY ANDREW GRANT

Communications of the future may be securely encoded in light that is twisted like fusilli pasta.

A long-distance transmission of particles of light above the Vienna skyline demonstrates a new way of relaying information using the tricks of quantum physics. Researchers exploited light's twistiness to establish a delicate quantum connection called entanglement between pairs of photons. The entanglement stayed intact even after one photon from each pair traversed three kilometers.

The successful link, described online July 23 at arXiv.org, suggests that twisted light may play a key role in implementing quantum communication systems, which require preserving entanglement over great distances. "It allows you to pack more information into your transmission," says Roger Andrews, a physicist at the University of the West Indies in St. Augustine, Trinidad and Tobago.

Physicists used this radar tower in Vienna to beam photons imparted with a twist to a detector three kilometers away.

MATHIAS STAMPFL/ZAMG/WIKIMEDIA COMMONS

Anyone with an Internet connection has received bits of data (1s and 0s) encoded in light. But scientists envision building communication networks that rely on encoding information in photons' fragile quantum properties, then using entanglement to disseminate that data to the intended recipient. A secure key established between parties would prevent information theft.

Physicists entangle photons via a property called polarization, the orientation of light's oscillating electric field. With the measurement of an entangled photon's polarization, one can predict the other photon's polarization. The challenge is finding other light properties that can also be entangled, which would enable each photon to transmit more quantum information over large distances.

One potential property is orbital angular momentum, the twistiness of a light beam. Successive light waves do not always line up like ocean waves along a straight coastline; looking at a beam head-on, waves can arrive in a corkscrew pattern. But many physicists expected that the turbulence of open air would degrade a beam's twistiness and destroy the entanglement, says physicist Martin Lavery of the University of Glasgow.

To test corkscrew-based entanglement, researchers led by Anton Zeilinger of the University of Vienna entangled pairs of photons (A and B) via polarization, then sent a bunch of photon B's through an instrument that converted polarization into orbital angular momentum. Now, in each pair, photon A's polarization was linked to photon B's degree of twistiness. Photon B's were then beamed from a tower in Vienna to a rooftop detector. Despite traveling about three kilometers, the photons retained entanglement. ■

MATTER & ENERGY

Revamping the measure of mass

New efforts bring scientists closer to redefining kilogram

BY SARAH SCHWARTZ

The metric system is on track for a mass makeover.

In an effort to provide accurate measurements at all scales, scientists are preparing to redefine four basic units by the end of 2018. The shift will most notably affect the kilogram, the base measure of mass and the last member of the International System of Units still defined by a physical object. Efforts are under way to check and fine-tune measurements of fundamental natural quantities — including Avogadro's number — that scientists will use to give the kilogram a new mathematical definition.

Since 1889, the standard for mass has been a 1-kilogram cylinder of platinum and iridium metal kept at the Bureau International des Poids et Mesures in Sèvres, France. While this standard is handled carefully, it's at risk of becoming dirty or damaged, says Michael Stock, a physicist at the bureau. "Any material object can change over time."

It's also difficult to accurately scale this physical standard down to very small masses, like those of electrons, says physicist David Newell of the National Institute of Standards and Technology in Gaithersburg, Md.

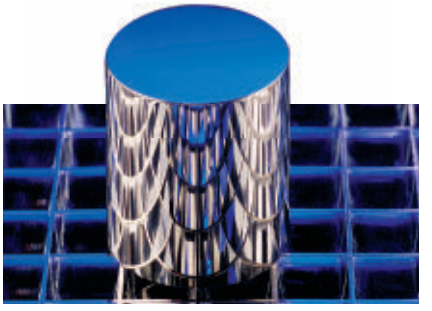
Scientists aim to give the kilogram a new definition based on nature's fundamental physical constants. This task requires a highly accurate measurement of Planck's constant, which links energy and frequency. Scientists can use Planck's constant to measure and describe mass, as the two are mathematically connected through another natural constant, the speed of light. Researchers are using the existing physical definition of a kilogram to measure Planck's constant as accurately as possible. Then this value can be set in stone and used to define mass in the future.

One way to do this is with devices called watt balances. Scientists measure Planck's constant using precisely known standards, including those for mass and electrical current. Once Planck's constant has been fixed, watt balances then use the constant to calculate unknown mass.

In another approach, scientists count the number of atoms in extremely pure 1-kilogram silicon spheres. This number allows scientists to calculate a different fundamental value, the Avogadro constant (or Avogadro's number). This constant describes the number — roughly 6.02×10^{23} — of units per mole, the metric unit for an amount of a substance. (A mole is the mass of a substance equal to its atomic or molecular weight expressed in grams.) A precise Avogadro constant can be used to calculate and confirm Planck's constant.

After cleaning, repolishing and remeasuring silicon orbs used for previous measurements, a team of researchers reported a new value of the Avogadro constant in *Metrologia* in March. When the new value and its uncertainty are averaged with previous calculations, the Avogadro constant comes out to $6.02214082 \times 10^{23}$ with an uncertainty of 18 parts in a billion, scientists report in the September *Journal of Physical and Chemical Reference Data*. This number is slightly smaller than the value of the constant currently described by NIST — $6.022140857 \times 10^{23}$.

The watt balance and atom-counting techniques now give nearly identical values of Planck's constant, with an uncertainty of less than 20 parts in a billion, says metrologist Ian Robinson of the National Physical Laboratory in Teddington, England. Scientists are still working to generate additional measurements and even lower uncertainties.



This metal cylinder is a copy of the international kilogram kept in France. Scientists want to replace this standard, the last physical object used to define a unit of the metric system.

ROBERT RATHE/NIST/FLICKR

In 2018, international delegates at a meeting of the General Conference on Weights and Measures will decide whether to approve the kilogram's new definition. Based on existing plans, many believe the redefinition will happen at this time, Stock says.

Because researchers' careful calculations have accounted for the existing definition of mass, the redefinition should cause no perceptible shift in measurement. "If we do our jobs right, nobody's going to notice a thing," says Newell. But future mass measurements should become stable, Robinson says.

While redefining the kilogram will be the most critical change ahead, Stock says, scientists also hope to redefine other units, including the mole and the kelvin, which measures temperature. These redefinitions will depend on fixing other constants, including the Avogadro constant. Making all of these changes at once will limit the number of times textbooks must be changed, Stock says.

The redefinitions won't mark an end to the quest for a perfect metric system, Newell says. "Metrologists are going to make the measurement exactly right. And the corollary is, they never finish their measurement." ■

$6.02214082 \times 10^{23}$ per mole

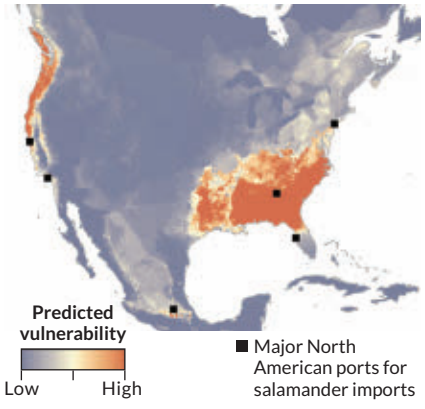
Newly calculated value of the Avogadro constant

LIFE & EVOLUTION

Where salamanders should be very afraid

A salamander-killing fungus hitchhiking via the international live-animal trade may prove especially disastrous if it invades three regions of North America.

Biologists haven't yet reported the deadly fungus, *Batrachochytrium salamandrivorans*, or *Bsal*, loose on the continent, say Tiffany Yap of UCLA and her colleagues in the July 31 *Science*. But North America's native salamanders might have little resistance to a disease thought to have jumped out of Asia before going on a recent salamander killing spree in Europe (*SN: 11/29/14, p. 6*). The researchers warn that *Bsal*, which can eat away skin, might cause particularly deep population declines or extinctions of these amphibians in species-rich swaths of the southeastern United States, the West Coast and Mexico.



Highly vulnerable Combining estimates of pathogen habitats and records of salamander species richness shows three swaths (dark orange) predicted to be highly vulnerable to a *Bsal* catastrophe. If the fungus arrives in North America, salamander losses in these zones could be especially great.

Salamander diversity ranks as one of the great underappreciated treasures of North America. Forty-eight percent of the world's 676 known species scurry around the continent.

The risk of fungus invasion via the international live-animal trade is high, Yap and colleagues say. From 2010 through 2014, all U.S. ports combined received more than 768,000 live salamanders either native to Asia or shipped through an Asian port. The most, about 420,000, arrived in Los Angeles, followed by 272,000 in Tampa, Fla. Until regulations are tightened to cope with containing *Bsal*, the researchers call for an immediate ban on importing live salamanders. *—Susan Milius*

MATTER & ENERGY

Buckyballs turn on copper's magnetism

A new recipe for magnetism calls for an infusion of nano-sized soccer balls.

When layered with sheets of carbon-atom cages called buckyballs, copper and manganese become permanent magnets, researchers report in the Aug. 6 *Nature*. The technique could enable engineers to expand the roster of metals for magnet-based technology, including computer memory and medical imaging.

Previously, iron, cobalt and nickel were the only elements to be room-temperature ferromagnets, materials that retain magnetism after exposure to a magnetic field. Despite bookending those three elements on the periodic table, copper and manganese ordinarily don't support the coordinated electron spin that's necessary for ferromagnetism.

Oscar Céspedes, a condensed matter physicist at the University of Leeds in England, and colleagues tried to remedy that by stacking metal films and sheets of buckyballs, which tend to steal electrons from metals. This subatomic robbery changed the behavior of the metals' remaining electrons. After exposure to a magnetic field, the metal-buckyball layer cakes exhibited about 3 percent of the magnetic strength of iron.

Céspedes says his team is trying out other metals and working to enhance the synthetic magnets' strength for use in commercial applications. *—Andrew Grant*

BODY & BRAIN

Spicy food linked to longevity

Spicy food in the diet seems to contribute to longevity, a study of thousands of people in a Chinese registry finds.

Men who ate spicy food at least once a week were 10 percent less likely to die during the seven-year study period than were those with a more bland diet. Among women with regular spicy food consumption, the mortality rate was reduced by 12 to 22 percent, varying by dose, during the study period. Eating spicy food three or more times a week was associated with the biggest decrease.

These observational data don't establish that spicy foods reduce mortality. But the findings suggest that men who ate spicy food three or more times a week had fewer fatal respiratory diseases. For women, the strongest associations were seen in respiratory and cardiac diseases and in infections.

Capsaicin, the active ingredient in chili peppers, might underlie the benefits, the scientists speculate in the Aug. 8 *BMJ*. *—Nathan Seppa*

GENES & CELLS

Gastric bypass surgery changes gut microbes

Weight loss surgery causes bacteria in the intestines to extract fewer calories from food, a new study suggests.

Changes to the gut microbiome last at least nine years after Roux-en-Y gastric bypass or gastric banding surgery, scientists report in the Aug. 4 *Cell Metabolism*. Groups of women who had either gastric bypass or an operation called vertical banded gastroplasty both had long-lasting changes to their microbiomes regardless of how much weight they lost.

Researchers transplanted bacteria from obese women and from women who had the surgeries into mice raised without gut microbes. Mice with gut bacteria from the surgery groups gained less body fat than did rodents with microbes transplanted from obese women.

Gastric bypass in particular switched the metabolism of microbes so that they burned fewer carbohydrates and more fat, the scientists write. *—Tina Hesman Saey*

T.A. YAP ET AL/SCIENCE 2015

Not getting the sleep you need?
Is your pillow the problem?

On its 10 year anniversary and with over five million satisfied customers, MyPillow® has been selected the *Official Pillow of the National Sleep Foundation!*

How Well Did You Sleep Last Night?

Did you toss and turn all night? Did you wake up with a sore neck, head ache, or was your arm asleep? Do you feel like you need a nap even though you slept for eight hours? Just like you, I would wake up in the morning with all of those problems and I couldn't figure out why. Like many people who have trouble getting a good night's sleep, my lack of sleep was affecting the quality of my life. I wanted to do something about my sleep problems, but nothing that I tried worked.

The Pillow Was the Problem

I bought every pillow on the market that promised to give me a better night's sleep. No matter how many pillows I used, I couldn't find one that worked and finally I decided to invent one myself. I began asking everyone I knew what qualities they'd like to see in their "perfect pillow", and got many responses: "I'd like a pillow that never goes flat", "I'd like my pillow to stay cool" and "I'd like a pillow that adjusts to me regardless of my sleep position." After hearing everyone had the same problems that I did, I spent the next two years of my life inventing MyPillow.

MyPillow® to the Rescue

Flash forward ten years and MyPillow, Mike Lindell's revolutionary pillow design, has helped 5 million people improve the quality of their sleep. MyPillow has received thousands of testimonials about the relief MyPillow has brought to people who suffered from migraines, snoring, fibromyalgia, neck pain and many other common issues.

Lindell has been featured on numerous talk shows, including *Fox Business News* and *Imus in the Morning*. Lindell and MyPillow have also appeared in feature stories in *The New York Times* and the *Minneapolis Star Tribune*. MyPillow has received the coveted "Q Star Award" for Product Concept of the Year from QVC, and has been selected as the Official Pillow of the National Sleep Foundation.

MyPillow's patented technology can help with all of the most common causes of sleep loss and allows you to adjust it to any sleeping position. You can even wash and dry MyPillow as easily as your favorite pair of blue jeans!

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- Jacqueline H.

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Michael J. Lindell
CEO, MyPillow, Inc.

Get the Sleep You've Been Dreaming About

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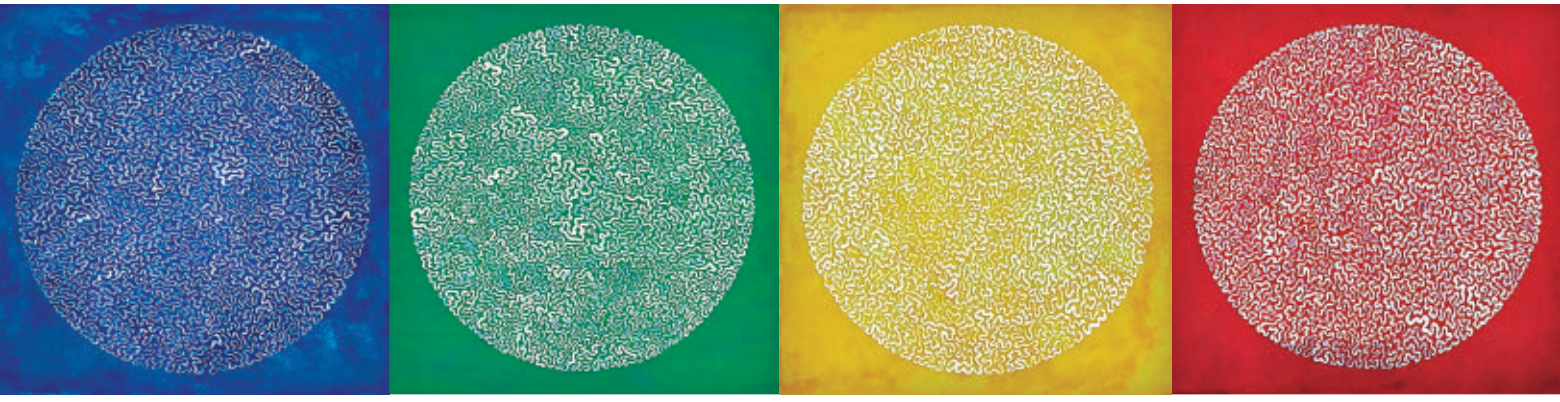


The Shifting NUCLEAR TERRAIN

The human genome's architecture is a moving target

By Sarah Schwartz

If you could unravel all the DNA in a single human cell and stretch it out, you'd have a molecular ribbon about 2 meters long and 2 nanometers across. Now imagine packing it all back into the cell's nucleus, a container only 5 to 10 micrometers wide. That would be like taking a telephone cord that runs from Manhattan to San Francisco and cramming it into a two-story suburban house.

Fitting all that genetic material into a cramped space is step one. Just as important is how the material is organized. The cell's complete catalog of DNA — its genome — must be configured in a specific three-dimensional shape to work properly. That 3-D organization of nuclear material — a configuration called the nucleome — helps control how and when genes are activated, defining the cell's identity and its job in the body.

Researchers have long realized the importance of DNA's precisely arranged structure. But only recently have new technologies made it possible to explore this architecture deeply. With simulations, indirect measurements and better imaging, scientists hope to reveal more about how the nucleome's intricate folds regulate healthy cells. Better views will also help scientists understand the role that disrupted nucleomes play in aging and diseases, such as progeria and cancer.

"It is conceivable that every nuclear process has an element of structure in it," says molecular geneticist Bing Ren of the University of California, San Diego School of Medicine. "It's surprising, in fact, that we studied DNA for so long and yet we still have relatively little understanding of its 3-D architecture."

Make that 4-D. Recent work shows that fully understanding the nucleome requires analysis of its rearrangements in space over time. A cell's nucleome changes during the course of a single day as the cell responds to its environment.

Last year, the National Institutes of Health launched a five-year, 4-D Nucleome program, committing more than $120 million to identify better tools and techniques for mapping the complexities of the genome's 4-D structure. Geneticists, molecular biologists, mathematicians, biophysicists and others are now on an ambitious quest to chart the ever-shifting nuclear terrain.

Location, location, location

The one-dimensional human genome is a biochemical instruction manual for building and operating a human being. Genetic instructions are written with four letters — A, T, C and G, abbreviations for the chemical subunits of DNA. The precise order of these letters encodes recipes for making the body's proteins, as well as directions for how to use these biological building blocks.

But in the body, a genome is more than information written in DNA, says biophysicist William Greenleaf of Stanford University. It's an interesting physical object.

In the nucleus of a human cell, the genetic material winds around protein spools, forming a net of DNA and protein called chromatin, which bundles into 46 parcels, the chromosomes. The chromatin arcs into thousands of loops, held in place by specialized proteins and the physical envelope of the nucleus. The genome manages to squeeze into its tight quarters without getting tangled like the earbuds

Within the nucleus, as in this artist's rendering, the genome coils around proteins and packs into a cell-specific architecture.

MARY ELLEN SCHERL

cord in your pocket, says geneticist and computer scientist Erez Lieberman Aiden of Baylor College of Medicine in Houston.

For years, scientists have been trying to work out the rules for chromatin's careful folding. In 2009, Aiden and his colleagues presented data in *Science* supporting a structure of dense, unknotted chromatin beads clustered into progressively larger clumps. A 2012 study in *Proceedings of the National Academy of Sciences* suggested that chromatin crumples into a range of different forms that vary on different chromosomes and over time.

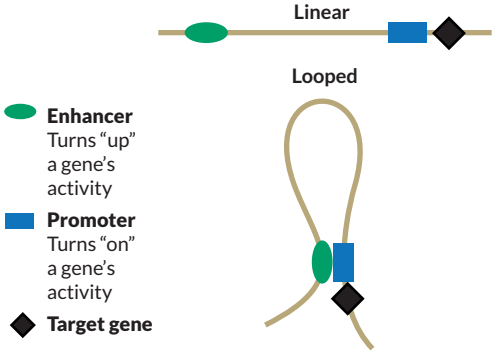
While the nucleome may appear like tangled spaghetti, it's more like a collection of structurally complex meatballs. Within the nucleus, chromosomes are arranged in specific locations. Each chromosome contains clusters of genetic material that get close enough, bundling together, to interact. These groupings can also engage with nearby clusters from other chromosomes.

Like the genetic text within it, the genome's shape holds specific instructions. "The way it's compacted forms this sort of physical memory of what the cell should be doing," Greenleaf says.

Loops of DNA that aren't needed by a particular cell are tucked away from the biological machinery that reads genetic blueprints, leaving only relevant genes accessible to produce proteins. Studies have shown that sections of the genome that are shoved toward the edges of a nucleus are often read less than centrally located DNA. Such specialized arrangements allow cells as diverse as brain cells, skin cells and immune cells to perform different jobs, even though each contains the same genome. "In different cell types, there are very large changes to the regions that are being used," Greenleaf says.

Sections of code that are separated by long stretches can wind up right next to each other, thanks to the looping. This positioning allows one part of the genome to interact with and control a gene that sits thousands of chemical letters away. For instance, enhancers — sections of DNA that increase a gene's protein-producing activity — often seem to be far away from the genes that they control. But in three dimensions, enhancers cozy up to genetic switches that turn on a target gene. In a study published in *Cell* in 2014, Aiden and colleagues reported that roughly 30 percent of observed genome loops put an enhancer next to a far-off gene, complicating efforts to understand any gene's regulation in isolation. "To understand such long-range interaction, we have to understand how DNA is folded," Ren says.

Close contact Enhancers, genetic elements that increase gene activity, are often linearly far away from the genetic switches they control. When loops form, enhancers sidle up to their targets.
SOURCE: J. PLANK AND A. DEAN/*MOLECULAR CELL* 2014



BOTH: E. OTWELL

Seeing is believing

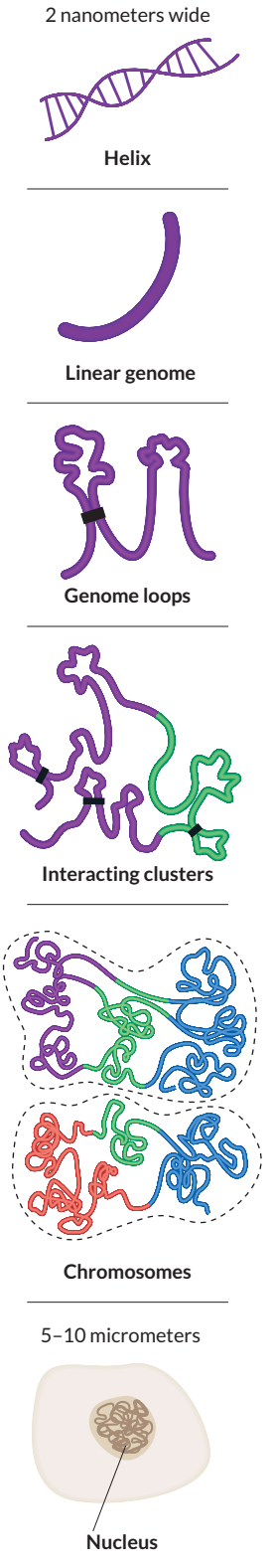
Visualizing the structure of the nucleome has proved challenging. Microscopes can't provide clear and complete images of nuclear architecture. But with modern DNA-reading technologies and the full text of the human genome, scientists are piecing together the genome's three-dimensional shape.

A technique called Hi-C is one of the best options scientists have to scope out the contours of the 3-D genome. Developed by Aiden and his colleagues in 2009, Hi-C indirectly detects which sections of the genome are closest to one another in space inside a cell.

Scientists first chop the genome's thread into small pieces within the nucleus, and then glue this genetic confetti back together with proteins. The proteins simply smash together any two DNA fragments that are sitting side-by-side, whether or not the fragments are close by in the actual sequence. The genome's thread often gets patched back into its original order. But if two linearly distant swaths of genetic code were placed next to each other by a loop, these pieces may end up stuck together, a reflection of their three-dimensional proximity.

In Hi-C, scientists mark the newly paired genome chunks and then count how many times different genome sections are attached. When two distant sections of DNA are frequently observed stuck together, this suggests the presence of a loop.

Packed tight Within a cell nucleus, linear human DNA forms precise loops. Clusters of looped and coiled genetic material can interact with other nearby clusters. Such interactions occur within and between chromosomes, which are arranged in specific locations within the nucleus.
SOURCES: S. RAO *ET AL/CELL* 2014; E. LIEBERMAN-AIDEN *ET AL/SCIENCE* 2009



In their 2014 study, Aiden and his colleagues used Hi-C to generate detailed spatial maps of the full genome in various human cells, including lung, breast and skin cells, as well as three types of cancer cells. The exploration uncovered thousands of genomic loops of varying size. Most are held in place by proteins called CTCF and cohesin. These proteins attach to a specific series of DNA letters that are arranged like bookends around the intervening genome. "The whole mechanism underlying this was sophisticated beyond anyone's expectation," Aiden says.

But Hi-C imaging is just one tool for exploring the genome's landscape. "The analogy would be to go around in life having earplugs and nose plugs and never touching anything," he says. "You never want to rely on one sense; one sense can trick you."

Mapping techniques that analyze proximity should be paired with imaging measurements to truly say something about the genome's geometry, says Indika Rajapakse, a computational biologist at the University of Michigan in Ann Arbor. Rajapakse and his colleagues, for instance, try to paint a spatially accurate picture of the genome by pairing Hi-C with a technique nicknamed 3D-FISH, which labels DNA in three dimensions with glowing chemical tags.

While structural data may indicate which regions of the nucleome are interacting, even the sharpest map doesn't say a thing about what such interactions mean for the cell, or how those interactions change. Scientists want to understand how the genome's structure is connected to the genetic activities that build and control living beings — and this understanding requires a fourth dimension of analysis.

Time passages

A nucleome is constantly changing. "Time means that stimuli are happening," Aiden says. A cell may change its activity as temperature changes, or as its human takes off for a run or goes to sleep.

To explore the link between a nucleome's architecture and its shifting actions over time, Rajapakse and his colleagues generated numerical representations of the relationships between shape and function in the human genome over a 56-hour period. The team paired structural analysis with a technique that measures which DNA instructions are being read and followed at any given time.

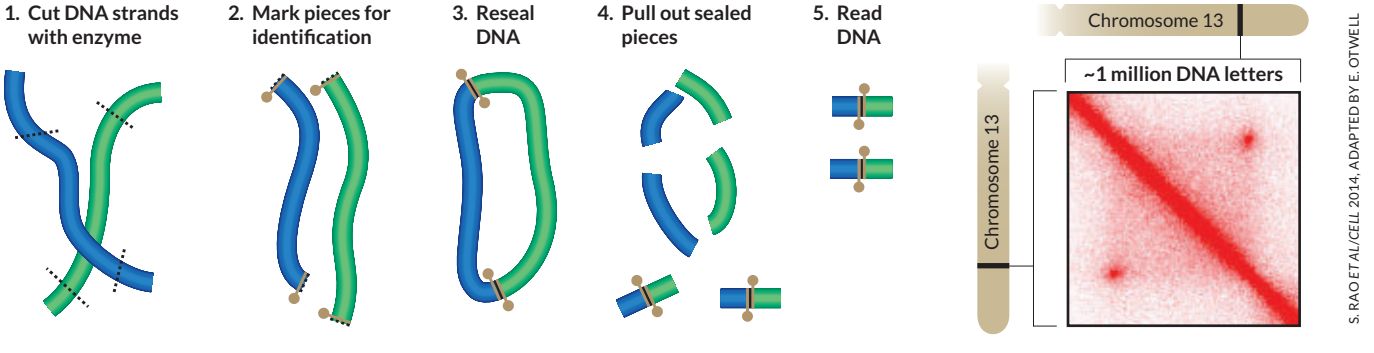
Nearly 2,000 genes shifted their shape, activity and position in relation to at least one other gene in the nucleome, the researchers reported in the *Proceedings of the National Academy of Sciences* in June. Two genes involved in regulating the body's daily cycles (*SN: 7/25/15, p. 24*), *CLOCK* and *PER2*, perform a synchronized dance toward and away from each other in a dependable 24-hour pattern, increasing and decreasing their activity in opposition to one another. Even on Hi-C maps that reveal loops and connections of distant genome bits, the two genes are too far apart to show any physical contact.

The researchers say that existing structural analyses may miss important interactions between distant genes. Understanding the dynamic relationships between nuclear structure and genetic function, Rajapakse says, is the future of nucleome research. The scientists hope that mathematical analyses of the genome will identify important 4-D differences between various cell types and between healthy and diseased cells.

Shaping health

Scientists already know that disrupting the nucleome can cause disease. If the wrong sections of the genome end up next to each other, the controls intended for one gene may be applied to a different gene, with problematic results. In a study published in May in *Cell*, an international team of researchers produced limb malformations in mice by re-creating genetic alterations

Chop, chop To identify sections of the genome that are spatially close to each other, the Hi-C method cuts DNA into pieces and reattaches neighboring pieces within the nucleus. Because bits of the genome that are nearby in 1-D are often nearby in 3-D, a partial Hi-C map (right) has intense values along the diagonal. Red dots at the corners of this map reveal distant areas of DNA on chromosome 13 that are joined by a loop.



S. RAO *ET AL/CELL* 2014, ADAPTED BY E. OTWELL

associated with hand and foot deformities in humans. Deleting or misplacing a chunk of genetic code can shift chromatin's orientation, in this case resulting in fused, misshapen or extra digits, the team showed.

Altered nucleomes have also been linked to aging and aging disorders. Hutchinson-Gilford progeria syndrome, a fatal premature aging condition, results from mutations in the gene that encodes lamin A, a protein that normally supports the membrane surrounding the nucleus. In progeria, the nucleus becomes deformed and chromatin is damaged.

In June, a study in *Science* linked disrupted nucleomes to a different premature aging condition, Werner syndrome (*SN: 5/30/15, p. 13*). Werner syndrome results when cells fail to produce working WRN protein, which, like lamin A, stabilizes a genome's 3-D structure. As a result, young adults suffer symptoms such as osteoporosis, cataracts and hair loss.

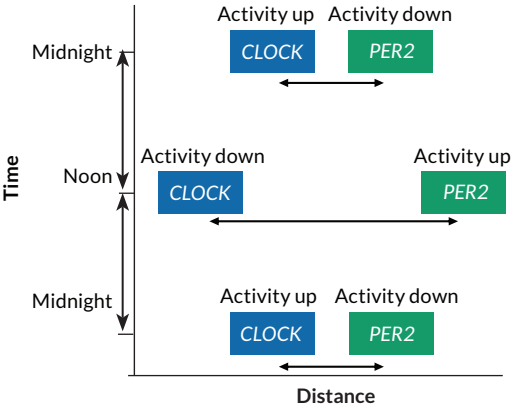
Even healthy cells show a tight link between genome structure and aging: Older nucleomes accumulate genetic damage and appear to compact less tightly. In 2006, scientists found that naturally aging cells showed similar structural changes to cells ravaged by progeria.

Adjustments to the nucleome also play a role in cancer. In fact, in 1914 German biologist Theodor Boveri made the connection between cancer and genetics while observing cancer cells' misshapen chromatin. Rearranging DNA from one chromosome to another can lead to tumors. Some genetic swaps are seen with high frequency in certain cancers, reflecting the close proximity of specific stretches of the genome.

In 2009, researchers identified eight genes that were moved away from their normal nuclear positions in breast cancer cells. The genes were so predictably misplaced that the scientists suggested looking at a gene's position in the nucleus as a potential indicator of cancer.

The nucleome's role in health and aging has given researchers a new framework to study human disease, Ren says. The field has reached a stage where genetics researchers can use insight from the nucleome to understand and guide their own experiments, Aiden says. "It's not just for people who are really passionate about these 3-D genomics questions."

A better understanding of the nucleome will profoundly impact medicine, he predicts. "There are whole classes of diseases where people are going to have aberrations of where their loops are."



Cyclical genes
In the nucleome, the circadian clock genes *CLOCK* and *PER2* move toward and away from each other in a consistent 24-hour cycle, increasing and decreasing their activity as they go.

H. CHEN *ET AL/PNAS 2015*, ADAPTED BY E. OTWELL

Much more remains to be understood about how a genome's shape directs its activity. Future maps might zero in on functionally interesting regions of the genome, Greenleaf says. But he cautions there is also a benefit to unbiased, general exploration. Focusing on one location in the nucleome might lead researchers to miss important structural information elsewhere, he says.

Rajapakse says a close relationship between data collection and quantitative modeling will be necessary to gain a complete understanding of the nucleome.

"Data will guide us to build mathematical models, and then we can make predictions and go to the lab," he says. His next projects will explore how to use nuclear structure and function to reprogram cellular systems, changing a nucleome's organization to turn one cell type into another, he says.

Once they have the nucleome's organizational rules in hand, some scientists, including Aiden, hope to engineer genomic loops in the lab. Because loops tightly control a gene's activities, engineered loops could be used in gene therapies as a biological on/off switch for inserted genes, Aiden says.

High-quality maps of the nucleome are poised to uncover rich biological truths, Aiden says. He views the task ahead as similar to early astronomy. For Galileo to discover that Jupiter had moons, or that the Milky Way was a galaxy packed full of stars, he simply had to point his telescope in the right direction.

"I feel like in a small way, 3-D genome maps are eloquent in that way," Aiden says. "Once you have that resolution...you can just read biology." ■

"There are whole classes of diseases where people are going to have aberrations of where their loops are."

EREZ LIEBERMAN AIDEN

Explore more

- Erez Lieberman Aiden. "Zoom!" GE Prize Essay. *Science*. December 2, 2011.

BY A HAIR Strands of hair left at a crime scene could carry bacteria that help identify a suspect.

SCENT OF DEATH One day, scientists may be able to identify the odors that seep from a dead body during different stages of decay.

FOOTFALL The soles of people's shoes pick up microbes from the floor and could offer clues about where a person has been.

DUST BUNNIES Fungal spores riding on specks of dust could help investigators track where a suspect or a bomb came from.

In the mid-1900s, Frances Glessner Lee built detailed miniature crime scenes, "Nutshell Studies of Unexplained Death," to help police learn to identify important evidence. The dioramas are on display in Baltimore at the Office of the Chief Medical Examiner.

WANTED:

Crime-solving bacteria and body odor

New techniques may boost credibility of forensic science

By Meghan Rosen

Forensic biologist Silvana Tridico was puzzled by pubic hair.

Specifically, pubic hair samples donated by two volunteers.

She had just finished analyzing the bacteria stuck to the hair of seven people. If each hair sample carried unique mixes of bacteria, Tridico reasoned, investigators might have a new tool to help identify crime suspects. Hair bacteria, like fingerprints, could offer a forensic link between criminals and the bits of bodily debris they left behind.

But two of the hair samples held nearly identical microbe populations. "I thought I'd made a mistake," Tridico says. She repeated the analysis, and still, the hairs' bacteria matched. One explanation came to mind.

"I said to my partner, 'I think they've had sex.'"

Tridico was right. Two of the study's participants had, in fact, had sex 18 hours before snipping off strands of their hair for Tridico's analysis. Their bacteria apparently mingled so much, she says, that their microbial medleys became indistinguishable. Since the telltale traces lingered for so many hours — even after the volunteers had showered — Tridico thinks the technique has the potential to match sex offenders to their victims.

"I'm so pumped," says Tridico, of Murdoch University in Perth, Australia. "I really think it's got traction."

Though still in early stages, her technique and other advances signal the rumblings of a seismic shift in the forensics field. One day, tiny microbes could hand investigators big clues. Bacteria shed from people's hair, skin and footprints, or fungi hidden in specks of dust, could help place suspects at the scene of a crime. And just a whiff of odor clinging to a fingernail or seeping from a dead body could help investigators track a missing person — or corpse.

As new techniques gain their scientific footing, researchers are also shoring up classic forensic tools that have taken recent high-publicity hits. Some of the most time-honored techniques, such as fingerprint analysis, have been resting on rickety foundations. In the last few years, researchers have taken a closer look at forensic science's tarnished old hide. Bit by bit, they're tugging it into the 21st century.

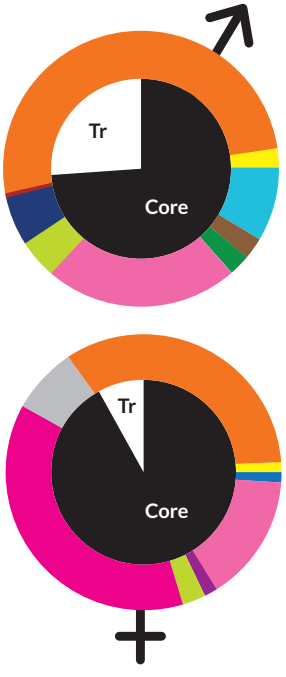
Traces of trouble

If justice is a woman clutching sword and scales, then forensic science is a sprawling beast, with a hodgepodge of tools stuffed in its fists.

These tools target almost every mark a person can leave behind: fingerprints, blood spatters, handwriting, DNA, hair and more. Each trace represents a little shred of history that might help investigators piece together a picture of the past.

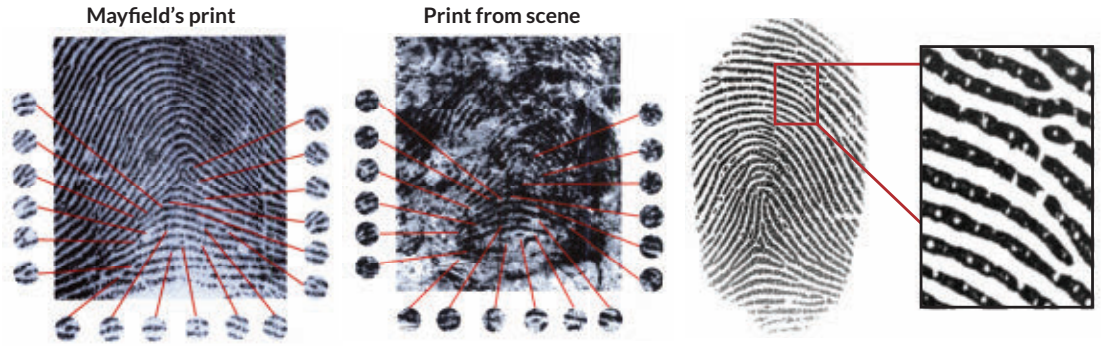
But not all forensic science disciplines are created equal. Some, such as fingerprint analysis, are steeped in more than a century of tradition but not a lot of data. Seasoned experts train apprentices in the craft, and examiners' opinions can carry too much weight.

Criminal forensics' shortcomings drew



To each his or her own People's pubic hairs harbor diverse collections of bacteria. In one study, men (top) had drastically different compositions of bacteria than women (bottom). Over five months, some types of bacteria stayed constant (core) and others appeared only transiently (Tr). SOURCE: S. TRIDICO *ET AL*/*INVESTIGATIVE GENETICS* 2014

OPPOSITE PAGE: CORINNE BOTZ



Fingered In the case of Brandon Mayfield, the FBI mistakenly matched one of his prints (left) to a smudgy print (middle) lifted from a plastic bag full of detonators. Investigators used features of Mayfield's fingerprints (shown in circles) to make the match. Researchers may be able to improve the process by comparing the individual pores dotting a person's fingertips (white specks in box at right).

international attention in 2004, when the FBI bungled the investigation of the Madrid train bombings. The bureau's lab matched a single smudged fingerprint on a plastic bag to an Oregon attorney named Brandon Mayfield — an innocent man. Mayfield spent two weeks in jail before the Spanish National Police identified an Algerian man as the fingerprint's actual source. The U.S. government formally apologized to Mayfield in 2006 and agreed to pay him $2 million.

The misidentification of Mayfield sparked renewed scrutiny of forensic techniques, says John Butler, a forensic DNA scientist at the National Institute of Standards and Technology in Gaithersburg, Md. "It really woke people up."

Soon after, a National Academies panel poked into forensics' scientific nooks and crannies. In 2009 it released a damning report. The story was grim: Deep cracks ran through several forensic bedrocks — especially those based on expert interpretations of patterns.

"If the claim is that you're able to exclude everyone on Earth but the person of interest, that is ridiculous."
CHRISTOPHE CHAMPOD

Experts often reach conclusions that are just too black or white. Testimony that two fingerprints "match," for example, implies that an examiner's findings are definitive.

But that's never the case, says Christophe Champod, a forensic scientist at the University of Lausanne in Switzerland, who reviewed recent advances in fingerprint identification in the August 5 *Philosophical Transactions of the Royal Society B*.

"If the claim is that you're able to exclude everyone on Earth but the person of interest," he says, "that is ridiculous."

Fingerprints and other forensic analyses can offer only probabilities, Butler says. But no one has a good handle on how to calculate them. Unlike DNA analyses, fingerprints lack the population data that would help pin down how certain an examiner is of a match.

The report exposed problems in other areas too. There's little evidence that handwriting and bite-mark analyses can reliably identify people. Blood spatter experts read too much into stain patterns.

"It was a very hard-hitting report," says study director Anne-Marie Mazza of the National Academies' Committee on Science, Technology and Law in Washington, D.C. "It said that the system was broken," she says, "that there was a lack of solid scientific basis for a number of techniques."

The report didn't shock everyone, Champod says. But it dropped a bomb on the public and members of the judiciary. "They were living with the illusion that all the science had been done for many, many years," he says.

In reality, it hadn't. Some disciplines, such as DNA and chemical analyses, were considered scientifically sound. But many techniques needed more grounding. So the National Academies report proposed a roadmap to improvement. In the six years since the report's publication, scientists have begun dreaming up new forensic tools to replace or work alongside those that are less than reliable. They're also beefing up the old standards.

"There's been a bit of a paradigm shift," Mazza says. "But change takes time. New ways of thinking take time."

Flawed cases

Americans may have adopted a new way of thinking about one forensic discipline this year, after reports of a more recent FBI fumble. The problem this time: microscopic hair analysis.

In April, the Justice Department and the FBI released a statement exposing errors made by FBI hair examiners. The magnitude of the misstep was breathtaking. In cases where microscopic hair comparisons linked a defendant to a crime, examiners made mistakes 96 percent of the time. In 33 out of 257 of these flawed cases, defendants received the death penalty.

Traditionally, examiners scrutinize hairs under a microscope, marking off distinctive features,

LEFT: OIG/U.S. DEPT. OF JUSTICE, "A REVIEW OF THE FBI'S HANDLING OF THE BRANDON MAYFIELD CASE," 2006; RIGHT: A. ANTHONIOZ AND C. CHAMPOD/*JOURNAL OF FORENSIC SCIENCES* 2014

such as shape and pigment patterns, inch by careful inch. If a strand of hair from a suspect looks like one found at a crime scene, prosecutors can tie a suspect to a crime.

But no one knows just how widespread different hair features are. So there's no way to figure out the odds that one suspicious strand of hair actually belongs to a particular suspect. What's more, microscopic hair analysis depends on a skillful eye. "It's totally based on your expertise and abilities," Tridico says. Overstate the evidence, and innocent people could go to jail, she says.

And that could happen, the investigation noted.

"The FBI had people who were saying things that were not supportable," says forensic geneticist Bruce Budowle, who worked at the FBI Laboratory Division for decades. The National Academies report in 2009 had uncovered a similar problem. In court, some hair examiners would state the odds that a hair belonged to a certain suspect, despite the fact that no statistical data existed to back up the claim. No one had even hammered out what it meant to say that two hairs "matched."

"I really hate that term, 'match,'" says Tridico, an expert at analyzing human and animal hairs. A jury might think it means there's no doubt a hair came from a certain suspect, she says. But there's always doubt. An examiner could potentially use hair analysis to narrow a pool of suspects, but it's just not possible to use the technique to identify an individual.

Today, most labs have moved away from microscopic hair comparisons. Labs rely more on a DNA-based technique called mitochondrial analysis to tell two hairs apart. In the technique, examiners collect DNA from within the tiny mitochondria that power a cell. These organelles are stuffed with their own DNA, which examiners can analyze for patterns and use to link hair samples from crime scenes to suspects.

Microbes are the new fingerprints

Tridico thinks hair analysis might improve with a metagenomics approach — going beyond the victim's or the suspect's DNA and instead looking at the bacteria loaded on a particular strand of hair, for example. Microbes on pubic hair differ from person to person, Tridico and colleagues reported last year in *Investigative Genetics*.

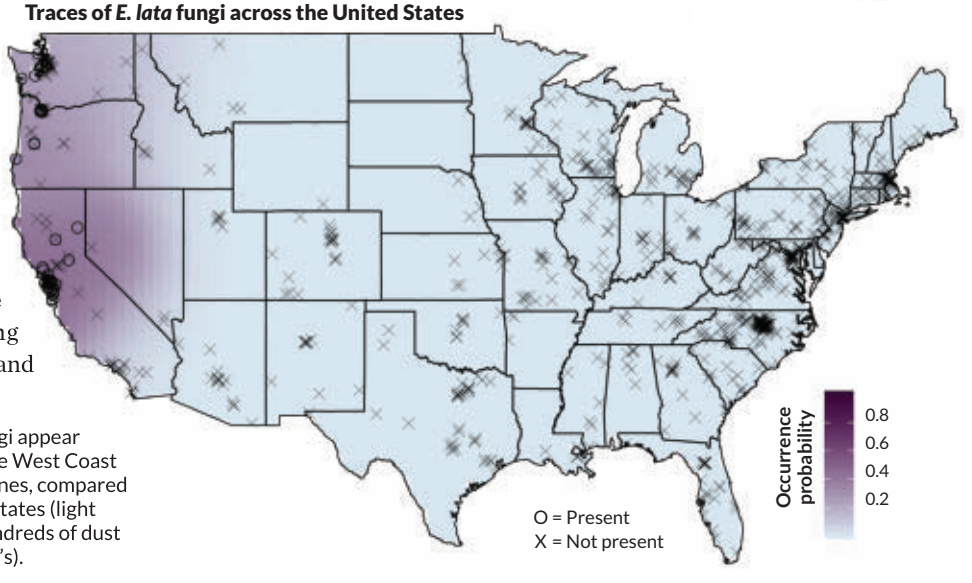
What's more, pubic hair bacteria could reveal more than a person's identity: They could even offer hints about lifestyle. One sample Tridico tested was covered in marine bacteria. "I thought it was really bizarre," she says. Then she found out that the hair belonged to someone who swam in the ocean every day.

Tridico thinks that hair bacteria could one day help investigators glean other telling details about suspects, including their ethnicity (different ethnic groups can carry different assortments of bacteria in their mouths and guts, so hair bacteria may differ too). That day is still a long way off, Tridico cautions. Big hurdles stand in the way of making new advances that would be accepted in the courtroom.

New forensic techniques face the same troubles vexing old ones. They need to be scientifically validated, they need to be reliable and, to become commonplace in crime labs, they need to be simple and cheap. All this requires money for research, which has been lacking.

Still, the idea of microbes as an identification tool is catching on.

Skin bacteria lingering on a computer keyboard can be matched to the person who touched it, scientists reported in 2010. "We're constantly leaving skin bacteria behind," says study coauthor Noah Fierer, a microbial ecologist at the University of Colorado Boulder. So if investigators can't scrape up enough human DNA to test, they could



Scattered spores Traces of *Eutypa lata* fungi appear more frequently in dust samples collected on the West Coast (purple areas), where the fungus infects grapevines, compared with samples from other regions of the United States (light blue). To make this map, scientists examined hundreds of dust samples for the fungus's presence (marked by O's).

MAP: N. GRANTHAM *ET AL*/*PLOS ONE* 2015; PUPKIS/ISTOCKPHOTO

potentially analyze bacterial traces instead.

Still, like Tridico, Fierer thinks microbe-based identification needs more testing. Scientists need to confirm how well it works outside the lab. And they'll need to gather a lot more data from a lot more people to find out whether a person's microbial signature is unique. "We're not locking people up in jail with this method," he says. "It's just a proof of concept."

In June, researchers backed up the concept with some population data. Looking at human gut bacteria from poop, researchers calculated that they could pick out individuals from a pool of hundreds of people. They reported their results in the *Proceedings of the National Academy of Sciences*.

The DNA of bacteria and other tiny organisms could even serve as a kind of biological tracking device. Bacteria from the floor, for example, can transfer to shoes, leaving an invisible record of a person's travels, ecologists suggested in May in *Microbiome*. And fungal spores riding on specks of dust can reveal roughly where in the United States those dust specks came from, Fierer and colleagues reported in April in *PLOS ONE*.

Fierer's team analyzed DNA from traces of fungi in 928 dust samples from across the country, and mapped where different fungus species tended to cluster geographically. The map let the researchers pinpoint a dust sample's origin within about 230 kilometers. Given the roughly 4,500 kilometers that stretch between east and west coasts, Fierer's technique could help investigators infer a person's general location.

"Let's say someone sent you a package with a bomb in it," he says. "The idea is that we could look at the dust in the sample and identify where the package had been shipped from."

Scent of a human

In some cases, the barest traces of an odor — a few chemicals wafting in the air — may implicate a perp. Living or dead, people may leave behind a telltale scent.

The scent of human decomposition was first admitted into a U.S. court of law in 2011, at the trial of Casey Anthony. After a utility worker discovered the skeletal remains of her 2-year-old daughter, Caylee, prosecutors accused Anthony of first-degree murder. Odor evidence hinted that a dead body had spent time in the trunk of Anthony's car: Two cadaver dogs had picked up the scent, as did a chemical analysis. In court, a forensic scientist reported that compounds in the air matched those known to leak from decaying bodies.

But no one has spelled out a reliable chemical signature for the scent of death, says analytical chemist Kenneth Furton of Florida International University in Miami.

"I testified that I didn't believe the science was sufficient," says Furton, who studies the odor of humans and their remains.

The odor and other forensic evidence presented in the case weren't enough to convict. On July 5, 2011, a jury found Anthony not guilty of murder. She was released two weeks later, having already served three years for lying to police.

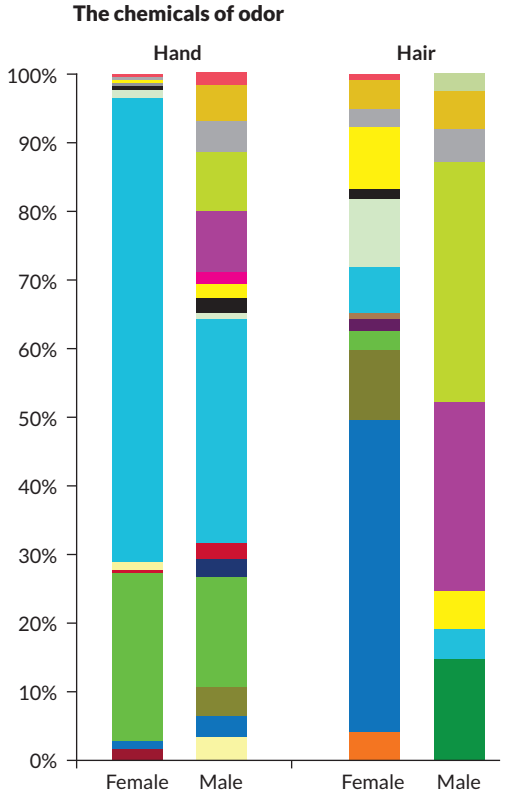
The scent of death is a slippery thing. "Once you die," Furton says, "the chemicals you give off start to change almost immediately — and they vary over time."

Within minutes of death, skin begins to blister and bag, and cells dissolve. A few days later, when microbes digest soft tissue, the body bloats and takes on a greenish hue. When the skin splits and slips away from the body, gases seep out, and muscles and fat start to decay. Bones are the last to crumble (*SN Online: 7/22/15*).

Each stage of the grisly process releases a different brew of chemicals. Identifying the ones that make up death's signature scent is like throwing a dart at a clock and trying to hit the second hand.

Human bar code

Odors from people's bodies are made of distinct chemical blends (each bar color at right represents a different chemical). Individuals' scents, whether from their hands or their hair, could serve as a kind of chemical identifier. Investigators could one day use odor to link suspects to crime scenes. SOURCE: J. BROWN *ET AL/FORENSIC SCIENCE INTERNATIONAL* 2013



Still, scientists hoping to pin down the scent of death have seen a few promising glimmers.

"I think it can be done," Furton says. Last year, he and colleagues picked out odors that could discern the stages of mouse decomposition, from fresh to advanced decay. Also in 2014, Belgian researchers writing in *Analytical and Bioanalytical Chemistry* suggested odor-trapping and analysis methods that could help scientists find chemicals specific to human corpses. Had scientists already identified these chemicals, the scent clinging to Anthony's trunk might have been more telling.

Though the scent of death remains elusive, scientists have begun using odors to identify the living. Just the chemicals wafting off people's bodies can distinguish them from others, Furton's lab reported in 2013 in *Forensic Science International*.

Furton's team collected nail clippings, hair snippets, saliva and cotton gauze pressed between the palms of 20 volunteers. Then the researchers analyzed odor compounds hovering in the air above the samples with a mass spectrometer.

The soap people use and food they eat contribute to their odor. After whittling those away to uncover the genetic component of scent, Furton's team found that each person's samples gave off a distinguishing chemical blend. "It's almost like a human bar code," Furton says.

He thinks that scent bar codes could offer investigators a clue when other biological evidence is scarce. Even if a perpetrator left a crime scene wiped clean of fingerprints or DNA, Furton says, "it's very possible they would still leave behind human scent."

And unlike some types of trace evidence, such as fingerprints, scent wouldn't rely so much on examiners' opinions.

Slow and steady

Matching a clean fingerprint with one inked on an official, 10-print card can be easy. Examiners run a print through a computer program that scans millions of other prints for similar patterns, and — voilà! — the program spits out a match.

But analyzing the smudgy, dirty, partial prints picked up from crime scenes requires more finesse. Computer programs aren't as good as the human eye at spotting details in low-quality prints. That's where the experts come in.

Fingerprint examiners look for distinguishing features — the forked ridge of a whorl or the end of an arch, for example — and manually punch the details into a print-scanning program. But these details rely on subjective judgments, and the reliability of these judgments can vary. "I always worry when people say, 'I've been doing this for 30 years, therefore I know what I'm doing,' " says Budowle, now at the University of North Texas Health Science Center in Fort Worth.

Rather than dumping fingerprints as an investigative tool, scientists have begun shoring up their scientific foundation (*SN: 5/13/14, p. 14*). In the *Proceedings of the National Academy of Sciences* in July, researchers studying 12 years of police fingerprint records confirmed what examiners had believed since the late 1800s: Fingerprints don't change much over time. So a long-term print database makes sense.

Meanwhile, researchers have been trying to better understand and improve the technique's reliability. Last year, Champod's team reported in the *Journal of Forensic Sciences* that analyzing the itty-bitty pores dotting people's fingertips could improve the reliability of fingerprint analysis. The metric might give examiners another way to differentiate between suspects.

These advances mark some of the forensic field's steps toward greater scientific credibility. "We have a better handle on the problems than we did six years ago when the National Academies report came out," Budowle says.

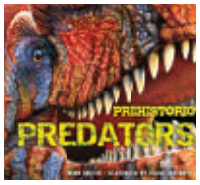
Forensic scientists are starting to fortify weak spots, but progress will be gradual, Butler cautions.

"You have to make changes as you go along," he says. "You can't shut down the entire criminal justice system and wait till we get everything perfect." ■

The microbes living on people's hair and skin could transfer to anything they touch (colored remnants in room model above). Those invisible traces may help investigators identify or track a suspect.

Explore more

- Sue Black and Niamh Nic Daeid, eds. "The paradigm shift for forensic science." *Philosophical Transactions of the Royal Society B*. August 5, 2015.



Prehistoric Predators
Brian Switek and Julius Csotonyi
APPLESAUCE PRESS, $19.95

BOOKSHELF

Children's book shows beauty of ancient predators

The great carnivores of the past have come a long way. Formerly sluggish, coldblooded and scaly, dinosaurs and other creatures have transformed with new scientific knowledge into speedy, graceful, often feathered marvels. Now science writer Brian Switek and illustrator Julius Csotonyi give the ever-popular meat eaters updated treatment in *Prehistoric Predators*.

The book is marketed to children, but it should impress adult fans of dinosaurs. The predators have gained dinofuzz but lost none of their majesty. The book starts in the Permian period, beginning 299 million years ago, and concludes long after the dinosaurs' demise, in the Pleistocene with *Titanus walleri*, a "terror bird" that lived until 1.8 million years ago. Each page highlights a predator, with information boxes providing the animal's size, when it lived, interesting facts and a very welcome pronunciation guide. Switek also elaborates on topics such as dinosaur brains, feathers and parenting.

The gargantuan greats are well represented, and *Tyrannosaurus rex* gets its due. But there are also less well-known carnivores that are sure to become favorites, including the reptile *Titanosuchus ferox* and the pterosaur *Quetzalcoatlus northropi*. The barely meter-long dinosaur *Sinornithosaurus millenii* had wicked extendable claws, showing that size isn't everything when it comes to effective hunting.

Each creature is lushly illustrated by Csotonyi; the art makes every page turn a wonder. —*Bethany Brookshire*

Gods of the Morning
John Lister-Kaye
PEGASUS, $26.95

BOOKSHELF

Scottish birds delight the reader

Good nature writing can take a landscape filled with strange species and render it familiar. It can also make a locale loaded with well-known creatures seem exotic. In *Gods of the Morning*, naturalist John Lister-Kaye does both with flair.

This enchanting book chronicles the changing of the seasons at a nature center in the Scottish Highlands. Lister-Kaye established the facility nearly 40 years ago on a former hunting estate in a remote area dappled with floodplains, forests, marshes and meadows.

Lister-Kaye focuses on birds and has a keen eye for detail. His lyrical turns of phrase take readers deep into the world of ravens and rooks (Eurasian relatives of crows) as well as barn owls and blackcaps (a type of warbler). Likening whooper swans' calls to flugelhorns, he writes, "When six or seven birds are flying together in close formation, wings almost touching, their soft flugelings overlap in a rare and disturbing music that can be heard for miles."

Tales of the area's mammals also abound, including an encounter with a magnificent buck early on a winter's morning. It's not always fulsome praise for wildlife, however: Lister-Kaye describes the year-round struggle of guarding his family's henhouse against foxes and the craftier, weasellike pine martens.

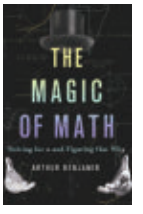
Pine martens play dual roles in the book, as chicken murderers and as one of the region's ecological success stories. The long-term recovery of pine marten populations from lows in the 1960s came largely thanks to Scottish foresters' increasingly tolerant attitudes toward "vermin," as well as an overall gain in suitable habitat.

But the account of that triumph is more than outweighed by the loss of many bird species that no longer call the glen home, probably in part because of a gradual warming of the climate. Warming has also caused the area's weather to be more fickle, leading to occasional breeding failures among many species, including the author's beloved rooks.

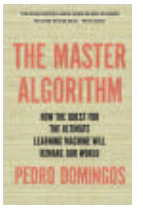
From poignant reflections on a bird that's flown into a windowpane to musings on childhood experiences that blossomed into his lifelong love of nature, Lister-Kaye's observations help readers connect with the natural world. —*Sid Perkins*

BOOKSHELF

Secret Science
Ulf Schmidt
A historian traces human experimentation involving chemical and biological weapons after World War I. *Oxford Univ., $39.95*



The Magic of Math
Arthur Benjamin
Learn classic ideas in algebra, geometry and more, while having fun with the author, a "mathemagician" and professor of mathematics. *Basic Books, $26.99*



The Master Algorithm
Pedro Domingos
A machine learning program that could derive all knowledge would change cancer treatment, dating, war and many other human experiences, a computer scientist writes. *Basic Books, $27.99*

Buy Books Reviews on the *Science News* website include Amazon.com links that generate funds for Society for Science & the Public programs.

Broadcom MASTERS semifinalists selected

On August 19, the Society for Science & the Public announced 300 semifinalists for the 2015 Broadcom MASTERS, a national science and engineering competition for sixth-, seventh- and eighth-grade students. The semifinalists hail from 226 middle schools in 39 states and American Samoa and represent 127 regional and state science fairs. California claims the highest representation this year with 61 students, followed by Florida, Texas, Massachusetts and Oregon.

Students qualified to enter Broadcom MASTERS by being among the top 10 percent of participants at SSP-affiliated science fairs. The semifinalists were selected from 2,230 applicants. Each application received three independent readings and evaluations by distinguished scientists, engineers and educators.

Finalists will be announced on September 2 and will then have an opportunity to travel to California for the Broadcom MASTERS finalist week in early October, where they will compete for a top award of $25,000.

View the full list of the semifinalists and their projects at **bit.ly/SSP_semifinalists2015**

Society receives high marks among nonprofits

The Society for Science & the Public has been named a Top-Rated Nonprofit by GreatNonprofits, an online resource that collects reviews from donors, volunteers and others about their experiences with nonprofit organizations. The Top-Rated ranking is awarded to nonprofits that receive 10 or more 4- or 5-star reviews and that maintain an overall rating of 3.5 stars. Thank you to all of our reviewers for making this possible!

Here's what people are saying about the Society's programs:

AN ALUMNUS: "Participating in Intel ISEF has been one of the most transformative and influential experiences of my life. I can think of no other event or organization that has had such a profound impact on that number of people and inspired them to enter a career in the STEM fields."

AN EDUCATOR: "The *Science News for Students* website is my go-to resource for disciplinary literacy. Thanks to donor support, they are able to provide a free resource for students and educators. The writing is engaging, and I find the articles especially helpful for teaching students to see cause-and-effect relationships, identify literary devices in informational text and to compare and contrast findings."

A PARENT: "As an educator and parent of an Intel ISEF alumnus, I can't begin to say enough about the opportunities that Society for Science & the Public provides for students. The interaction that goes on between young people from all over the world combined with the support they receive from some of the best scientists and business people from across the globe is unparalleled."

A VOLUNTEER: "I was a volunteer at Intel ISEF for four years and hope to return! The organization goes above and beyond to make sure that the kids have a great time and enjoy the returns of all their hard work."

Read more reviews or leave your own at **bit.ly/SSP_TopRated**

Upcoming alumni events

Are you an alumnus or alumna of the Society? Did you participate in one or more of our educational competitions, including the Intel Science Talent Search (formerly Westinghouse), Intel International Science and Engineering Fair or Broadcom MASTERS?

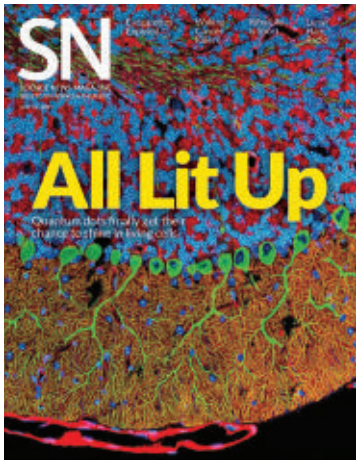
If so, please join us at one of our upcoming September events:

SEPTEMBER 4
SSP Alumni Pizza Party
YALE CENTER FOR ENGINEERING INNOVATION AND DESIGN, NEW HAVEN, CONN.

SEPTEMBER 9
Reception for Science Talent Search Alumni
AKAMAI TECHNOLOGIES, CAMBRIDGE, MASS.

SEPTEMBER 17
SSP Alumni Happy Hour
WASHINGTON, D.C.

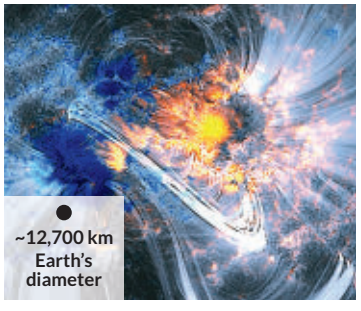
For more information about upcoming alumni events, or to reconnect with the Society, contact Carolyn Carson at ccarson@societyforscience.org.



JULY 11, 2015

Sizing up sunspots

Christopher Crockett's "A loopy look at sunspots" *(SN: 7/11/15, p. 32)*, prompted reader **Bill Prince** to suggest showing Earth's diameter to give perspective to the photo of part of the sun's surface. Here's the image again, with Earth for scale.



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Untangling the faith debate

*In "A biologist takes aim at religion" (*SN: 7/11/15, p. 27*), **Bruce Bower** reviewed* Faith vs. Fact, *a book arguing that real knowledge about the universe comes from science, not spirituality.*

A number of readers wrote in to challenge one particular line from the review: "If religion is irrational, it should have been eradicated through natural selection among Stone Age folk." **William Check** wrote, "Where is the logic behind that assertion? Humans are predominantly irrational, driven mostly by emotions — fear, greed, anger, hatred, lust, power. Rationality only arose as a significant force in the 16th or 17th century, and its influence is still pretty anemic."

The use of "irrational" in the sentence is a bit of a red herring, **Bower** says. You can call a belief irrational if it doesn't follow classical rules of logic, but, as a few readers pointed out, the key issue is really whether that belief was evolutionarily advantageous. Researchers don't yet know how religion got started or why it has been such a big part of the human experience. But anthropologists suggest that ancient religious, spiritual or supernatural beliefs had big benefits for early humans, such as promoting codes of conduct within groups. Such benefits would have enhanced survival and reproduction, which might explain why religion has persisted over the course of human evolution. But it's a complicated issue that's still being debated, a point not well explained in the review.

A reflective hobby

*In "The moon bouncer" (*SN: 7/11/15, p. 4*), **Julia Rosen** described how Nobel laureate and ham radio enthusiast Joseph Taylor reflects radio waves off the lunar surface.*

"Your article on Joe Taylor neglected to mention that he invented WSJT, a software program that makes amateur radio moon bounce much easier," wrote **Eric Norris**. "This has allowed many, many more hams to experience the thrill of moon bounce since smaller antennas and less power are required for success." **Norris** also recalled a memorable meeting with Taylor: "I had been giving talks for years at local ham clubs and conventions called 'Moon Bounce for the Masses,' where I described how easy it is now to do moon bounces using Joe's software. I arrived at a convention forum room early one morning to set up my laptop. As I was about to begin, I looked up and there was Joe in the second row! After being apoplectic for a few minutes, I managed to stammer out my presentation. Joe was gracious throughout."

Learning from bad leaders

*A daring leader with bad information can guide a group right into trouble. In "Bold, incorrect spiders mislead groups" (*SN: 7/11/15, p. 13*), **Susan Milius** reported that colonies suffer while spiders slowly catch on to their leader's errors.*

Readers gleefully drew comparisons between the spiders and their least-favorite politicians, public figures and other notable leaders. "I've had bosses like that," quipped **Breandán Mac Séarraigh** on Facebook.

Others took the implications of the study more seriously. "While caution should be exercised in extrapolation to other animal behavior, the implications for the decline of human empires is self-evident. The increasing consolidation of executive control to an oligarchical group may create potential weakness if 'bold, incorrect views' are present," wrote **Adrian Bartoli**. "One obvious current example is the decline of the United States in scientific prominence as current political and religious views toward global climate change, stem cell research and science in general have impeded progress." But **Roger Eagan** pointed out that spiders and humans are very different: "Saying that a certain velvet spider has a 'bold personality' only confuses this behavior with human connotations of such psychological terms. Can't we recognize, describe and name such diversity of behavior in other species without always making ourselves the measure of all things?"

NASA SDO

Long tongue, meet short flower

The "tongues" of South Africa's long-tongued flies are certainly long, but they're not flexible. So a fly has to hover at a distance to sip from a flower's shallow nectar cup, as seen in the above photograph, which was honored in the 2015 *BMC Ecology* Image Competition.

The drinking tube on this particular species, *Prosoeca ganglbaueri*, can grow up to 5 centimeters long. When folded backward during flight, about half of it sticks out behind the fly's body. Extreme length lets flies either dabble in shallow blossoms or reach into flowers with deeper nectar tubes. As the mouthparts of various long-tongued flies lengthened through the ages, more than 120 flower species, including *Zaluzianskya microsiphon* (right), coevolved longer tubes.

Most of these fly-specialist flowers bloom pink or white. But those color preferences aren't inborn for the flies, says Michael Whitehead, an ecologist (and photographer of both shots) at the Australian National University in Acton. His current research reveals that flies learn color preferences based on what's rewarding in their local floral buffet. In some places, flies learn only a narrow range of sweet colors. But in landscapes with more options, the flies willingly sip pink, white — and blue.
— Susan Milius

The nectar tube of the *Zaluzianskya microsiphon* flower fits this fly's long tongue like a glove.

BOTH: M. WHITEHEAD

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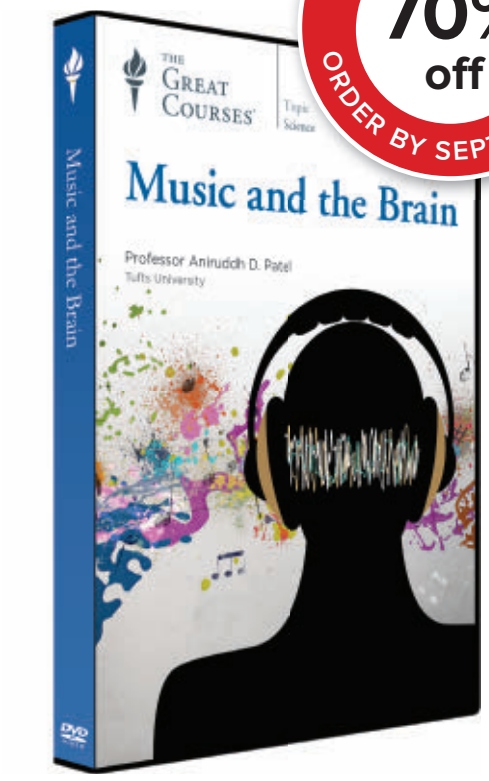

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