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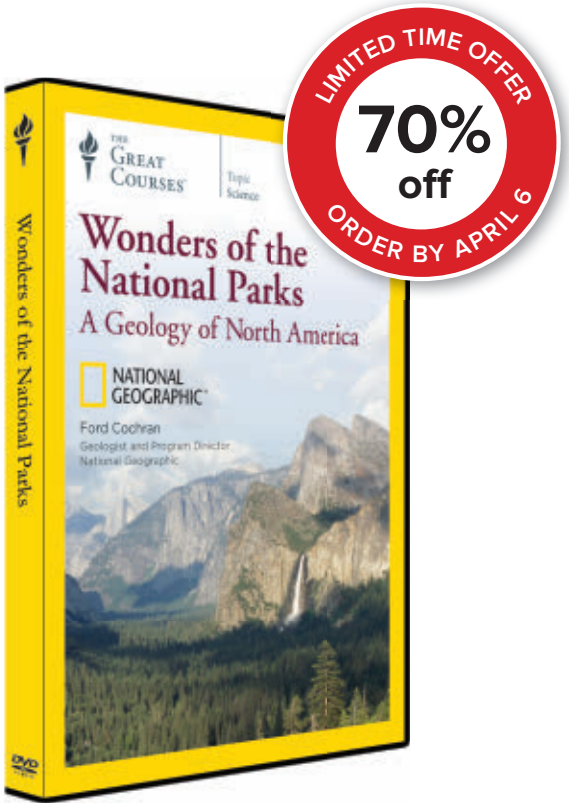

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ScienceNews


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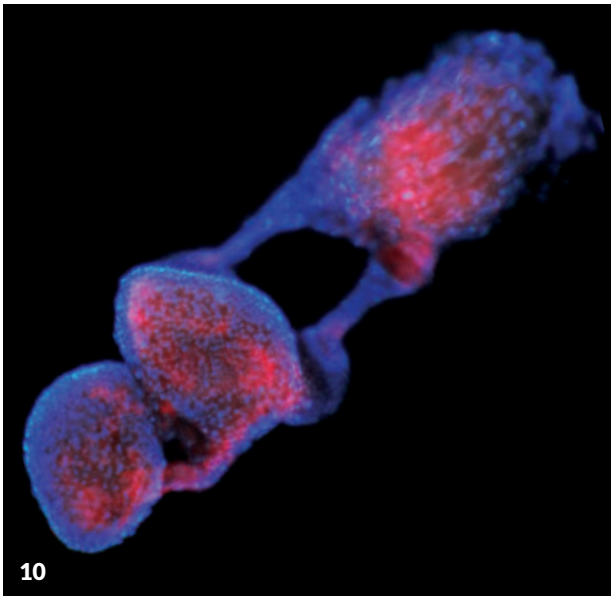
Features

News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Departments

SOCIETY UPDATE
Volunteer, judge or interpret at Intel ISEF

COVER A cancer cell has large surface proteins with chains of sugars (illustrated) that hide the tumor from immune attack. *Nicolle Rager Fuller*

CLOCKWISE FROM TOP: TASSII/ISTOCKPHOTO; X. WANG *ET AL*/*NATURE COMMUNICATIONS* 2017; S. BORDENSTEIN/VANDERBILT UNIV.

Lab tests aren't the answer for every science question

In the second half of the 17th century, the chemist and polymath Robert Boyle and philosopher Thomas Hobbes engaged in a divisive debate centered on a temperamental, mechanical contraption known as an air pump. In a series of famous experiments, Boyle used the air pump, which has been called "the cyclotron of its age," to test basic scientific principles such as the relationship between a gas's pressure and its volume. But the debate was about more than the scientific results; it was about the very nature of science. As Simon Schaffer and Steven Shapin recount in their 1985 history of the controversy: "Robert Boyle maintained that proper natural philosophical knowledge should be generated through experiment and that the foundations of such knowledge were to be constituted by experimentally produced matters of fact. Thomas Hobbes disagreed."

To question the value of experimentation in science would be heretical among most modern scientists. So much of today's effort to understand nature depends on properly designed experiments that control for unwanted variables and are detailed enough to be reproducible. In any high school physics class, students drop objects from the same height and clock how fast they fall to understand gravity, or pull various objects across a table to calculate coefficients of friction. Controlled experiments are even popular in studying the messiness of animal behavior: The chimpanzee tests described on Page 8 by writer Bruce Bower examine how social status affects the spread of a food-snagging strategy.

But controlled experiments still have plenty of limitations. Researchers must have a deep knowledge of their systems and the potential variables at work — a near-impossible task for many areas of inquiry. Assumptions have to be made, about whether a setup really mimics the real world and whether subjects will respond naturally in a lab environment. On Page 18, freelance writer Laura Sanders describes some of the troubles in trying to understand how smartphones are changing people's brains. "This is a lot like drawing conclusions about the effects of baseball on players' brains after observing three swings in the batting cage," says experimental psychologist Andrew Przybylski.

In some cases, experimental tests can't be done because they are unethical. Other times, tests don't turn out as expected: Two crafty chimps in the food-snagging study found a way to game the system that probably delighted the scientists but also added fuzziness to the results.

In short, experimentation is not always the answer — and certainly not the only answer. In this modern era, with more complicated instruments and more clever testing regimes, we should remind ourselves of the value of observational work. Some of this issue's most surprising stories rely on data straight from the natural world. Researchers have found, for example, Canadian fossils that might represent the oldest known life (Page 6). Other scientists uncovered evidence that the Amazon isn't quite as wild as we might think (Page 13). By placing monitoring devices on the trunks of just a couple of elephants in Africa, a team discovered that some pachyderms sleep just two hours a day (Page 10). Try studying that in the lab. — *Elizabeth Quill, Acting Editor in Chief*

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CANYONLANDS NATIONAL PARK

Canyonlands National Park offers an escape to a place of heights and depths, an alien world of fins, spires, baking sun, and shadowy silence. The Green and Colorado Rivers, and their confluence in the park, divide the park into three districts: Island in the Sky, a high plateau between the rivers in the north; the Maze and Horseshoe Canyon, west of both rivers; and the Needles, southeast of the rivers. Roads lead into these districts, but there are no bridges between them, just a long drive around the park. Four-wheel-drive roads lead to the remote areas, as do the rivers, which require experience to raft. Be sure to get the appropriate permits before exploring the backcountry. Bring plenty of water and supplies, and know what kind of country you are heading into.

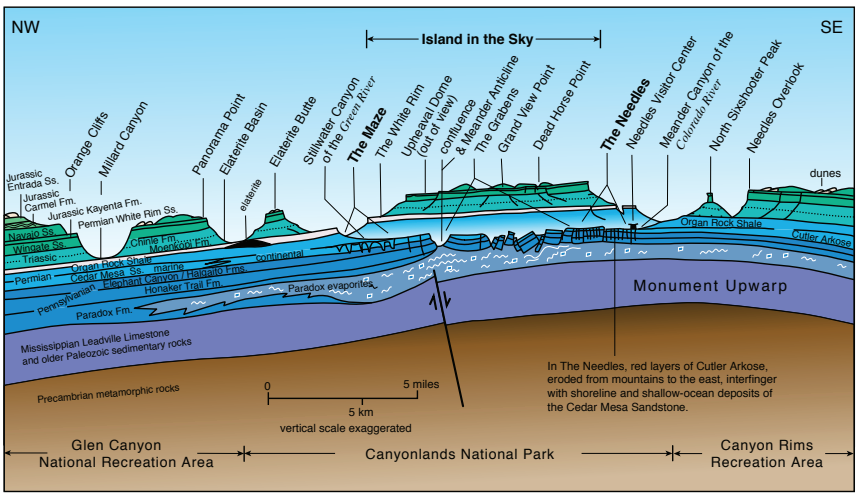
The layer-cake geology of the Colorado Plateau shows up beautifully in Canyonlands National Park. The Colorado and Green Rivers have exposed mile upon mile of sedimentary rocks: Pennsylvanian, Permian, Triassic, and Jurassic, the oldest deep in the canyons. The layered rocks are part of the north end of the Monument Upwarp, so they cross Canyonlands in a broad, gentle arch.

Like its neighbor Arches National Park, Canyonlands is underlain by salty evaporite beds of the Paradox Formation. In Pennsylvanian time, the continental collision that formed the supercontinent Pangaea also pushed up the Appalachians, the Ancestral Rockies, and a range called Uncompahgria in western Colorado. Uncompahgria was thrust westward over other rock. It weighed down land farther west, forming the Paradox Basin, a gulf with restricted circulation. In Paradox Basin, a balance between evaporation and circulation resulted in ideal conditions for the formation of evaporites: there was enough evaporation for minerals to be concentrated in the seawater, and yet the gulf was regularly replenished with fresh supplies of seawater. The basin filled with the Paradox Formation: up to 4,000 feet (1,220 m) of salt, gypsum, potash, and anhydrite along with thin layers of mud and silt, and then with limestone and shale of the Honaker Trail Formation.

On the shelf of Permian White Rim Sandstone that surrounds the Island in the Sky, the White Rim Road is a favorite hiking, 4WD, and mountain biking trail.

Toward the end of Pennsylvanian time, the basin had filled and alluvial fans from the mountains—the Cutler Arkose—began to reach Canyonlands. As the mountains wore down, wind winnowed the alluvium and built dunes, which became the Permian Cedar Mesa Sandstone. Through the rest of Permian and Triassic and into Jurassic time, dune sand alternated with the red sandy mud of tidal flats and floodplains as the climate and sea level changed. Many of the formations are interfingered in the area. Occasionally, a period of increased erosion left a conglomerate layer, such as the Shinarump at the base of the Chinle Formation.

The rivers did most of the sculpting in Canyonlands, but their work was aided by the way deep vertical joints split the rocks and by the influence of salt under part of the national park. Erosion was, of course, aided by the great elevation of the high desert. Once the Colorado River had cut headward into this land, it gave the other rivers and streams of the region the energy to cut very deeply.



Northwest-southeast cross section of Canyonlands National Park.

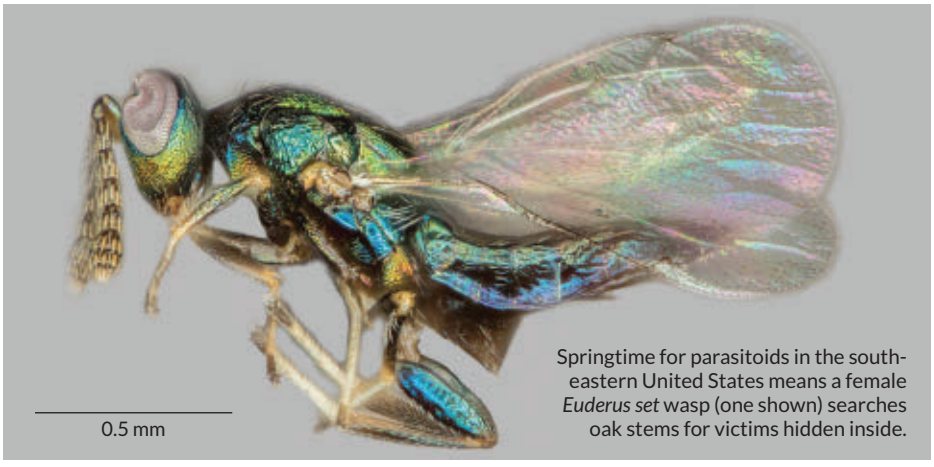
Excerpt from the April 1, 1967 issue of *Science News*

50 YEARS AGO

LSD may damage chromosomes

Two New York researchers have found the hallucinogenic drug will markedly increase the rate of abnormal change in chromosomes. [Scientists] tested LSD on cell cultures from the blood of two healthy individuals ... [and] also found similar abnormal changes in the blood of a schizophrenic patient who had been treated with [LSD]. The cell cultures showed a two-fold increase in chromosomal breaks over the normal rate.

UPDATE: Psychedelic-era reports that LSD damages chromosomes got lots of press but fell apart within a few years. A review in *Science* in 1971 concluded that ingesting moderate doses of LSD caused no detectable genetic damage. Researchers are still trying to figure out the molecular workings of the drug. Recent evidence suggests that the substance gets trapped in a pocket of the receptor for serotonin, a key chemical messenger in the brain. Its prolonged stay may explain why LSD trips can last up to a day or more (*SN: 3/4/17, p. 16*).



Springtime for parasitoids in the southeastern United States means a female *Euderus set* wasp (one shown) searches oak stems for victims hidden inside.

IT'S ALIVE

Wasps are experts at crypt escape

Parasites can drive their hosts to do weird, dumb things. But in certain oak trees, the parasites themselves get played.

"Creepy and awesome," says Kelly Weinersmith of Rice University in Houston, who has helped reveal a Russian doll of nested parasitisms.

The saga begins when two majestic live oak species in the southeastern United States send out new shoots, and female crypt gall wasps (*Bassettia pallida*) arrive to lay eggs. A wasp mom uses the delivery end of her reproductive tract to drill through tree bark, injecting each of her eggs into a separate spot in the oak. Wasp biochemistry induces the tree to form a botanical womb with an edible lining largely free of oak defense chemicals. The tree is hijacked into nurturing each larva, and wasp life is good — until the unlucky ones get noticed by a second exploiter.

Another wasp species, a newly discovered *Euderus*, arrives, barely visible to the naked eye but "amazingly iridescent," Weinersmith says. Her colleague at Rice, Scott Egan, named these jewel blue and green specks after Set, an Egyptian god of evil and chaos.

The hole in an oak stem (magnified above) is the tantalizing escape route that a crypt gall wasp almost finished before it died. Its head got stuck, and the darker part of the gap is where a second wasp species, *Euderus set*, bit through its victim's head to freedom.

E. set wasps enslave the *B. pallida* as laborers and living baby food. *E. set* females sense their prey inside the gall and inject eggs that hatch and feed on the original occupant. When the invaders mature, they are typically too frail to dig themselves out of the tree. But that's not a problem, Weinersmith, Egan and colleagues report in the Jan. 25 *Proceedings of the Royal Society B*. That's because, despite having a gnawing parasite inside, *B. pallida* wasps dig a tunnel to freedom.

Almost. When infested with *E. set*, the tunnelers don't manage a large enough hole for their own escape. They die with their heads plugging the tunnel exit, perfect for the *E. set* attackers, who chew an escape hole through the stuck noggins.

Weinersmith and Egan may be the first to describe *E. set*'s manipulation, but what could be a much earlier example was collected by Alfred Kinsey — yes, that Kinsey. Before shocking mid-20th century America with explicit chronicles of human sexual behavior, he specialized in gall wasps. He named more than 130 new species in just three years, collecting at least 5.5 million specimens, now at New York's American Museum of Natural History. One of his *Bassettia* has its head stuck in a too-small exit hole in a stem, suggesting a chaos-and-death wasp lurks inside. — *Susan Milius*

FROM TOP: S.P. EGAN *ET AL*./ZOOKEYS 2017; SEAN LIU

Watch a video of wasp escape artists at **bit.ly/wasp_parasite**

INTRODUCING

Gecko gives predators the slip

Large, detachable scales make a newly discovered species of gecko a tough catch. When a predator grabs hold, Madagascar's *Geckolepis megalepis* strips down and slips away, looking more like slimy pink Silly Putty than a rugged lizard.

All species of *Geckolepis* geckos have tear-off scales that regrow within a few weeks, but *G. megalepis* boasts the largest. Some of its scales reach nearly 6 millimeters long. Mark Scherz, a herpetologist and taxonomist at Ludwig Maximilian University of Munich, and colleagues describe the new species February 7 in *PeerJ*.

The hardness and density of the oversized scales may help the gecko to escape being dinner, Scherz says. Attacking animals probably get their claws or teeth stuck on the scales while *G. megalepis* contracts its muscles, loosening the connection between the scales and the translucent tissue underneath. The predator is left with a mouthful of armor, but no meat. "It's almost ridiculous," Scherz says, "how easy it is for these geckos to lose their scales." — *Elizabeth S. Eaton*

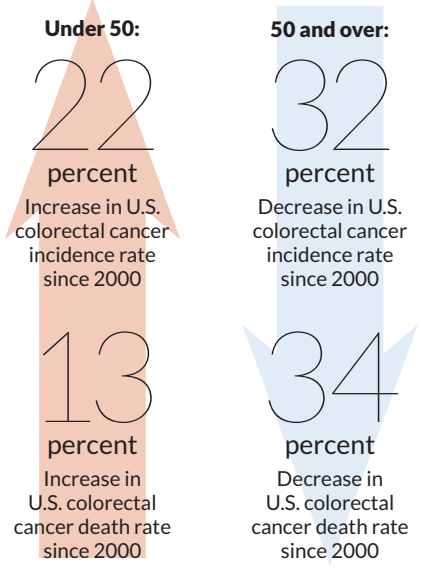
Geckolepis megalepis (left) lets go of its scales to elude enemies, exposing the pinkish tissue underneath (right).

SCIENCE STATS

Colorectal cancer is on the rise among younger adults in the United States

In recent years, rates of colorectal cancer cases and deaths in the United States rose among young and middle-aged adults, according to an American Cancer Society study of colorectal cancer trends between 2000 and 2014. At the same time, rates of colorectal tumors and deaths dropped in people age 50 and older, researchers report online March 1 in *CA: A Cancer Journal for Clinicians*.

Few people under age 50 get colorectal cancer, but incidence in this group has risen since 2000, from 5.9 new cases per 100,000 people to 7.2 per 100,000 in 2013. The rate for people age 50 and older was 119.3 per 100,000 in 2013. New cases are still most prevalent in people 65 and older: 58 percent of the estimated 135,430 new diagnoses in 2017 are expected to occur in that older age group.



Overall, colorectal cancer incidence and death rates are declining. Researchers attribute the drop to decreases in smoking and red meat consumption, an increase in aspirin use — which can calm inflammation that spurs tumor growth — and improvements in screening and treatment. Researchers suspect that an increased prevalence of obesity, unhealthy diets and sedentary lifestyles contributed to the rise in colorectal cancer cases and deaths among adults younger than 50. — *Tina Hesman Saey*

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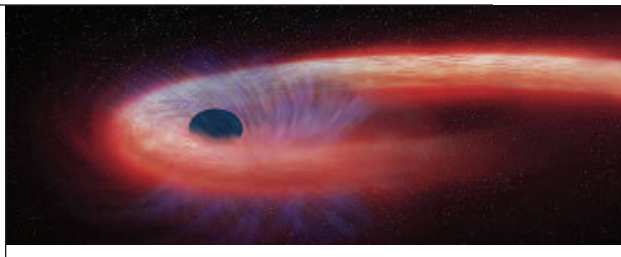


THE -EST

Black hole enjoys long stellar feast

Black holes are speed eaters, usually scarfing down a star in less than a year. But a supermassive black hole in a galaxy about 1.8 billion light-years away has been gorging on a single star for more than 10 years (illustrated above), longer than any other observed supermassive black hole meal.

Astronomers detected the extraordinary feast in X-ray images from ESA's XMM-Newton spacecraft and NASA's Chandra and Swift satellites. From 2005 to 2008, X-rays from the region grew 100 times brighter — probably as the black hole began devouring the star — and the glow has been largely sustained ever since. The consumed star may be a hefty one with 10 times the mass of the sun, which could explain the extended meal. The X-ray flare probably won't dim significantly for several years, the astronomers predict February 6 in *Nature Astronomy*. — *Ashley Yeager*

LIFE & EVOLUTION

Tiny fossils could be oldest signs of life

Hydrothermal vents spewed microbes, researchers contend

BY MEGHAN ROSEN

Tiny, iron-rich fossils exhumed from the depths of an ancient ocean could reveal the cradle of life.

These micrometer-scale structures are probably remnants of microorganisms that once lived amid hydrothermal vents, researchers suggest in the March 2 *Nature*.

"In a nutshell, what we've found are the oldest microfossils on Earth," says study coauthor Matthew Dodd, a biogeochemist at University College London. The rocks that hold the fossils came from Quebec and date to somewhere between 4.28 billion and 3.77 billion years ago — when Earth was still a baby. The next oldest microfossils reported are just under 3.5 billion years old, though their validity has been debated (*SN: 2/8/14, p. 16*).

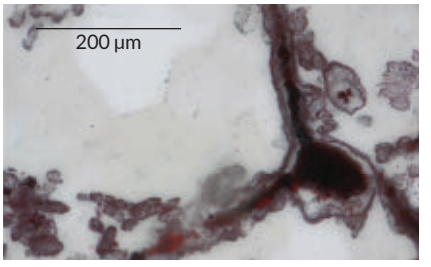
If Dodd's structures truly are remnants of microbes, "it's fantastic. I love it," says astrobiologist Martin Van Kranendonk of the University of New South Wales in Sydney. But he's not convinced. In fact, he says, "there's just not definitive proof that any of the textures or the minerals or features they have is unique of life."

Claims of early life are frequently fraught with controversy. For one, says Dodd, "these are big claims — these are our origins." And scientists studying early life typically don't have a lot to work with. It's not like they're looking at dinosaur bones. In billions-of-years-old microbes, obvious cellular bits and other familiar flags of life have often been stripped away. And in Earth's oldest rocks, extreme heat and pressure could have cooked and squashed any remnants of life beyond recognition.

So researchers rely on chemical tests and analyses of rock patterns and textures — which are sometimes microscopic — to amass different lines of evidence. Last year, Van Kranendonk and colleagues reported evidence of ancient microbial structures in 3.7-billion-year-old rocks from Greenland (*SN: 10/1/16, p. 7*).

Though those structures, called stromatolites, may be similar in age to Dodd's microfossils, they came from an entirely different environment: shallow marine waters, perhaps touched by sunlight. Microbes thriving in two different environments so early in Earth's history would mean that life arose and diversified quickly, Dodd says. "Life didn't really struggle to get a foothold."

His team looked at jasper rocks believed to be the leftovers of matter that once belched out of hydrothermal vents and then rained down on the seafloor. The researchers spotted narrow tubes and filaments of the iron-rich mineral hematite that resemble those made by bacteria today, Dodd says. Specks of iron clung to the sticky surface of the ancient microbes, forming a kind of armored coat that preserved the organisms' shapes, he says.



This filament and clump of iron ore (lower right) may have once been a strand of microbial cells attached to rocks around a hydrothermal vent.

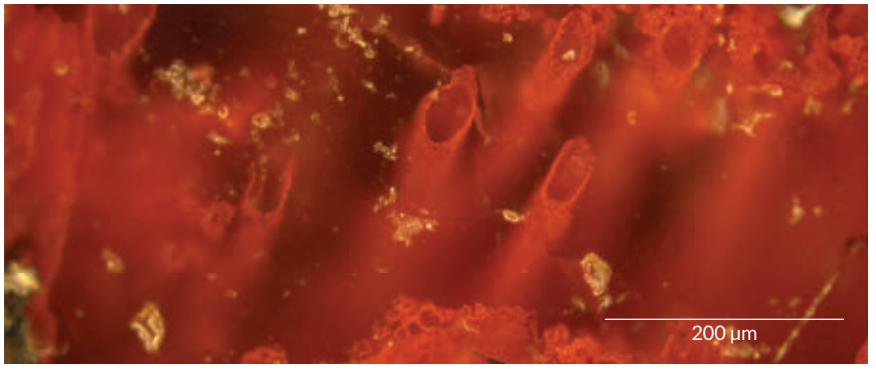
Dodd's team also uncovered other hints, including a carbon signature associated with life and minerals such as apatite linked to biological activity. Taken together, the hints add up to life, he says. "There's no other mechanism that can explain all of these observations."

Biology is indeed one possible explanation, says astrobiologist Abigail Allwood of NASA's Jet Propulsion Laboratory in Pasadena, Calif. "But the evidence could equally be interpreted as nonbiological."

Each line of evidence, she points out, reflects processes that could have actually occurred at different times, layering potential clues in a way that looks biological but really isn't. "You can't just wave your arms and say this all happened together," she says.

Paleobiologist David Wacey of the University of Western Australia in Crawley agrees that "the individual lines of chemical evidence are not particularly strong." But combined with the microstructures, he says, the authors come up with a "pretty convincing biological scenario."

Wacey expects the Quebec rocks to now be scrutinized in great detail. "There will, no doubt, be arguments," he says. But the study may revitalize the case for hydrothermal vents as a potential birthplace for life. ■



These microscopic tubes of hematite, an ore of iron, are remnants of microbes, researchers propose. The structures were found in rocks dating to at least 3.77 billion years ago.

BOTH: M. DODD

BODY & BRAIN

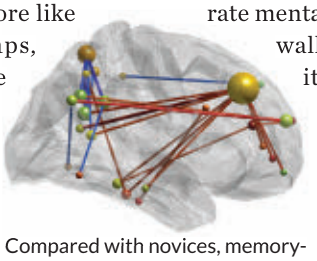
Memory training rejiggers the brain

Neuroscientists can't say how long connectivity changes last

BY LAURA SANDERS

Just six weeks of training can turn average people into memory masters.

Boosting mnemonic skills came with overhauls in brain activity, resulting in brains that behaved more like those of memory champs, researchers report in the March 8 *Neuron*.



Compared with novices, memory-trained people have some brain connections that are stronger (red) and others that are weaker (blue).

The findings show just how adaptable the human brain is, says neuroscientist Craig Stark of the University of California, Irvine. "The brain is plastic," he says. "Through use, it changes."

It's not yet clear how long those brain changes last, but the memory gains persisted for four months.

In an initial matchup, 17 people who place high in World Memory Championships throttled a group of people with average memories. Twenty minutes after seeing a list of 72 words, the experts remembered an average of 70.8 words; the nonexperts, only 39.9 words.

In subsequent matchups, some nonexperts got varying levels of help. Fifty-one novices were split into three groups. A third of these people spent six weeks learning the method of loci, a strategy used by ancient Greek and Roman orators. A person must imagine an elaborate mental scene, such as a familiar walking path, and populate it with memorable items. New information can be placed onto this scaffold as a way to quickly "see" long lists.

Other people trained to improve short-term memory, performing a tricky task of simultaneously keeping track of series of locations they see and numbers they hear. The rest of the participants had no training.

After training, people who learned the method of loci performed nearly as well as memory experts. But the rest didn't show such improvement. Study coauthor Martin Dresler, a neuroscientist at the Radboud University Medical Center in the Netherlands, says the most interesting changes happened in the brain.

Before and after training, nonexperts underwent scans that pinpointed brain areas that were active at the same time, an indication that these areas work together closely. Dresler and colleagues looked at 2,485 connections in networks important for memory and visual and spatial thinking. Training in the method of loci seemed to reconfigure many connections, making some stronger and others weaker. The overall effect was to make brains "look like those of the world's best memorizers," Dresler says. The results suggest that large-scale changes across the brain, not in individual areas, drive the increased memory capacity. No such changes were seen in the other groups.

The researchers didn't test whether the method of loci training improved other thinking skills. That means that the study can't answer bigger questions about whether brain training has more general benefits. ■

EARTH & ENVIRONMENT

Warmer soils may belch a lot of carbon

New estimate ups predicted CO_2 emissions as climate changes

BY THOMAS SUMNER

As the planet warms, carbon stashed in soil could escape into the atmosphere far faster than thought. In a worst-case scenario, carbon dioxide emissions from soil-dwelling microbes could go up by 34 to 37 percent by 2100, researchers say in the March 10 *Science*. Previous studies predicted only a 9 to 12 percent rise if no efforts are taken to curb climate change. That extra CO_2 could intensify warming.

Much of the extra emissions will come from soils at depths overlooked by previous work, says study coauthor and biogeochemist Margaret Torn of Lawrence Berkeley National Laboratory in California. "We ignore the deep at our peril."

Globally, soils store over three times as much carbon as the atmosphere. Dead organisms such as plants contribute to this stockpile. Carbon-munching microbes belch some of that carbon into the air as CO_2. Rising temperatures will spur the microbes to speed up plant eating, scientists warn, releasing more CO_2.

Researchers have mimicked warming by heating the top 5 to 20 centimeters of soil plots and measuring emissions. Scientists had largely assumed that any CO_2 gains from farther down were insignificant, says study coauthor Caitlin Hicks Pries, a Lawrence Berkeley ecologist.

Using heating coils and rods, the team warmed a soil plot for over two years in the forested foothills of California's Sierra Nevada. The warmth extended to a meter down, the full depth of the soil. Heating replicated the roughly 4 degrees Celsius of warming expected by 2100 in a worst-case scenario. Annual carbon emissions jumped from 1,100 to 1,450 grams per square meter. Some 40 percent of the increase originated below a depth of 15 centimeters, with 10 percent originating below 30 centimeters.

If other soils behave similarly, by 2100, the increase in the CO_2 emission rate from just the soils deeper than 30 centimeters could equal current CO_2 emission rates from oil burning, the team says.

Biogeochemist Katherine Todd-Brown of the Pacific Northwest National Laboratory in Richland, Wash., warns that soils' net impact on climate change is unclear. The amount of carbon entering soils could also jump as higher CO_2 levels and warmer environments promote plant growth. That increased carbon drawdown could offset increased soil emissions. ■

M. DRESLER *ET AL*/*NEURON* 2017

BODY & BRAIN

Testosterone therapy is a mixed bag

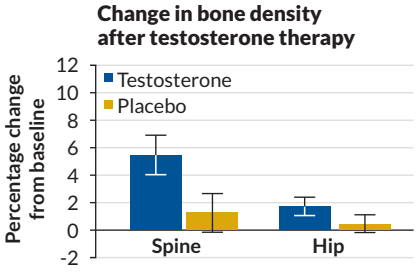
Questions remain about benefits of hormone replacement

BY MEGHAN ROSEN

As a treatment for the ailments of aging, testosterone's benefits are hit or miss.

For men with low testosterone, the hormone therapy is helpful for some health problems but not so much for others, researchers report in five papers published February 21 in *JAMA* and *JAMA Internal Medicine*. Testosterone therapy was good for the bones but didn't help memory. It remedied anemia and was linked to a lower risk of heart attack and stroke. But treatment also upped the amount of plaque in the arteries, an early indicator of heart attack risk.

"It's a very confusing area," says Caleb Alexander, a prescription drug researcher at Johns Hopkins Bloomberg School of Public Health who was not involved with the work. "Testosterone very well may help men feel more energized," he says. "But the real question is: At what cost?"



Stronger bones Effects of testosterone therapy are still unclear, but new studies found some benefits. Twelve months of a daily dose of testosterone was tied to gains in bone density.
SOURCE: P.J. SNYDER *ET AL/JAMA INTERNAL MEDICINE* 2017

As men age, their testosterone levels tend to drop. Researchers have suggested that boosting levels back up might counter some signs of aging. But the risks of such treatment remain unclear, says Alexander. Dozens of studies have tackled the question, but the results "point in lots of different directions," he says.

Despite the lack of clarity, the number of men taking the hormone has soared. One analysis estimated that 2.2 million men filled testosterone prescriptions in 2013 compared with 1.2 million in 2010. That includes many men with borderline testosterone levels that don't meet guidelines for treatment, Alexander says.

The new studies attempted to answer some of the long-standing questions. Four report findings from a set of clinical trials called the Testosterone Trials, designed to evaluate the effects of testosterone therapy in men age 65 or older.

One study found that the density and strength of hip and spine bones improved after a year of a daily dose of testosterone. It's not yet known whether these gains will translate to fewer fractures. Daily treatment also helped men recover from anemia, raising levels of hemoglobin, an oxygen-carrying molecule in blood, a second study showed. But testosterone didn't seem to improve memory or cognition.

HUMANS & SOCIETY

Low-status chimps are trendsetters

Contrary to expectations, apes copy subordinates' behavior

BY BRUCE BOWER

Chimps with little social status influence their comrades' behavior to a surprising extent, a new study suggests.

A method for snagging food from a box spread among captive chimps who saw a low-ranking female demonstrate the technique, say primatologist Stuart Watson of the University of St. Andrews in Fife, Scotland, and colleagues. But in captive groups where an alpha male introduced the same method, few chimps copied it, the team reports online February 7 in the *American Journal of Primatology*.

"I suspect that even wild chimpanzees are motivated to copy obviously rewarding behaviors of low-ranking individuals, but the limited spread of rewarding behaviors demonstrated by alpha males was quite surprising," Watson says. Previous work found that captive chimps more often copy rewarding behaviors of dominant versus lower-ranking group mates. Watson doesn't know why in this case the high-ranking apes weren't copied much.

The spread of new behaviors in groups of monkeys and apes depends on a variety of factors — including an innovator's social status, age and sex — that can interact in unpredictable ways. "That's why social learning in groups is so interesting to study," says Elizabeth Lonsdorf, a primatologist at Franklin & Marshall College in Lancaster, Pa.

Perhaps animals in the new study were monitoring potential threats from the alpha males more than their box-opening skills. "Alpha male chimps are large, powerful and prone to temper tantrums, so it makes sense to be vigilant for signs of what they'll do next," Watson says.

Or maybe lower-ranking chimps are sometimes unwilling to copy rewarding behaviors in front of a dominant chimp, Lonsdorf says. Researchers have seen this form of deference in some monkeys.

Watson's team studied 38 chimps at a research facility in Texas. A low-ranking female from each of two groups and a dominant male from each of two other groups were trained to open a box and remove fruit. They then performed this feat in front of their groups on two subsequent days. Trained chimps moved a sliding door on the box up or down until it locked to reveal one of two chambers with food. After each demonstration, group members had eight hours to manipulate the box however they liked.

Individuals who watched low-ranking chimps open the box, but not those who saw alpha chimps do the same, used the demonstrated method as their first choice more often than expected by chance.

Unexpectedly, two low-ranking females discovered a way to game the box after watching alpha males open it. These animals realized that the contraption held two pieces of fruit, one in an upper chamber exposed by sliding the

J. HIRSHFELD

Two studies attempted to untangle how hormone therapy affects the heart and blood vessels. One study linked treatment with more plaque buildup in the vessels that carry blood to the heart. Too much plaque can block blood flow and cripple the heart. But the second study didn't find more heart attacks, strokes or other cardiovascular problems in men taking the hormone. In that study, researchers examined medical records of over 44,000 men, about 8,800 of whom had been given a prescription for testosterone treatment. Over about three years of follow-up, these men actually had a lower risk of cardiovascular problems than men who hadn't been given a testosterone prescription, researchers report.

These studies do "little overall to clarify the role of testosterone replacement" for cardiovascular risk and cognitive function, says cardiologist Dimitri Cassimatis of Emory University School of Medicine in Atlanta. But, he says, they strengthen the evidence for testosterone's benefits on bone density and anemia. ■

door down until it locked and another in a lower chamber revealed by sliding the door up to lock. Each chimp managed to slide the door up and down just enough, without locking it, to snatch both snacks.

In one group, the alpha male, who had demonstrated the locking technique, copied the low-ranking female's superior approach. In a second group, two high-ranking females adopted the method after seeing it performed by their inferior.

Watson doesn't know if low-ranking chimps are particularly apt to devise clever behaviors. It wouldn't be surprising, he says, since chimps low on the social totem pole typically get less food than others and need to supplement their diets in creative ways.

In the wild, it's unclear why certain behaviors catch on, Lonsdorf says. For example, females move to new groups at sexual maturity, so they may bring useful knowledge from one group to another. In one case, chimps apparently learned how to collect ants after observing the behavior in a newcomer (*SN: 2/9/13, p. 20*). ■

JOHAN63/ISTOCKPHOTO

EARTH & ENVIRONMENT

New tests reveal hotter mantle

Novel way to study peridotite ups temperature estimates

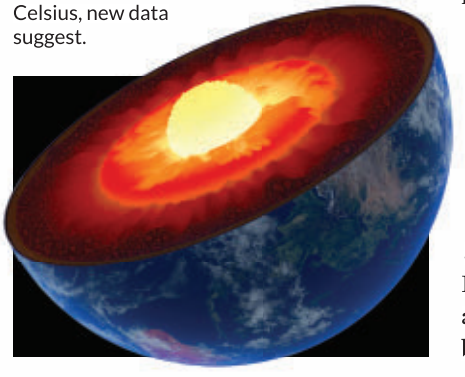
BY THOMAS SUMNER

Temperatures across Earth's mantle are about 60 degrees Celsius higher than thought, a new study claims. Such toasty temperatures would make the mantle runnier than earlier research suggested, which may help explain the details of how tectonic plates glide over the mantle, geophysicists report in the March 3 *Science*.

"Scientists have been arguing over the mantle temperature for decades," says study coauthor Emily Sarafian of MIT and the Woods Hole Oceanographic Institution in Massachusetts. "Scientists will argue over 10 degree changes, so changing it by 60 degrees is quite a large jump."

The mostly solid mantle sits between Earth's crust and core. But taking its temperature is trickier than dropping a thermometer down a hole.

Scientists know from the paths of earthquake waves and from measures of how electrical charge moves through Earth that a boundary exists a few dozen kilometers below Earth's surface. Above that boundary, mantle rock can begin to melt on its way up to the surface. By mimicking the extreme conditions in the Earth — by squeezing and heating bits of mantle that erupt from undersea volcanoes or similar rocks synthesized in the lab — scientist can determine the melting temperature of mantle rock. Using these facts, scientists have estimated that temperatures at the boundary depth below Earth's oceans are about 1314° to 1464° when adjusted to surface pressure.



Temperature estimates for the mantle should be upped by 60 degrees Celsius, new data suggest.

But water content in the mantle's dominant rock, peridotite, has caused problems. Water can lower peridotite's melting point, but researchers can't prevent the water content from changing over time. Previously, scientists tried to dry out peridotite and then correct for known mantle water levels in their calculations. The scientists, however, couldn't tell for sure if samples were water-free.

The uncertainty stems from the fact that peridotite is a mix of the minerals olivine and pyroxene, whose grains are too small to experiment with individually. Sarafian and colleagues overcame this challenge by inserting spheres of pure olivine large enough to study into synthetic peridotite. The spheres exchanged water with the surrounding rock until they had the same dampness, and so could be used to measure water content.

The team found that the "dry" peridotite used in previous studies wasn't dry at all. In fact, the water content was spot on for the mantle's actual wetness. "By assuming the samples are dry, then correcting for mantle water content, you're actually overcorrecting," Sarafian says.

The work suggests that the melting boundary under the eastern Pacific Ocean where two plates diverge, for example, would be 1410°, up from 1350°, if adjusted to surface pressure. A hotter mantle is less viscous and more malleable, Sarafian says. Scientists have puzzled over some aspects of plate tectonics, such as to what extent the mantle resists movement of the overlying plate. That resistance depends in part on the mix of rock, temperature and how melted the rock is at the boundary between the two layers. The new knowledge could shed light on those details.

The revised temperature is only for the melting boundary, says Caltech geologist Paul Asimow, who wrote a perspective in *Science* on the study. Researchers should not assume temperatures elsewhere in the mantle would be boosted by a similar amount, he says. ■

GENES & CELLS

Bacterial genes sterilize mosquitoes

Discovery offers new strategy for combating disease spreaders

BY ELIZABETH S. EATON

A pair of bacterial genes may enable genetic engineering strategies for curbing populations of virus-transmitting mosquitoes.

Bacteria that make the insects effectively sterile have been used to reduce mosquito populations in the wild. Now, two research teams have identified genes in those bacteria that may be responsible for the sterility, the groups report February 27 in *Nature* and *Nature Microbiology*.

"It's a great advance," says Scott O'Neill, a biologist at Monash University in Clayton, Australia. People have been trying for years to understand how the bacteria manipulate insects, he says.

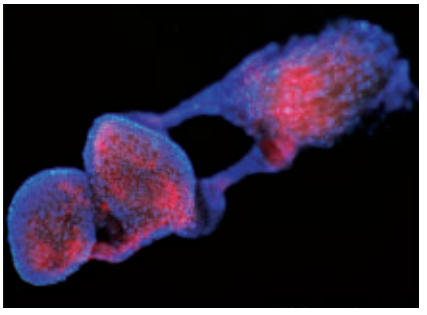
Wolbachia bacteria "sterilize" male mosquitoes through a mechanism called cytoplasmic incompatibility, which affects sperm and eggs. When an infected male breeds with an uninfected female, his modified sperm kill the eggs after fertilization. But when he mates with an infected female, her eggs remove the sperm modification and develop normally.

Researchers at Vanderbilt University in Nashville pinpointed a pair of genes connected to *Wolbachia*'s sterility mechanism. The genes are not in the bacterium's DNA itself, but in a virus embedded in its chromosome.

When the team took the two genes from the *Wolbachia* strain found in fruit flies and inserted the pair into uninfected males, the flies could no longer reproduce with healthy females, says Seth Bordenstein, a coauthor of the study in *Nature*. But modified uninfected males successfully reproduced with *Wolbachia*-infected females, mimicking how the sterility mechanism functions naturally.

The ability of infected females to "rescue" the modified sperm reminded researchers at the Yale School of Medicine of an antidote's reaction to a toxin.

They theorized that the gene pair consists of a toxin gene, called *cidB*, and an antidote gene, *cidA*. The team inserted the toxin gene into yeast, activated it and saw that the yeast was killed. But when both genes were present and active, the yeast survived, says Mark Hochstrasser, a coauthor of the study published in *Nature Microbiology*. Hochstrasser's team also created transgenic flies but used the strain of *Wolbachia* that infects common *Culex pipiens* mosquitoes.



Wolbachia bacteria (red) effectively sterilize male insects by infecting the testes (blue, a wasp testes shown at 100 times magnification). Researchers have identified *Wolbachia* genes that may be responsible for the sterility.

S. BORDENSTEIN/VANDERBILT UNIV.

These two genes could be used to control *Aedes aegypti* mosquitoes, which can carry diseases such as Zika and dengue.

Wolbachia's sterility effect doesn't always kill 100 percent of the eggs, says Bordenstein. But adding additional pairs of the genes to the bacteria could make the sterilization more potent.

The two genes could also be inserted directly into male mosquitoes, says Bordenstein. By releasing genetically altered males into populations of wild mosquitoes, scientists could "essentially crash the population," he says. Hochstrasser notes that altering mosquitoes is safer than infecting mosquitoes with *Wolbachia* because the bacteria could have long-term negative effects.

O'Neill, who directs a research program that releases *Wolbachia*-infected mosquitoes, cautions against mosquito control through genetic engineering because of public concerns about the technology. "We think it's better that we focus on a natural alternative," he says. ■

LIFE & EVOLUTION

Elephants may set new sleep record

2 hours per day of snoozing is lowest seen among mammals

BY SUSAN MILIUS

Fitbit-style tracking of two wild African elephants suggests their species could break sleep records for mammals. The elephants get by just fine on about two hours of sleep a day. Much of that shuteye comes while standing up — the animals sleep lying down only once every three or four days, the new data show.

Most of what scientists previously knew about sleeping elephants came from captive animals or from limited field observations, says neuroethologist Paul Manger of the University of the Witwatersrand in Johannesburg. In zoos and enclosures, elephants have been recorded snoozing about three to almost seven hours over a 24-hour period.

Using electronic monitors on wild African elephants, however, so far reveals more extreme behavior. Data are hard to collect, but two females wearing activity recorders for about a month averaged less sleep than other recorded mammals. Especially intriguing is the elephants' ability to skip a night's sleep without needing extra naps later, Manger and colleagues report March 1 in *PLOS ONE*.

"The remarkably short amount of sleep in wild elephants is a real elephant in the room for several theories for the function of sleep," says Niels Rattenborg of the Max Planck Institute for Ornithology in Seewiesen, Germany. Ideas that sleep restores or resets aspects of the brain for peak performance can't explain animals that sleep only a little and don't need catch-up rest, says Rattenborg, who wasn't involved in the elephant study. The results also don't fit well with the thought that animals need sleep to consolidate memories. "Elephants are usually not considered to be forgetful animals," he says.

Before the latest elephant sleep stats, horses were the record-holders among

mammals for the shortest sleep requirement at two hours, 53 minutes, Manger says. Donkeys weren't far behind at three hours, 20 minutes. Game rangers familiar with wild African elephants, however, claimed the pachyderms virtually never slept.

To investigate, Manger and colleagues implanted activity monitors in the trunks of the matriarchs of two herds in Chobe National Park in Botswana. An implant about the size of a Fitbit activity tracker shouldn't bother an elephant trunk, Manger says, because it's "250 pounds of muscle." Trunks, like human hands, are important for exploring and manipulating the world, so they're rarely still for long. The researchers assumed that a trunk monitor motionless for at least five minutes probably meant the animal was asleep. Gyroscopes in neck collars helped researchers figure out whether animals were standing up or lying down.

> "The remarkably short amount of sleep in wild elephants is a real elephant in the room for several theories for the function of sleep."
> **NIELS RATTENBORG**

The trunk implants caught occasions when the matriarchs went as long as 46 hours without any form of sleep. A predator, poacher or bull elephant loose in the neighborhood might explain the restlessness, Manger says. Animals in captivity don't face the same dangers.

African elephants' low sleep requirements join a growing body of results showing that wild animals don't need as much sleep as studies of captive animals suggest, Rattenborg says. His monitoring of wild sloths has revealed they aren't as slothful as captives. Also, other work finds that great frigate birds and pectoral sandpipers still perform well on less than two hours of sleep a day.

Still, it's unclear how these findings for two females will translate to entire elephant populations. But the results do fit a trend that links larger species with shorter sleep and smaller species with longer sleep, Manger says. Some bats, for example, routinely sleep 18 hours a day. He and colleagues are toying with the idea that sleep duration might be related to a daily time budget. Bigger animals may sleep less as they need that time for tasks to sustain their size. Building and maintaining an elephant body, for example, may take more feeding time than maintaining a little bat body, Manger says. ■

The first study of electronically monitored sleep in wild elephants (one of two shown) finds a record-breaking low average for mammals.

P. MANGER

Computers can now defeat professional poker players at heads-up no-limit Texas Hold'em. Pro Jason Les plays poker against Libratus as computer scientist Tuomas Sandholm, one of the bot's creators, looks on.

MATH & TECHNOLOGY

Artificial intelligence bests poker pros

Computer programs triumph in heads-up no-limit Texas Hold'em

BY EMILY CONOVER

In the battle of wits between humans and machines, computers have just upped the ante.

Two new poker-playing programs can best professionals at heads-up no-limit Texas Hold'em, a two-player version of poker without restrictions on the size of bets. It's another in a growing list of complex games, including chess, checkers (*SN: 7/21/07, p. 36*) and Go (*SN: 12/24/16, p. 28*), in which computers reign supreme.

Computer scientists from the University of Alberta in Canada report that their program, known as DeepStack, roundly defeated professional poker players, playing 3,000 hands against each. The program didn't win every hand — sometimes the luck of the draw was against it. But after the results were tallied, DeepStack beat 10 out of 11 players, the scientists report online March 2 in *Science*. (DeepStack also beat the 11th competitor, but that victory was not statistically significant.)

"This work is very impressive," says computer scientist Murray Campbell, one of the creators of Deep Blue, the computer that bested chess grandmaster Garry Kasparov in 1997. DeepStack "had a huge margin of victory," says Campbell, of IBM's Thomas J. Watson Research Center in Yorktown Heights, N.Y.

Likewise, computer scientists led by Tuomas Sandholm of Carnegie Mellon University in Pittsburgh recently trounced four elite heads-up no-limit Texas Hold'em players with a program called Libratus. Each contestant played 30,000 hands against the program during a tournament held in January in Pittsburgh. Libratus was "much tougher than any human I've ever played," says poker pro Jason Les.

> "Heads-up no-limit Texas Hold'em ... is, in fact, far more complex than chess."
>
> MURRAY CAMPBELL

Previously, Michael Bowling — one of DeepStack's creators — and colleagues had developed a program that could play a two-person version of poker in which the size of bets is limited. That program played the game nearly perfectly: It was statistically unbeatable within a human lifetime (*SN: 2/7/15, p. 14*). But no-limit poker is vastly more complicated because when any bet size is allowed, there are many more possible actions. Players must decide whether to go all in, play it safe with a small wager or bet something in between. "Heads-up no-limit Texas Hold'em ... is, in fact, far more complex than chess," Campbell says.

In the card game, each player is dealt two cards facedown and both players share five cards dealt faceup, with rounds of betting between stages of dealing. Unlike chess or Go, where both players can see all the pieces on the board, in poker, some information is hidden — the two cards in each player's hand. Such games, known as imperfect-information games, are particularly difficult for computers to master.

To hone DeepStack's technique, the researchers used deep learning — a method of machine learning that seems to formulate an intuition-like sense of when to hold 'em and when to fold 'em. When it's the program's turn, it sorts through options for its next few actions and decides what to do. As a result, DeepStack's nature, compared with previous poker programs, "looks a lot more like humans'," Bowling says.

Libratus computes a strategy for the game ahead of time and updates itself as it plays to patch flaws in its tactics that its human opponents have revealed. Near the end of a game, Libratus switches to real-time calculation, during which it further refines its methods. Libratus is so computationally demanding that it requires a supercomputer to run. (DeepStack can run on a laptop.)

Teaching computers to play games with hidden information, such as poker, could lead to real-life applications. "The whole area of imperfect-information games is a step towards the messiness of the real world," Campbell says. Computers that can handle that messiness could assist with business negotiations or auctions, and could help guard against hidden risks, in cybersecurity, for example. ■

CARNEGIE MELLON UNIV.

HUMANS & SOCIETY

Ancient peoples reshaped Amazon

Cultivated tree species still dominate some forest areas

BY BRUCE BOWER

Welcome to the somewhat civilized jungle. Plant cultivation by native groups has shaped the landscape of at least part of South America's Amazon forests for more than 8,000 years, researchers say.

Of dozens of tree species partly or fully domesticated by ancient peoples, 20 kinds of fruit and nut trees still cover large chunks of Amazonian forests, say ecologist Carolina Levis of the National Institute for Amazonian Research in Manaus, Brazil, and colleagues. Numbers and variety of domesticated tree species increase on and around previously discovered Amazonian archaeological sites, the team reports in the March 3 *Science*.

The new report, says archaeologist Peter Stahl of the University of Victoria in Canada, adds to previous evidence that "resourceful and highly developed indigenous cultures" intentionally altered some Amazonian forests.

Southwestern and northwestern Amazonian forests contain the greatest numbers and diversity of domesticated tree species, Levis' team found.

Over the last 300 years, modern Amazonians and others may have helped spread cultivated trees. For instance, 17th century Europeans set up plantations in the southwestern Amazon that exploited cacao trees already cultivated by local communities, the scientists propose.

Their findings build on a 2013 survey of plots all across the Amazon led by ecologist and study coauthor Hans ter Steege of the Naturalis Biodiversity Center in Leiden, the Netherlands. Of about 16,000 tree species, just 227 accounted for half of all trees, the 2013 study concluded.

Of that number, 85 species have physical features signaling partial or full domestication by Amazonians before European contact, the new study finds. Studies of plant DNA and plant remains previously suggested that domestication started over 8,000 years ago. Crucially, 20 domesticated tree species — five times the number expected by chance — dominate their respective Amazonian landscapes, especially near archaeological sites and rivers where people probably congregated, Levis' team says.

The team suspects ancient native groups domesticated plants throughout much of the Amazon. Ecologist Crystal McMichael of the University of Amsterdam says it's more likely that ancient people domesticated trees just in certain areas. In the new study, only Brazil nut trees show clear signs of human-caused expansion into nearby forests from an area of ancient domestication, says McMichael. Other trees may have mainly been domesticated by native groups or Europeans more recently, she says. ■

ATOM & COSMOS

Faraway galaxy has oldest known dust

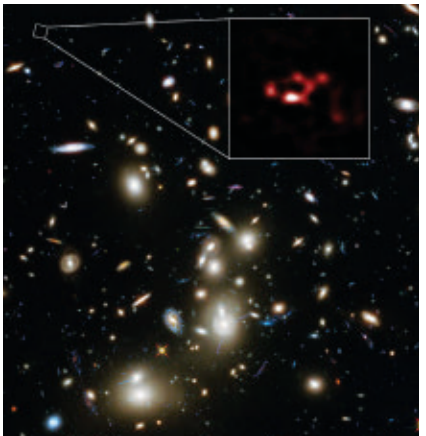
Observations could provide new clues to cosmic reionization

BY ASHLEY YEAGER

Astronomers may have spotted some of the earliest stardust ever created in the cosmos.

Astrophysicist Nicolas Laporte of University College London and colleagues detected the dust in a galaxy seen as it was when the universe was only 600 million years old. The observations, published in the March 10 *Astrophysical Journal Letters*, could help scientists learn more about an early period known as cosmic reionization, when ultraviolet radiation stripped electrons from hydrogen atoms.

The distant galaxy A2744_YD4 (inset) is rich in dust that was probably produced by the first supernova explosions in the universe.



D. COE/STSCI, J. MERTEN/UNIV. OF HEIDELBERG AND BOLOGNA ASTRONOMICAL OBS., ALMA (ESO, NAOJ, NRAO), NASA, ESA, ESO

"Dust is ubiquitous in nearby and more distant galaxies, but has, until recently, been very difficult to detect in the very early universe," says Michal Michalowski, a University of Edinburgh astrophysicist who was not involved in the study. "This paper presents the most distant galaxy for which dust has been detected."

The galaxy, called A2744_YD4, lies behind the Abell 2744 galaxy cluster. That cluster acts as a gravitational lens, magnifying and brightening the distant galaxy's light. Laporte and colleagues observed the galaxy and its dust with ALMA, the Atacama Large Millimeter/submillimeter Array in Chile.

Dust in such a remote galaxy comes from supernovas of massive stars that must have been among the universe's earliest stars. Astronomers estimate the first stars formed some 400 million years after the Big Bang, which occurred 13.8 billion years ago. Laporte and colleagues estimate that A2744_YD4's dust, at 600 million years after the Big Bang, weighs in at about 6 million times the mass of the sun. "This means that supernova explosions are able to produce large amounts of dust very quickly," Michalowski says.

Laporte and colleagues also detected positively charged, or ionized, oxygen atoms and a signature of hydrogen that suggests the galaxy's gas is ionized.

Reionization completely rebooted the universe so that ionized rather than neutral atoms pervaded space. Understanding what drove this switch gives clues to how stars and galaxies arose in the early universe. Finding ionized oxygen in such a remote galaxy "provides evidence that at least a fraction of cosmic reionization was caused by galaxies like A2744_YD4," Michalowski says. ■

EARTH & ENVIRONMENT

Climate change may worsen nutrition

Mineral, protein levels could drop in food crops, scientists warn

BY SUSAN MILIUS

A dinner plate piled high with food from plants might not deliver the same nutrition toward the end of this century as it does today. Climate change could shrink the mineral and protein content of wheat, rice and other staple crops, mounting evidence suggests.

Selenium, a trace element essential for health, already falls short in diets of one in seven people worldwide. Studies link low selenium with such troubles as weak immune systems and cognitive decline. And in severely selenium-starved spots in China, children's bones don't grow to normal size or shape. This element could become sparser in soils of major agricultural regions as the climate changes, an international research group announced online February 21 in *Proceedings of the National Academy of Sciences*.

Likewise, zinc and iron deficiencies could grow as micronutrients dwindle in major crops worldwide, Harvard University colleagues Samuel Myers and Peter Huybers and collaborators warn online January 6 in the *Annual Review of Public Health*. Futuristic field experiments on wheat and other major crops predict that more people will slip into nutritional deficits late in this century because of dips in protein content, Myers reported February 16 at the Climate and Health Meeting held in Atlanta.

"If we'd sat down 10 years ago and tried to think what the effects of anthropogenic carbon dioxide emissions might be on human health, none of us would have anticipated that one effect would be to make our food less nutritious," Myers said. "But we can't fundamentally disrupt and reconfigure most of the natural systems around our planet without encountering unintended consequences."

Figuring out those unintended nutrient consequences isn't easy. For selenium, scientists have only a rough idea of the element's global movements. It's unclear what proportions erode out of rocks or waft onto land from sea, says Lenny Winkel, a biogeochemist at ETH Zurich and the Swiss aquatic research group Eawag in Dübendorf. She was the principal investigator for the selenium project in the new *Proceedings* paper. As far as she knows, it presents the first global look at selenium levels in soils and what basic factors influence what's there. This scale, she says, was "a bit bold."

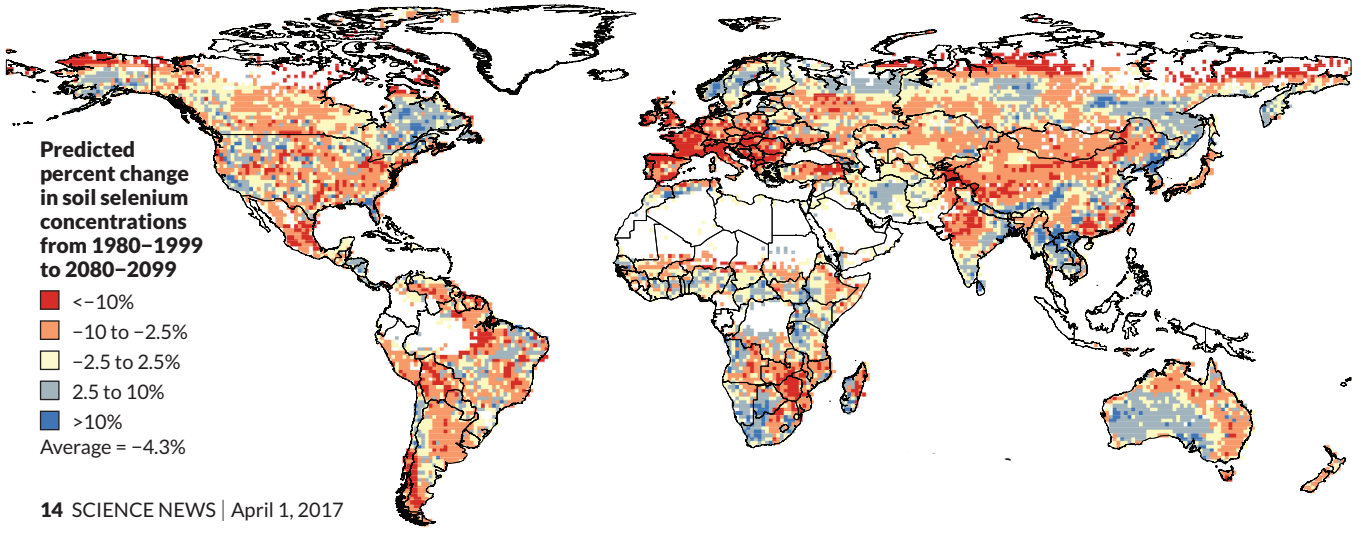
Starting with more than 33,000 data points from other sources, Winkel and colleagues pieced together a map of selenium concentrations in soils across much of the globe. Climate popped out as one of the more important predictors of selenium content in soil, a link that hadn't shown up in small studies. Places where climate turns land arid generally have lower selenium, but soil character matters, too. Places with high organic carbon, as in a woodland rich with fallen leaves, as well as places with abundant clay, tend to do better at retaining selenium.

By the end of the century, about two-thirds of heavily cultivated agricultural land would probably lose selenium under an intermediate scenario of climate change, Winkel and colleagues conclude. With a projected average end-century warming of 2.2 degrees Celsius compared with 1986 to 2005, selenium drops by an average of 8.7 percent in breadbasket regions in the study. Only 19 percent of croplands seem likely to gain selenium.

The new map "is worrisome," says plant physiologist Philip White of the James Hutton Institute in Invergowrie, Scotland. White, who studies agricultural plants, has published on selenium but was not part of the new study. As a rule of thumb, he says, natural selenium concentrations in soil "are directly related to the selenium available in plants."

That may be a rule of thumb. But Winkel says that to refine predictions, scientists

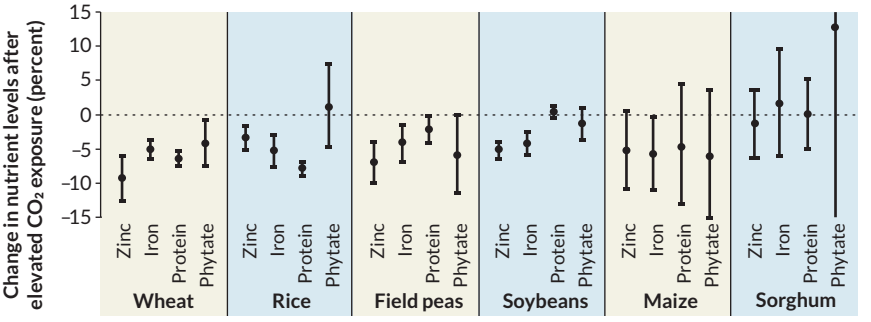
Selenium slump Soil concentrations of the element selenium, essential for human life, could change by the end of the 21st century, according to computer simulations based on an intermediate scenario for climate change. The analysis identified what influences soil selenium now — including precipitation and concentrations of organic carbon in soil — and predicted future concentrations based on those influences. Selenium levels will decline in most agricultural regions, the analysis suggests.



G.D. JONES ET AL./PNAS 2017

need to consider how plant species vary in building up selenium in their tissues. Brazil nuts, for instance, accumulate so much selenium that extreme and persistent fans can develop signs of overdosing. One sign of excess: otherwise unexplained garlic breath.

Excess can be an issue because the healthful ranges of selenium are narrow. "You can quickly get too much or too little," Winkel says. This Goldilocks problem complicates planning for what to do about shortages: What boosts health among the nutrient-poor might not be so good for well-fed people with varied sources of selenium.



Nutrient drop Major crops showed some changes in nutrient concentrations when grown with extra atmospheric CO_2 in experiments in Australia, Japan and the United States. Sorghum and maize, plants capturing carbon with what's called a C_4 pathway, may be better at preserving nutrients in a carbon-enriched atmosphere than most crops. Concentrations of phytate, which can sabotage humans' zinc uptake, decreased only in wheat. That dip might help offset zinc losses, but zinc decreased even more than phytate content did. SOURCE: S.S. MYERS *ET AL*/*NATURE* 2014

Zinc and iron concentrations in crops, too, will probably shift as climate changes, Myers and colleagues reported in *Nature* in 2014. They analyzed harvest samples from a total of 41 cultivated varieties of major crops (wheat, rice, field peas, soybeans, maize and sorghum) grown with the expensive and elaborate experimental protocol known as FACE, for Free-Air CO_2 Enrichment. In Australia, Japan and the United States, test crops grew in outdoor fields within futuristic Stonehenge circles of skinny ducts blowing extra carbon dioxide to mimic mid- to late-century atmospheres. Sites varied, but at the time, researchers reported their baseline CO_2 as 363 to 386 parts per million and pushed pipes to deliver 546 to 586 ppm.

Based on samples from these far-flung experiments, the researchers found iron concentrations in wheat dropped an average of 5 percent. Zinc levels fell 9 percent. Most other crops showed a tendency toward declines too, although maize and sorghum, which use what's called the C_4 pathway for carbon capture, showed signs of possible resilience.

Then Myers asked: "So what?"

Figuring that out wasn't easy. A major plant source of the minerals for Ethiopia might not matter much for England with its meat-rich diet. Myers and colleagues put together a database of how much of 95 foods people eat in 188 countries around the world, and then calculated where the relatively modest downturns of zinc would put people at risk in the future. Nutrient changes by 2050 would push about 138 million more people into zinc deficiency, the researchers reported in 2015. And for over 2 billion people already zinc deficient, future crop declines could make their health problems even worse.

The shortfall could be especially hard on women and children. Too little zinc raises pregnant women's risks of premature delivery and can doom children to poor weight gain and growth. A robust immune system needs adequate zinc, and public health specialists blame 100,000 child deaths a year on immune responses so enfeebled by skimpy zinc that children couldn't fight off pneumonia or diarrhea.

Livestock also may have to contend with plant nutrition changes. There will be complex interactions among CO_2, temperature and water, which we don't fully understand yet, says Jerry Hatfield. He's a plant physiologist at the U.S. Department of Agriculture's National Laboratory for Agriculture and the Environment in Ames, Iowa. Some of the best evidence so far for effects of CO_2 enhancement comes from FACE experiments in rangeland grasses, he says. Rising CO_2 spurred rapid growth but weakened the grasses' ability to take up nitrogen. Grass short on nitrogen didn't have the raw materials for the usual protein content of livestock forage.

Just how the soaring CO_2 lowers nutrient content remains a puzzle. The prevailing hypothesis has been that extra carbon in the atmosphere lets plants bulk up with carbohydrates, in a sense diluting anything that isn't a carbohydrate, plant micronutrients included.

Not so, says plant physiologist Arnold Bloom of the University of California, Davis, a coauthor of the 2014 nutrient paper in *Nature*. A wide range of experimental results show that although most nutrients go down, some do not and some even go up. That doesn't fit with a general pattern of low, "diluted" concentrations.

With nutrient concentrations going down, it might seem that people could solve the problem just by eating more. But there may not be more. Early studies raised hopes that extra CO_2 might give plants' carbon-trapping machinery extra raw material for growth spurts and bonanza yields. But sustained growth now looks elusive. Experiments tracking growth over years suggest that plants may not sustain initial surges, and theoretical predictions that build in such details as pests and water supplies are not encouraging. The 2014 report from the Intergovernmental Panel on Climate Change notes that crop yields are more likely to decrease than soar and agriculture will have to change to try to compensate.

"Global demand for food is rising more steeply than ever before in human history," Myers said in Atlanta. In 40 years, agriculture will have to produce 70 percent more food than it does today just to keep even as Earth's population grows by several billion people. Yet in this time of growing need, human activities are transforming the climate in ways that could make farming even more of a challenge. ■

HUMANS & SOCIETY

Ancient dental plaque reveals Neandertal diet and disease

Plaque preserved in fossilized teeth confirms that Neandertals were flexible eaters and hints that they self-medicated with an ancient equivalent of aspirin.

DNA recovered from calcified plaque on teeth from four Neandertals suggests that those from grassland areas around Belgium's Spy cave ate woolly rhinoceros and wild sheep, while their counterparts from the forested region around Spain's El Sidrón cave consumed a menu of moss, mushrooms and pine nuts.

The evidence bolsters an argument that Neandertal diets spanned the spectrum of carnivory and herbivory based on the resources available, microbiologist Laura Weyrich of the University of Adelaide in Australia and colleagues report online March 8 in *Nature*.

The best-preserved remains were from a young male from El Sidrón whose teeth showed signs of an abscess. DNA from a diarrhea-inducing stomach bug and several gum disease pathogens turned up in his plaque. Genetic material from poplar trees, which contain the pain-killing aspirin ingredient salicylic acid, and a plant mold that makes the antibiotic penicillin hint that he may have used natural medication to ease his ailments.

The researchers were even able to extract an almost-complete genetic blueprint, or genome, for one ancient microbe, *Methanobrevibacter oralis*. At roughly 48,000 years old, it's the oldest microbial genome sequenced, the researchers report. — *Helen Thompson*

GENES & CELLS

Researchers take more steps toward lab-built yeast

Synthetic yeast is on the rise.

Scientists have constructed five more yeast chromosomes from scratch, in addition to the one already announced in 2014 (*SN: 5/3/14, p. 7*). The new work, reported in the March 10 *Science*, brings researchers closer to completely lab-built yeast.

"We're doing it primarily to learn a little more about how cells are wired," says geneticist Jef Boeke of the New York University Langone Medical Center. But scientists might also be able to tinker with a synthetic yeast cell more efficiently than a natural one, allowing more precise engineering of everything from antiviral drugs to biofuels.

Calcified dental plaque from the upper jaw of a young Neandertal male from El Sidrón cave in Spain suggests that Neandertals used natural medicines.

Boeke was on the team that reported the first synthetic yeast chromosome. Now, several hundred scientists in five countries are working to make all 16 *Saccharomyces cerevisiae* chromosomes and integrate them into living cells. With six finished, Boeke hopes the remaining 10 will be built by the end of 2017.

Each synthetic chromosome is based on one of *S. cerevisiae*'s but with tweaks for efficiency. Researchers cut out stretches of DNA that can jump around and cause mutations, as well as parts that code for the same information multiple times.

When the researchers put chunks of synthetic DNA into yeast cells, the cells swapped out parts of their original DNA for the matching engineered snippets.

Yeast is a eukaryote — it stores its DNA in a nucleus like human cells do. Eventually, this research could produce synthetic chromosomes for more complicated organisms, Boeke says, but such feats are still far in the future. — *Laurel Hamers*

BODY & BRAIN

Microcephaly, other birth defects are on the rise since Zika's arrival

Certain birth defects were 20 times as prevalent in babies born to Zika virus–infected mothers in the United States in 2016 as they were before the virus cropped up in the country. That estimate comes from a study by the U.S. Centers for Disease Control and Prevention. The finding strengthens the evidence that a mother's Zika infection during pregnancy raises her baby's risk of microcephaly and other brain malformations.

The study, published March 3 in the CDC's *Morbidity and Mortality Weekly Report*, examined data collected through birth defect surveillance programs in Massachusetts, North Carolina and Atlanta in 2013 and 2014. In that time frame — before Zika's U.S. arrival — microcephaly, brain abnormalities or other Zika-associated birth defects appeared in about three out of every 1,000 live births.

But from January to September 2016, 26 babies out of 442 born to mothers with suspected Zika virus infection during pregnancy showed these defects, according to data from the U.S. Zika Pregnancy Registry. That's an incidence of nearly 60 per 1,000 pregnancies, far higher than the pre-Zika level.

Though the two datasets were collected using different measures and so aren't directly comparable, the findings bolster previous evidence suggesting that certain brain defects appear much more frequently in babies born to Zika-infected mothers. — *Laurel Hamers*

ATOM & COSMOS

Triplet of high-energy neutrinos detected from unknown source

Three high-energy neutrinos have been spotted traveling in tandem.

The IceCube Neutrino Observatory in Antarctica detected the trio of lilliputian particles on February 17, 2016. This is the first time the experiment has seen a triplet of neutrinos that all seemed to come from the same place in the sky and within 100 seconds of one another. Researchers report the find February 20 at arXiv.org.

Physicists still don't know where high-energy neutrinos are born. The three neutrinos' proximity in time and space suggests the particles came from the same source, such as a flaring galaxy or an exploding star. But the scientists couldn't rule out the possibility of a fluke — the triplet could simply have been the result of accidental alignment between unassociated neutrinos.

PALEOANTHROPOLOGY GROUP MNCN-CSIC

Eight different observatories followed up on the neutrino triplet, checking for some sign of the particles' origins. The telescopes, which searched for gamma rays, X-rays and other wavelengths of light, found nothing clearly associated with the particles. But scientists were able to rule out some possible explanations, like a nearby stellar explosion caused by the collapse of a dying star. *— Emily Conover*

ATOM & COSMOS

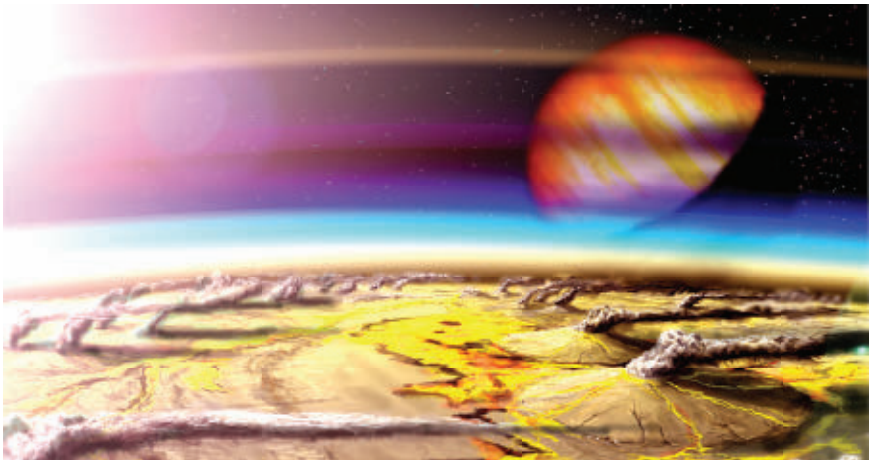
Hydrogen volcanoes might boost exoplanets' potential for life

Volcanoes that belch hydrogen could bump up the number of potentially habitable planets in the universe.

Ramses Ramirez and Lisa Kaltenegger, both of Cornell University, modeled the atmospheres of planets blemished with hydrogen-spewing volcanoes. Gaseous eruptions could warm planets and ultimately widen a star's habitable zone, the region where liquid water can exist on a planet's surface, by about 30 to 60 percent, the researchers report in the March 1 *Astrophysical Journal Letters*. That would be like extending, for example, the outer edge of the sun's habitable zone from about 254 million kilometers — just beyond Mars' orbit — to 359 million kilometers, or roughly to the asteroid belt between Mars and Jupiter.

Exoplanets that astronomers had thought too cold to support life might, in fact, be ripe for habitability if they have hydrogen volcanoes, the researchers say. One example is TRAPPIST-1h, the farthest-out planet identified in an odd system of seven Earth-sized planets just 39 light-years from Earth (*SN: 3/18/17, p. 6*). That world is thought to be icy like Jupiter's moon Europa.

Adding planets to a star's habitable zone means more exotic worlds could be targets in the search for signs of life beyond our solar system. Astronomers plan to search for these signs with the James Webb Space Telescope, slated to launch in 2018, and the European Extremely Large Telescope, scheduled to begin operations in 2024. *— Ashley Yeager*



W. HENNING/NASA GODDARD SPACE FLIGHT CENTER

Hydrogen-spewing volcanoes may warm worlds that reside far from their parent star (one illustrated), enhancing the planets' ability to support life, a new study finds.

ATOM & COSMOS

Saturn's 'Death Star' moon may not conceal ocean after all

An ocean of liquid water probably doesn't lurk beneath the icy surface of Mimas, Saturn's smallest major moon, new calculations suggest. In 2014, scientists had proposed the ocean to help explain an odd wobble in the moon's orbit (*SN: 11/15/14, p. 16*).

Other ocean-harboring moons, such as Jupiter's Europa and Saturn's Enceladus, are crisscrossed by fractures opened by strong tides that cause their oceans to bulge outward. Mimas, though freckled with craters, lacks any such cracks.

Planetary scientist Alyssa Rhoden of Arizona State University in Tempe and colleagues calculated whether Mimas' icy shell could withstand the stress of a subsurface ocean pushing outward. Taking into account the moon's elongated orbit, the team estimates that a subsurface ocean would produce tidal stresses larger than those on crack-riddled Europa. Mimas therefore probably doesn't have an ocean, the researchers conclude February 24 in the *Journal of Geophysical Research: Planets*. *— Thomas Sumner*

GENES & CELLS

Human genes best Neandertal genes in the brain and testes

Humans and Neandertals are still in an evolutionary contest, a new study suggests.

Geneticist Joshua Akey of the University of Washington in Seattle and colleagues examined activity of more than 700 genes for which at least one person studied carried a human and a Neandertal version. Human versions of some genes are more active than Neandertal versions, especially in the brain and testes, the researchers report in the Feb. 23 *Cell*. In other tissues, some Neandertal versions of genes were more active than their human counterparts.

In the brain, human versions were favored over Neandertal variants in the cerebellum and basal ganglia. That finding may help explain why Neandertals had proportionally smaller cerebellums than humans do. Neandertal versions of genes in the testes, including some needed for sperm function, were also less active than human varieties. That finding is consistent with earlier studies that suggested male human-Neandertal hybrids may have been infertile, Akey says.

But Neandertal genes don't always lose. In particular, the Neandertal version of an immunity gene called *TLR1* is more active than the human version.

Lopsided gene activity may help explain why carrying a Neandertal version of some genes has been linked to human disorders, such as lupus and depression (*SN: 3/5/16, p. 18*). Usually, both copies contribute equally to a gene's total activity. Less robust activity of a version inherited from Neandertals might cause total activity to dip to unhealthy levels, for instance. *— Tina Hesman Saey*

Digital Minds

Are smartphones changing our brains?

By Laura Sanders

Not too long ago, the internet was stationary. Most often, we'd browse the Web from a desktop computer in our living room or office. If we were feeling really adventurous, maybe we'd cart our laptop to a coffee shop. Looking back, those days seem quaint.

Today, the internet moves through our lives with us. We hunt Pokémon as we shuffle down the sidewalk. We text at red lights. We tweet from the bathroom. We sleep with a smartphone within arm's reach, using the device as both lullaby and alarm clock. Sometimes we put our phones down while we eat, but usually faceup, just in case something important happens.

Our iPhones, Androids and other smartphones have led us to effortlessly adjust our behavior. Portable technology has overhauled our driving habits, our dating styles and even our posture. Despite the occasional headlines claiming that digital technology is rotting our brains, not to mention what it's doing to our children, we've welcomed this alluring life partner with open arms and swiping thumbs.

Scientists suspect that these near-constant interactions with digital technology influence our brains. Small studies are turning up hints that our devices may change how we remember, how we navigate and how we create happiness — or not.

Somewhat limited, occasionally contradictory findings illustrate how science has struggled to pin down this slippery, fast-moving phenomenon. Laboratory studies hint that technology, and its constant interruptions, may change our thinking strategies. Like our husbands and wives, our devices have become "memory partners," allowing us to dump information there and forget about it — an off-loading that comes with benefits and drawbacks. Navigational

TASSII/ISTOCKPHOTO

strategies may be shifting in the GPS era, a change that might be reflected in how the brain maps its place in the world. Constant interactions with technology may even raise anxiety in certain settings.

Yet one large study that asked people about their digital lives suggests that moderate use of digital technology has no ill effects on mental well-being.

The question of how technology helps and hinders our thinking is incredibly hard to answer. Both lab and observational studies have drawbacks. The artificial confines of lab experiments lead to very limited sets of observations, insights that may not apply to real life, says experimental psychologist Andrew Przybylski of the University of Oxford. "This is a lot like drawing conclusions about the effects of baseball on players' brains after observing three swings in the batting cage."

Observational studies of behavior in the real world, on the other hand, turn up associations, not causes. It's hard to pull out real effects from within life's messiness. The goal, some scientists say, is to design studies that bring the rigors of the lab to the complexities of real life, and then to use the resulting insights to guide our behavior. But that's a big goal, and one that scientists may never reach.

Evolutionary neurobiologist Leah Krubitzer is comfortable with this scientific ambiguity. She doesn't put a positive or negative value on today's digital landscape. Neither good nor bad, it just is what it is: the latest iteration on the continuum of changing environments, says Krubitzer, of the University of California, Davis.

"I can tell you for sure that technology is changing our brains," she says. It's just that so far, no one knows what those changes mean.

Of course, nearly everything changes the brain. Musical training reshapes parts of the brain. Learning the convoluted streets of London swells a mapmaking structure in the brains of cabbies. Even getting a good night's sleep changes the brain. Every aspect of our environment can influence brain and behaviors. In some ways, digital technology is no different. Yet some scientists suspect that there might be something particularly pernicious about digital technology's grip on the brain.

"We are information-seeking creatures," says neuroscientist Adam Gazzaley of the University of California, San Francisco. "We are driven to it in very powerful ways." Today's digital tools give us unprecedented exposure to information that doesn't wait for you to seek it out; it seeks you out, he says. That pull is nearly irresistible.

Despite the many unanswered questions about whether our digital devices are influencing our brains and behaviors, and whether for good or evil, technology is galloping ahead. "We should have been asking ourselves [these sorts of questions] in the '70s or '80s," Krubitzer says. "It's too late now. We're kind of closing the barn doors after the horses got out."

Attention grabber

One way in which today's digital technology is distinct from earlier advances (like landline telephones) is the sheer amount of time people spend with it. In just a decade, smartphones have saturated the market, enabling instant internet access to an estimated 2 billion people around the world. In one small study reported in 2015, 23 adults, ages 18 to 33, spent an average of five hours a day on their phones, broken up into 85 distinct daily sessions. When asked how many times they thought they used their phones, participants underestimated by half.

In a different study, Larry Rosen, a psychologist at California State University, Dominguez Hills, used an app to monitor how often college students unlocked their phones. The students checked their phones an average of 60 times a day, each session lasting about three to four minutes for a total of 220 minutes a day. That's a lot of interruption, Rosen says.

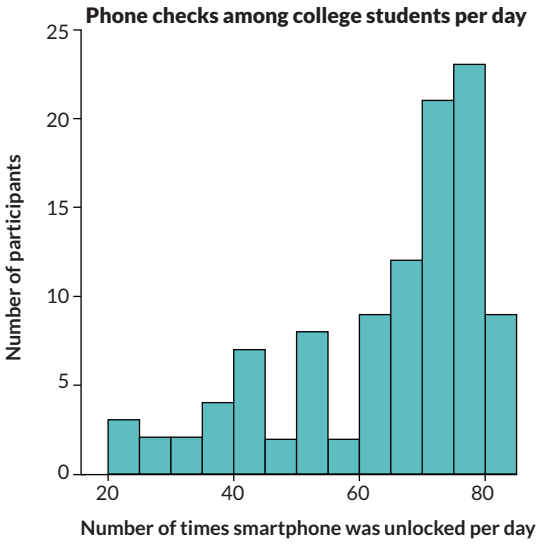
Smartphones are "literally omnipresent 24-7, and as such, it's almost like an appendage," he says. And often, we are compelled to look at this new, alluring rectangular limb instead of what's around us. "This device is really powerful," Rosen says. "It's really influencing our behavior. It's changed the way we see the world."

Technology does that. Printing presses, electricity, televisions and telephones all shifted people's habits drastically, Przybylski says. He proposes that the furor over digital technology melting brains and crippling social lives is just the latest incarnation of the age-old fear of change. "You have to ask yourself, 'Is there something magical about the power of an LCD screen?' " Przybylski says.

Yet some researchers suspect that there is something particularly compelling about this advance. "It just *feels* different. Computers and the internet and the cloud are embedded in our lives," says psychologist Benjamin Storm of the University of California, Santa Cruz. "The scope of the amount of information we have at our fingertips is beyond anything we've ever experienced. The

90
percent
Portion of Americans who reported using a technology device in the hour before bedtime
SOURCE: MICHAEL GRADISAR *ET AL/J. CLIN. SLEEP MED.* 2013

49
percent
Portion of U.S. college students who reported checking their phones at least once overnight
SOURCE: L. ROSEN *ET AL/ SLEEP HEALTH* 2016



What am I missing? In one small study of 104 college students, more than half unlocked their phones more than 60 times a day.
SOURCE: L. ROSEN

temptation to become really reliant on it seems to be greater."

Memory outsourcing

Our digital reliance may encourage even more reliance, at least for memory, Storm's work suggests. Sixty college undergraduates were given a mix of trivia questions — some easy, some hard. Half of the students had to answer the questions on their own; the other half were told to use the internet. Later, the students were given an easier set of questions, such as "What is the center of a hurricane called?" This time, the students were told they could use the internet if they wanted.

People who had used the internet initially were more likely to rely on internet help for the second, easy set of questions, Storm and colleagues reported online last July in *Memory*. "People who had gotten used to using the internet continued to do so, even though they knew the answer," Storm says. This kind of overreliance may signal a change in how people use their memory. "No longer do we just rely on what we know," he says.

That work builds on results published in a 2011 paper in *Science*. A series of experiments showed that people who expected to have access to the internet later made less effort to remember things. In this way, the internet has taken the place formerly filled by spouses who remember birthdays, grandparents who remember recipes and coworkers who remember the correct paperwork codes — officially known as "transactive memory partners."

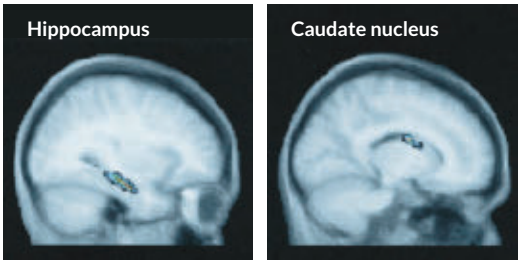
"We are becoming symbiotic with our computer tools," Betsy Sparrow, then at Columbia University, and colleagues wrote in 2011. "The experience of losing our internet connection becomes more and more like losing a friend. We must remain plugged in to know what Google knows."

That digital crutch isn't necessarily a bad thing, Storm points out. Human memory is notoriously squishy, susceptible to false memories and outright forgetting. The internet, though imperfect, can be a resource of good information. And it's not clear, he says, whether our memories are truly worse, or whether we perform at the same level, but just reach the answer in a different way.

"Some people think memory is absolutely declining as a result of us using technology," he says. "Others disagree. Based on the current data, though, I don't think we can really make strong conclusions one way or the other."

The potential downsides of this memory outsourcing are nebulous, Storm says. It's possible that digital reliance influences — and perhaps even weakens — other parts of our thinking. "Does it change the way we learn? Does it change the way we start to put information together, to build our own stories, to generate new ideas?" Storm asks. "There could be consequences that we're not necessarily aware of yet."

Research by Gazzaley and others has documented effects of interruptions and multitasking, which are hard to avoid with incessant news alerts, status updates and Instagrams waiting in our pockets. Siphoning attention can cause trouble for a long list of thinking skills, including short- and long-term memory, attention, perception and reaction time. Those findings, however, come from experiments in labs that ask a person to toggle between two tasks while undergoing a brain scan, for instance. Similar effects have not been as obvious for people going about their daily lives, Gazzaley says. But he is convinced that constant interruptions — the dings and buzzes, our own restless need to check our phones — are influencing our ability to think.



A group of people who navigated by building spatial maps of a virtual environment had, on average, more activity in the hippocampus (brain scan, left) than people who found their way using simpler strategies. Those people relied more heavily on the caudate nucleus (right).

FROM TOP: T. TIBBITTS; G. IARIA *ET AL*/*J. NEUROSCI*. 2003

Making maps

Consequences of technology are starting to show up for another cognitive task — navigating, particularly while driving. Instead of checking a map and planning a route before a trip, people can now rely on their smartphones to do the work for them. Anecdotal news stories describe people who obeyed the tinny GPS voice that instructed them to drive into a lake or through barricades at the entrance of a partially demolished bridge. Our navigational skills may be at risk as we shift to neurologically easier ways to find our way, says cognitive neuroscientist Véronique Bohbot of McGill University in Montreal.

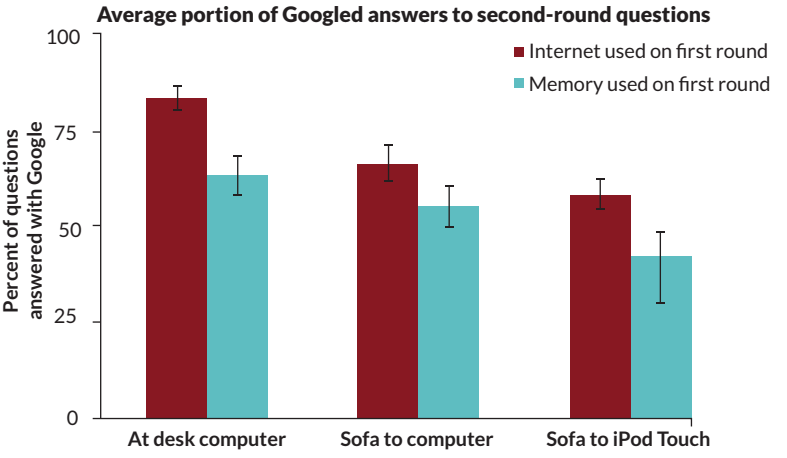
Historically, getting to the right destination required a person to have the lay of the land, a mental map of the terrain. That strategy takes more work than one that's called a "response strategy," the type of navigating that starts with an electronic voice command. "You just know the response — turn right, turn left, go straight. That's all you know," Bohbot says. "You're on autopilot."

A response strategy is easier, but it leaves people with less knowledge. People who walked through a town in Japan with human guides did a better job later navigating the same route than people who had walked with GPS as a companion, researchers have found.

Scientists are looking for signs that video games, which often expose people to lots of response-heavy situations, influence how people get around. In a small study, Bohbot and colleagues found that people who average 18 hours a week playing action video games such as *Call of Duty* navigated differently than people who don't play the games. When tested on a virtual maze, players of action video games were more likely to use the simpler response learning strategy to make their way through, Bohbot and colleagues reported in 2015 in *Proceedings of the Royal Society B*.

That easier type of response navigation depends on the caudate nucleus, a brain area thought to be involved in habit formation and addiction. In contrast, nerve cells in the brain's hippocampus help create mental maps of the world and assist in the more complex navigation. Some results suggest that people who use the response method have bigger caudate nuclei, and more brain activity there. Conversely, people who use spatial strategies that require a mental map have larger, busier hippocampi.

Those results on video game players are preliminary and show an association within a group that may share potentially confounding similarities.



Google begets Google Compared with people who had to rely on memory (blue bars) to answer an initial mix of easy and hard trivia questions, people who used Google to find answers (red bars) were more likely to use Google for a second, easy set of questions. Inconvenience (having to get up from the sofa to walk to a computer or an iPod Touch) didn't stop the Googling.

SOURCE: B.C. STORM, S.M. STONE AND A.S. BENJAMIN/ *MEMORY* 2016

Yet it's possible that getting into a habit of mental laxity may change the way people navigate. Digital technology isn't itself to blame, Bohbot says. "It's not the technology that's necessarily good or bad for our brain. It's how we use the technology," she says. "We have a tendency to use it in the way that seems to be easiest for us. We're not making the effort."

Parts of the brain, including those used to navigate, have many jobs. Changing one aspect of brain function with one type of behavior might have implications for other aspects of life. A small study by Bohbot showed that people who navigate by relying on the addiction-related caudate nucleus smoke more cigarettes, drink more alcohol and are more likely to use marijuana than people who rely on the hippocampus. What to make of that association is still very much up in the air.

Sweating the smartphone

Other researchers are trying to tackle questions of how technology affects our psychological outlooks. Rosen and colleagues have turned up clues that digital devices have become a new source of anxiety for people.

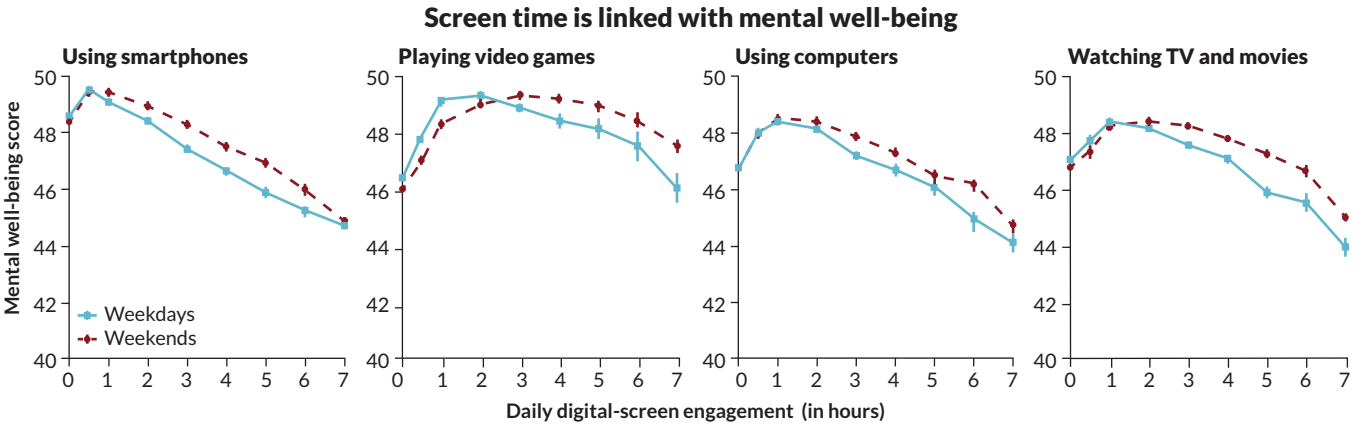
In diabolical experiments, Cal State's Rosen takes college students' phones away, under the ruse that the devices are interfering with laboratory measurements of stress, such as heart rate and sweating. The phones are left on, but placed out of reach of the students, who are reading a passage. Then, the researchers start texting the students, who are forced to listen to the dings without being able to see the messages or respond. Measurements of anxiety spike, Rosen has found, and reading comprehension dwindles.

Other experiments have found that heavy technology users last about 10 minutes without their

45
percent
Portion of 14- to 18-year-olds who reported always or almost always texting while watching TV

SOURCE: DELOITTE 2016 DIGITAL DEMOCRACY SURVEY

T. TIBBITTS



Screen age British teenagers' mental well-being, based on a 14-question survey about happiness and life satisfaction, seemed to shift with hours spent using digital media. Scores averaged between 40 and 50. Each type of media had a sweet spot, suggesting that moderate digital technology use may have benefits.

SOURCE: A.K. PRZYBYLSKI AND N. WEINSTEIN/*PSYCHOLOGICAL SCIENCE* 2017

phones before showing signs of anxiety.

Fundamentally, an interruption in smartphone access is no different from those in the days before smartphones, when the landline rang as you were walking into the house with bags full of groceries, so you missed the call. Both situations can raise anxiety over a connection missed. But Rosen suspects that our dependence on digital technology causes these situations to occur much more often.

"The technology is magnificent," he says. "Having said that, I think that this constant bombardment of needing to check in, needing to be connected, this feeling of 'I can't be disconnected, I can't cut the tether for five minutes,' that's going to have a long-term effect."

The question of whether digital technology is good or bad for people is nearly impossible to answer, but a survey of 120,000 British 15-year-olds (99.5 percent reported using technology daily) takes a stab at it. Oxford's Przybylski and Netta Weinstein at Cardiff University in Wales have turned up hints that moderate use of digital technology — TV, computers, video games and smartphones — correlates with good mental health, measured by questions that asked about happiness, life satisfaction and social activity.

When the researchers plotted technology use against mental well-being, an umbrella-shaped curve emerged, highlighting what the researchers call the "Goldilocks spot" of technology use — not too little and not too much.

"We found that you've got to do a lot of texting before it hurts," Przybylski says. For smartphone use, the shift from benign to potentially harmful came after about two hours of use on weekdays, mathematical analyses revealed. Weekday recreational computer use had a longer limit: four hours and 17 minutes, the researchers wrote in the February *Psychological Science*.

For even the heaviest users, the relationship between technology use and poorer mental health wasn't all that strong. For scale, the potential negative effects of all that screen time was less than a third of the size of the positive effects of eating breakfast, Przybylski and Weinstein found.

Even if a relationship is found between technology use and poorer mental health, scientists still wouldn't know why, Przybylski says. Perhaps the effect comes from displacing something, such as exercise or socializing, and not the technology itself.

> "We went from using stones to crack nuts to texting on a daily basis. Clearly the brain has changed."
>
> LEAH KRUBITZER

We may never know just how our digital toys shape our brains. Technology is constantly changing, and fast. Our brains are responding and adapting to it.

"The human neocortex basically re-creates itself over successive generations," Krubitzer says. It's a given that people raised in a digital environment are going to have brains that reflect that environment. "We went from using stones to crack nuts to texting on a daily basis," she says. "Clearly the brain has changed."

It's possible that those changes are a good thing, perhaps better preparing children to succeed in a fast-paced digital world. Or maybe we will come to discover that when we no longer make the effort to memorize our best friend's phone number, something important is quietly slipping away. ■

Explore more

■ Adam Gazzaley and Larry D. Rosen. *The Distracted Mind*. MIT Press, 2016.

Laura Sanders is a freelance science writer based in Corvallis, Oregon.

T. TIBBITTS

CANCER'S Sweet Cloak

Sugars on cell surfaces help tumors hide from immune system

By Esther Landhuis

Shrink yourself small enough to swoop over the surface of a human cell, and you might be reminded of Earth's terrain. Fats, or lipids, stay close to the surface, like grasses and shrubs. Proteins stand above the shrubs, as mighty oaks or palm trees. But before you could distinguish the low-lying lipids from the towering proteins, you'd see something else adorning these molecules — sugars.

If proteins are the trees, sugars are the mosses that dangle from the branches or, perhaps, the large fronds of the palm. "The cell surface is basically coated with sugars," says Carolyn Bertozzi, a chemist at Stanford University. "They're what viruses, bacteria and other cells see first when they touch down on a target cell."

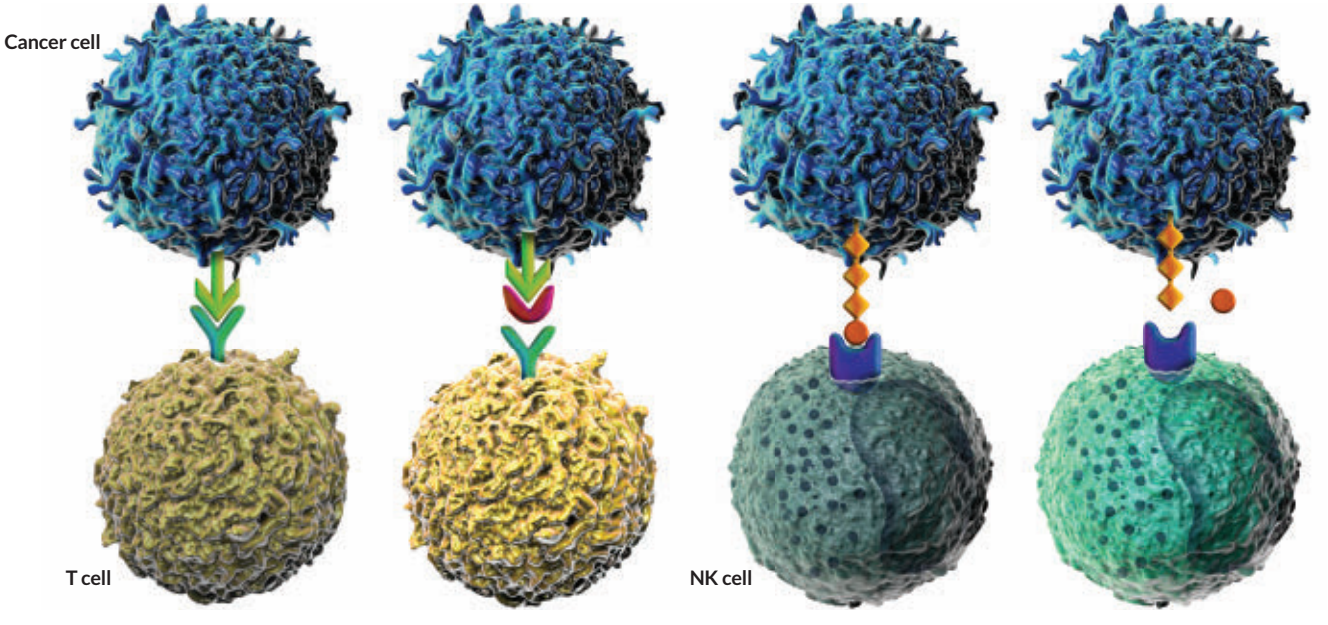
The sugars that attach to cell-surface proteins and lipids often take on elaborate structures. Information encoded within these structures helps cells recognize each other and relay messages in virtually every tissue and organ system. Yet compared with life's other building blocks — proteins, lipids and nucleic acids — sugars languish in research obscurity. Most sugars are so complex that many scientists are ill-equipped to understand the basic biology, Bertozzi says. "They literally steer their research program in a different direction."

Not Bertozzi. She's among a small crew of scientists who have spent their careers steeped in sugars. Some of their studies have led to a new insight into cancer therapy: Manipulating sugars on the surface of tumor cells has the potential to expand an exciting new class of cancer drugs.

Much of the current optimism about fighting cancer focuses on immune therapies — drugs that awaken the body's defenses to attack tumors (*SN: 12/27/14, p. 8*). The therapies focus on blocking protein interactions that suppress the immune system (*SN: 7/11/15, p. 14*). Such treatments have helped thousands of patients with cancers once untreatable, including former President Jimmy Carter, who was treated in 2015 and 2016 for advanced melanoma.

But so far these drugs, called checkpoint blockers, work only against some cancers, such as melanoma, kidney cancer and non-small cell lung cancer, and not for all patients.

Surface tension Current immune therapies block interactions between PD-L1 proteins (light green) on tumor cells and PD-1 proteins (teal) on T cells to awaken the immune system to the tumor. A new wave of therapies could target parallel interactions between sialic acid sugars (orange) on the tumor and sugar-binding Siglec proteins (purple) on natural killer cells and other innate immune cells. SOURCE: V.H. TRANG AND P.D. SENTER/*PNAS* 2016



PD-1 (teal) is a protein on T cells. If tumor protein PD-L1 (light green) binds to it, the T cell leaves the tumor alone.

Blocking the protein on the tumor (shown) or the protein on the immune cell can wake up T cells to attack the tumor.

Siglecs (purple) are on immune cells, such as natural killer cells. If sialic acids (orange) bind to Siglecs, the cells ignore the tumor.

New therapies could awaken natural killer cells by trimming sialic acids from the tumor (shown) or blocking Siglecs.

NICOLLE RAGER FULLER

An estimated 10 to 20 percent of cancer patients who get the drugs show improvement.

A new wave of potential immune therapies aims to target cell-surface sugars instead of proteins. Researchers hope these new approaches will rouse new warriors — an entirely different part of the immune system — to the fight. Current protein-targeting immune therapies activate killer T cells, part of the adaptive immune system with a memory for intruders and an ability to respond to specific threats.

Sugar-targeting drugs, on the other hand, would alert cells of the innate immune system, such as natural killer cells, or NK cells, and macrophages. Innate immune cells also help defend the body against bad guys, be they flu viruses or cells that have turned cancerous, but the innate cells kick into action more quickly and with less specialized responses than T cells. The two systems are complementary.

Clever disguise

Knowing what to attack requires immune cells to distinguish self from foreign, and sugars play a key role. One class of surface sugars, called sialic acids, mark the body's cells as "self." Sialic acids have a range of biological functions — their roles are so essential that preventing synthesis of these sugars in mice kills the animals in utero.

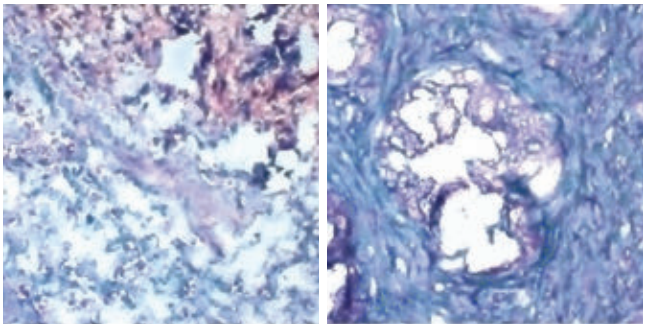
To our defense system, cell-surface sugars are a molecular fingerprint, telling a roving immune cell, "This one's OK. Move along," Bertozzi says. Certain pathogens, such as the bacteria that cause gonorrhea or streptococcal infections, have taken advantage. They coat themselves with sialic acids to hide from the immune system. Several years ago scientists wondered if tumors might use a similar trick. "We thought, 'if bacteria are doing that, maybe cancer cells do too,'" says glycobiologist Ajit Varki of the University of California, San Diego.

The connection was stunning: Sialic acids seemed to protect tumors from the immune system.

That suspicion has roots in a strange but widespread observation researchers had made many years before: Sialic acids cluster in unusual ways on the surface of tumor cells. The observation intrigued Bertozzi. In the late 1990s, while starting up her lab at the University of California, Berkeley, she saw sialic acids as a potential marker for cancer. An expert in designing chemical reactions to tag molecules within living systems, Bertozzi thought about developing an early detection test that measured excess sialic acids.

Paper after paper came out linking cancer with an overgrowth of cell-surface sugars. However, none of the studies explained what triggers the ramp-up of sialic acids or why it matters. "What was the biological consequence? We didn't know," Bertozzi says. So her cancer detection idea sat on the back burner.

Then Bertozzi came across a 2010 paper in the *Journal of Immunology* that suggested there was more to the story. In that study, researchers in Israel used chemicals to cause tumors in mice bred to have weak immune systems. Tumors growing in these animals had lower levels of sialic acids, compared with tumors induced in normal mice. In separate experiments in lab dishes, the researchers stripped sialic acids off the surface of tumor cells and saw natural killer cells wake up and attack the cancer. To the researchers, the connection was stunning: Sialic acids seemed to protect tumors from the immune system.



Cancer tissues have extra sugars (stained blue) that bind to the protein Siglec-9 on natural killer cells and so quiet the immune response. Left panel shows breast cancer tissue; right shows prostate cancer.

H. LÄUBLI ET AL/PNAS 2014

Connecting the dots

While Bertozzi puzzled over sialic acids, a few other research teams had already spent decades studying immune cells that recognize and bind to these sugars.

Paul Crocker, an immunologist at the University of Dundee in Scotland, studies macrophages, part of the early responding, innate immune system. Greek for "big eaters," macrophages feel their way with sticky spaghetti-like arms to find and devour pathogens and dying cells. In 1986, Crocker's team discovered a protein that makes macrophages sticky. The researchers later named it sialoadhesin because it binds to sialic acids on the surface of other cells. Checking for signature DNA sequences in the gene that codes for sialoadhesin, researchers were excited to discover the protein wasn't a lone ranger — it's part of a large family of proteins already known to help immune cells signal to each other. "That was a breakthrough moment," Crocker says.

In 1993, Varki and colleagues found a different set of immune cells, from the adaptive immune system, that also recognize sialic acids. B cells, which help call T cells into action, have a surface protein called CD22 that binds to cell-surface sialic acids.

A flurry of studies turned up more immune cell surface proteins with similar features. A total of 14 proteins, known as "Siglecs," now make up this group of immune cell molecules that bind to sialic acid sugars. The founding members, sialoadhesin and CD22, are known as Siglec-1 and Siglec-2.

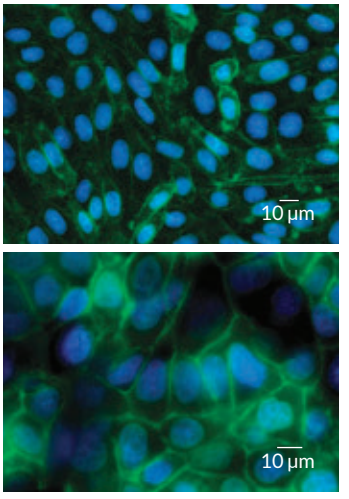
When Siglec-7 was discovered on natural killer cells, Crocker's attention went to cancer. Guarding against tumors is "what NK cells are famous for," he says.

By 2014, a trio of papers confirmed that Crocker's shift to focusing on cancer made sense. Varki's lab and a team led by Stephan von Gunten of the University of Bern in Switzerland analyzed biopsy material from people with various cancers. These studies showed that sialic acids on patient tumors indeed bind to Siglecs on human innate immune cells.

Once again, the cell-surface sugars acted like a cloak. When sialic acids bind to Siglecs on the surface of NK cells, these immune cells lose their cancer-fighting ability. That fact was shown in a common cell culture test that mixed immune cells with radioactive tumor cells. When NK cells attacked, the tumor cells burst and released radioactivity. But when NK activity was weak, less radioactivity leeched out.

Bertozzi and colleagues provided further support for the cloaking idea by working out a method to adjust the level of sialic acids on cells. The system was artificial — synthetic sugar molecules planted on the surface of human cancer cell lines — but it clearly showed cause and effect, she says. By dialing up sialic acids, the researchers could protect cells from NK killing. The team shared its findings in 2014 in *Nature Chemical Biology*.

With evidence from multiple labs suggesting that tumors cloak themselves in sialic acids to thwart the immune system, it was time to think about devising treatments that awaken the immune cells from their sugar-induced stupor.



Synthetic sialic acids (green) stick to the surface of cancer cells from rodents (top) and humans (bottom), giving researchers a way to test the effects of adjusting sugar levels on immune cell activity.

Unpredictable diversity

Sugars far outnumber proteins among surface molecules responsible for distinguishing tumor from normal, Varki says. So you'd think they would make easier drug targets. Trouble is, sugars are immensely harder to study than proteins.

Both proteins and sugars adopt three-dimensional shapes to do their work. Once researchers have a protein's genetic blueprints in hand, they can predict its structure. Sugars, on the other hand, have no clear templates. A sugar's shape and structure are determined by a sequence of enzymatic reactions that can be hard to predict. Different cells turn on different sugar-modifying enzymes, so the same sugar can adopt a range of conformations. The "degree of complexity is thousands, if not millions, times that of proteins," Varki says.

These structural differences affect how well sugars bind to proteins and lipids. And those interactions can have life-or-death ramifications, such as shielding cancer cells from immune attack.

Sugars are the "dark matter" of the biological universe, Varki says. They "affect everything, but hardly anybody studies them."

Another checkpoint

To further complicate matters, sugars such as sialic acid are just one part of a tumor's cell-surface barcode. Other players such as proteins also tell immune cells whether to attack or move on. The good news is that current immune therapies awaken immune cells to fight cancer by disrupting some of these proteins. Bertozzi and others think they can apply similar strategies to target cell-surface sugars.

Protein-based immune therapies work by deactivating cellular "off" switches on immune cells. One off switch involves a protein called PD-1 on the surface of T cells. When PD-1 latches onto the protein PD-L1 on a tumor cell, the T cell is turned off, rendered powerless against the cancer.

Siglecs play a similar role to PD-1, but mostly on natural killer cells and macrophages rather than T cells. The sialic acids on tumor cells work like the PD-L1. Just as existing immunotherapy drugs block PD-1, it's conceivable to design new therapies to block Siglecs so that innate immune cells won't be turned off. Indeed, biotech companies are pursuing these and other sugar-centric approaches.

But blocking too many of the immune system's off switches could be dangerous. They have an important job: guarding against overzealous T cell activity that could trigger autoimmune disease.

Rather than go after Siglecs on immune cells, Bertozzi and colleagues are focusing on the sialic acids on the tumor cells. As long as a tumor cell wears a thick coat of sialic acid, immune cells won't touch it, she says. "If you could strip off those sugars, the immune system could see the cancer cell for what it really is — something that needs to be destroyed."

Many organisms, including humans and some microbes, have an enzyme that clips sialic acids off the ends of larger carbohydrate, protein or lipid molecules. Some versions of these enzymes, called sialidases, are commercially available as lab reagents. Bertozzi's group decided to make its own by purifying large batches of the enzyme from bacterial cultures.

The trick was finding a way to point the sialidase specifically at tumor cells without letting it cut willy-nilly everywhere else.

Cancer cell editing

To get the sialidase to focus on tumor cells, Bertozzi and colleagues repurposed Herceptin, a blockbuster cancer drug. Herceptin is an antibody that recognizes a protein called HER2 on the surface of many breast tumors. When the antibody binds to HER2, it marks the tumor cell for destruction by innate immune cells, such as natural killer cells and macrophages. And since Herceptin binds to tumor cells better than normal cells, Bertozzi figured it could work as a delivery

J.E. HUDAK, S.M. CANHAM AND C.R. BERTOZZI/*NAT. CHEM. BIOL.* 2014

device to bring sialidase to tumors.

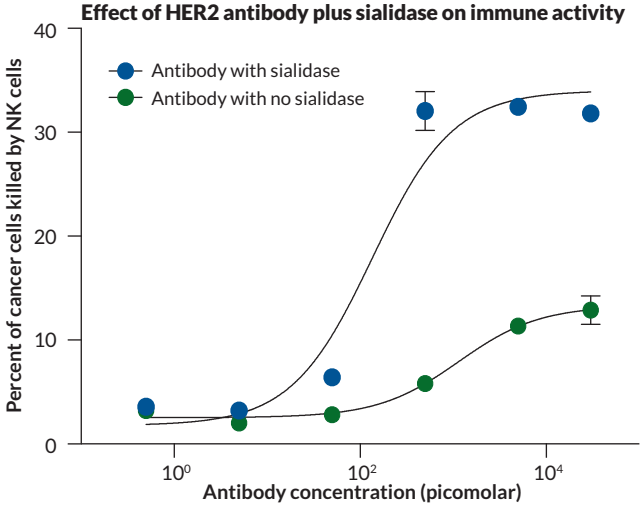
Using a method her lab had developed for joining antibodies to small molecules, Bertozzi's team fused a sialidase enzyme with the Herceptin antibody. The researchers added the antibody-enzyme combo into a mixture of breast cancer cells with varying levels of HER2 on the surface. When the drug latched onto HER2 proteins on the tumor cells, the sialidase trimmed sialic acids like a chemical lawn mower, Bertozzi explains.

The strategy — published in September in *Proceedings of the National Academy of Sciences* — looks promising in these lab dish experiments, but it will take additional refining before the approach can be tested in people. One safety consideration relates to the antibody's target, HER2. Though it is found in excess on breast cancer cells, the protein is also found at low levels on normal cells. So it's possible the "lawn mower" could stray and trim sialic acids from cells that need the sugars for proper function.

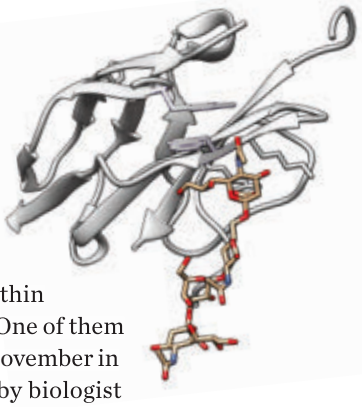
Another concern: The engineered molecules contain bacterial sialidase, which — like other foreign proteins entering our bodies — would probably trigger a vigorous immune response. The antibody-enzyme combination "is a good proof of principle" showing it's feasible to edit molecules on cancer cells, Varki says. "But I don't think [the injections] would be practical to do repeatedly."

Bertozzi is thinking along similar lines. Since publishing version 1.0 of the chemical lawn mower, her lab group has created version 2.0 and is now testing it in animal models. Version 3.0 will fuse antibodies with human sialidase, which is less likely to trigger an immune response, Bertozzi says. Her team is also working to attach sialidase to antibodies attracted to molecules other than HER2, to direct the enzyme to different kinds of tumors.

License to kill Herceptin is an antibody that binds to the protein HER2 on the surface of some breast cancer cells. Researchers fused Herceptin with sialidase, an enzyme that cuts sialic acids off larger molecules, and showed this antibody-enzyme combo (blue circles) rouses natural killer cells to kill cancer cells. An antibody with no sialidase enzyme had little effect on immune activity. SOURCE: H. XIAO *ET AL*/*PNAS* 2016



V.H. TRANG AND P.D. SENTER/*PNAS* 2016



In this crystal structure, the Siglec-7 protein (gray ribbon) binds to sialic acid (red atoms are oxygen, yellow are carbon and blue are nitrogen).

Two-faced macrophages

Meanwhile, other secrets lurk within the sugar coating on tumor cells. One of them emerged in a study published in November in *Nature Immunology*. A team led by biologist Joy Burchell of King's College London was studying a large protein studded with sugars, including sialic acids. Called MUC1, this protein adorns the surface of normal epithelial cells found in the lungs, stomach, intestines, eyes and other organs. Modified forms of MUC1 appear on various cancer cells. Siglec-9 on the surface of macrophages is known to bind to tumor-specific versions of MUC1.

When those odd MUC1s bind to Siglec-9 on macrophages, the immune cells are thrown into a trance, the researchers found. The binding quiets macrophages in such a way that they ignore the tumor cell. Researchers had known macrophages adopt this weird state around tumors, but this study shows that MUC1 drives the transformation.

Not only does the MUC1–Siglec-9 interaction seem to shut down macrophage activity, it makes macrophages, which have some PD-L1, display even more. The finding raises questions because PD-L1 is a target of some immune therapies.

Current immune therapies unleash T cells to attack tumors by blocking the off-switch interactions between PD-1 and PD-L1. Focusing on the innate immune system could also help, and this paper suggests a possible target, Burchell says. She plans to work with a company to test, among other things, if blocking Siglec-9 can slow tumor growth in mice. And Varki cofounded Siamab Therapeutics in Newton, Mass., to design therapies that target other abnormal sugars on cancer cells. None of these drugs have entered human testing.

The under-the-radar work on sialic acids over the last few decades may have exposed just the edge of a dense forest. It's likely that other sugars also form cloaks to shield tumor cells from immune attack, Bertozzi says. Translating such insights into actual therapies will require biologists to jump into the sugar fray and venture deeper than ever before. Bertozzi is hopeful: "We might be on the cusp of entering that phase." ■

Explore more

- Carolyn Bertozzi. "The sugar coating on your cells is trying to tell you something." TedXStanford. Watch her talk at bit.ly/SN_BertozziTedX
- Vivian H. Trang and Peter D. Senter. "Cutting back on the carbs." *Proceedings of the National Academy of Sciences*. September 13, 2016.

Esther Landhuis is a freelance science journalist based in the San Francisco Bay Area.

In 1835, the Gardens of the Zoological Society of London housed an assortment of exotic animals, many of which struggled to survive.

The Zoo
Isobel Charman
PEGASUS BOOKS, $27.95

BOOKSHELF

Shocking stories tell tale of zoo's founding

When Tommy the chimpanzee first came to London's zoo in the fall of 1835, he was dressed in an old white shirt.

Keepers gave him a new frock and a sailor hat and set him up in a cozy spot in the kitchen to weather the winter. Visitors flocked to get a look at the little ape roaming around the keepers' lodge, curled up in the cook's lap or tugging on her skirt like a toddler. Tommy was a hit — the zoo's latest star.

Six months later, he was dead.

Tommy's sorrowful story comes near the middle of Isobel Charman's latest book, *The Zoo*, a tale of the founding of the Gardens of the Zoological Society of London, known today as the London Zoo. The book lays out a grand saga of human ambition and audacity, but it's the animals' stories — their lives and deaths and hardships — that catch hold of readers and don't let go.

Charman, a writer and documentary producer, resurrects almost three decades of history, beginning in 1824, when the zoo was still just a fantastical idea: a public menagerie of animals "that would allow naturalists to observe the creatures *scientifically*."

It was a long, hard path to that lofty dream, though: In the zoo's early years, exotic creatures were nearly impossible to keep alive. Charman unloads a numbing litany of animal misery that batters the reader like a boxer working over a speed bag. Kangaroos hurl themselves at fences, monkeys attack each other in cramped, dark cages and an elephant named Jack breaks a tusk while smashing up his den. Charman's parade of horrors boggles the mind, as does the sheer number of animals carted from all corners of the world to the cold, wet enclosures of the zoo.

Her story is an incredible piece of detective work, told through the eyes of many key players and famous figures, including Charles Darwin. Charman plumbs details from newspaper articles, diaries, census records and weather reports to craft a narrative of the time. She portrays a London that's gritty, grimy and cold, where some aspects of science and medicine seem stuck in the Dark Ages. Doctors still used leeches to bleed patients, and no one had a clue how to care for zoo animals.

Zoo workers certainly tried — applying liniment to sores on a lion's legs, prescribing opium for a sick puma and treating a constipated llama with purgatives. But nothing seemed to stop the endless conveyor belt that brought living animals in and carried dead ones out. Back then, caring for zoo animals was mostly a matter of trial and error, Charman writes. What seems laughably obvious now — animals need shelter in winter, cakes and buns aren't proper food for elephants — took zookeepers years to figure out.

Over time the zoo adapted, making gradual changes that eventually improved the lives of its inhabitants. It seemed to morph, finally, from mostly "a playground of the privileged," as Charman calls it, to a reliable place for scientific study, where curious people could learn about the "wild and wonderful" creatures within.

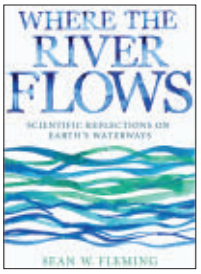
One of those people was Darwin, whose ideas about human origins clicked into place after he spent time with Jenny the orangutan. Her teasing relationship with her keeper, apparent understanding of language and utter likeness to people helped convince Darwin that humankind was just another branch on the tree of life, Charman writes.

Darwin's work on the subject wouldn't be published for decades, but in the meantime, the zoo's early improvements seemed to have stuck. Over 30 years after Tommy the chimpanzee died in his keeper's arms, a hippopotamus gave birth to "the first captive-bred hippo to be reared by its mother," Charman notes. The baby hippo not only survived — she lived for 36 years.

Seeing Jenny the orangutan's similarities to people helped Darwin formulate his ideas about human origins.

Readers may wonder how standards for animal treatment have changed over time. But Charman sticks to history, rather than examining contrasts to modern zoos. Still, what she offers is gripping enough on its own: a bold, no-holds-barred look at one zoo's beginning. It was impressive, no doubt. But it wasn't pretty. — *Meghan Rosen*

FROM TOP: HERITAGE IMAGE PARTNERSHIP LTD/ALAMY STOCK PHOTO; PRINTED BY W CLERK, HIGH HOLBORN



Where the River Flows
Sean W. Fleming
PRINCETON UNIV., $26.95

BOOKSHELF

To understand rivers, let physics be your guide

Spend an hour wandering along a river and you may wonder why the water rushing by chose this particular path over any other. While many nature writers might offer philosophical musings on the subject, *Where the River Flows* author Sean Fleming has physics on his side.

Physics isn't the lens through which most people think about rivers. Fleming, a hydrologist, aims to change that. Only about 0.006 percent of the world's freshwater is in a river at any given moment. But these hydrological highways transport a massive amount of water across the planet. Physics can explain where that water moves and help predict the ecological impact of its travels.

The physical force that water exerts on its surroundings (whether it carves a canyon, for instance) is just the beginning. Equations that quantify the rate at which particles disperse through water can help scientists predict whether a farm dumping manure into a river will make a swimming hole downstream unsafe. And hunting for patterns in streamflow measurements over time can be something like using a prism to spread white light into a rainbow. Both are a type of spectral analysis, in which a complex system is separated into its individual components.

Fleming makes some more unusual connections, too. Information theory — a framework that can be used to quantify the amount of information conveyed by a measurement — is most commonly associated with computer science. But Fleming explains how the concept can help scientists find value in variable rainfall data, which is important for making accurate predictions about river flow. He also delves into fractal geometry. Geologists find similarities to fractals (series of the same pattern that repeats at different scales) in aerial views of river basins, where tiny rivulets flow into larger and larger streams, as well as in streamflow data collected over different time intervals.

Fleming's decades of experience shine through in this book. Abstract physics concepts feel more relevant when applied to concrete phenomena that readers can visualize. But *Where the River Flows* isn't a light read. Occasionally, it wanders into textbook territory, walking through equations in great detail when conceptual examples might have conveyed the same information. Readers who don't mind wading through such diversions will find that the math does, in the end, illustrate a point. Those who choose to skip the equations will still find nuggets of wisdom elsewhere in this book. — *Laurel Hamers*

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Volunteer, Judge, Interpret at the

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Become a Judge

Approximately 1,000 judges are needed to evaluate research covering 22 scientific disciplines. Judging will take place at the Los Angeles Convention Center from Tuesday, May 16, 2017, through Wednesday, May 17, 2017. Judges must have a minimum of six years related professional experience beyond receiving a B.A., B.S., Master's degree, Ph.D., M.D. or equivalent (D.O., Ed.D., D.D.S., D.V.M., etc.).

Volunteer to Interpret

About 200 interpreters are needed to work with students throughout the week. The greatest need for interpreters is during judging on Wednesday, May 17, 2017. Technical knowledge is not required.

Every morning, interpreters and finalists will meet at breakfast to discuss finalists' project and language needs. Many students are fluent in English but would like interpreters just in case. There will be four-hour shifts throughout each day until about 6:00 p.m.

Spanish, Arabic, Russian and Mandarin interpreters are needed most. Other languages include Bahasa Malaysia, Bengali, Cantonese, Czech, Filipino, Finnish, French, German, Gujarati, Hindi, Hungarian, Indonesian, Italian, Japanese, Kazakh, Korean, Polish, Portuguese, Romanian, Sinhala, Slovak, Thai, Turkish, Urdu and Vietnamese.

Serve as a General Volunteer

More than 500 general volunteers are needed for a variety of activities beginning Thursday, May 11, 2017, through Friday, May 19, 2017. Daytime, evening and weekend shifts are available for everyone ages 14 years and up. On-site training will be provided.

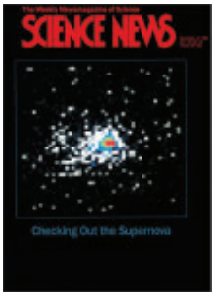
For more information and to register, visit **student.societyforscience.org/volunteers**

Please send any questions to **isefvolunteer@societyforscience.org**

FEBRUARY 18, 2017

Stellar storyteller

Astronomers caught their first glimpse of supernova 1987A on February 24, 1987. *Science News* reported on the discovery just days later, and our writers have been following the exploding star ever since. Scroll through *Science News*' archived coverage, including the December 12, 1987 cover below, and watch a new video recounting the supernova's discovery at bit.ly/SN_1987A



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Supernova surprise

Astronomers continue to learn a lot from supernova 1987A, which burst onto the scene 30 years ago. Thanks to new detectors that can pick up neutrino signals and even gravitational waves, scientists will be ready when the next nearby star explodes, ***Emily Conover*** *reported in "Waiting for a supernova"* (SN: 2/18/17, p. 24).

Steve Capps wondered how neutrinos inside an exploding star could push a shock wave toward the star's surface to make it go supernova. "That seems to be some fairly potent interaction by the neutrinos," **Capps** wrote. "In many other articles, neutrinos are described as having infinitesimal interactions with matter — practically zero. How can both of these be true?"

It is true that neutrinos interact feebly with matter. But exploding stars produce a lot of neutrinos. 1987A, for example, emitted roughly 10 billion trillion trillion more neutrinos than there are stars in the observable universe. "There are so many neutrinos interacting with such extremely dense material inside the star that they end up giving the shock wave a significant amount of energy as they exit," **Conover** says.

Heart to heart

An implanted soft robotic sleeve restored normal blood flow to pigs' failing hearts, ***Meghan Rosen*** *reported in "New robot keeps blood pumping"* (SN: 2/18/17, p. 18).

Online reader **gizmowiz** wondered if a chest compression machine that straps to the outside of the body might be a better, less invasive option than surgically inserting a device around the heart.

Automated CPR machines exist today and are primarily used in emergency situations, says **Ellen Roche**, a biomedical engineer who helped invent the robotic sleeve. Powered by batteries or air compressors, the machines are cumbersome and designed for short-term use only, she says. The robotic sleeve potentially could help people with long-term cardiovascular troubles.

Tight squeeze

A team of scientists claims to have made metallic hydrogen by compressing the element at 4.9 million times atmospheric pressure, ***Emily Conover*** *reported in "New claim staked for metallic hydrogen"* (SN: 2/18/17, p. 14).

"The idea that we can create almost 5 million atmospheric pressures is more amazing than the metallic hydrogen," wrote online reader **Robert Stenton**. "It might be easier to turn heavy hydrogen, deuterium or tritium into its metallic form."

Scientists have indeed tried squeezing deuterium in diamond vises. "They've yet to create a metal that way, but deuterium does form a solid, as hydrogen does," **Conover** says. "Other elements are known to become metallic under pressure, too. Oxygen, for example, becomes metallic at nearly a million times atmospheric pressure."

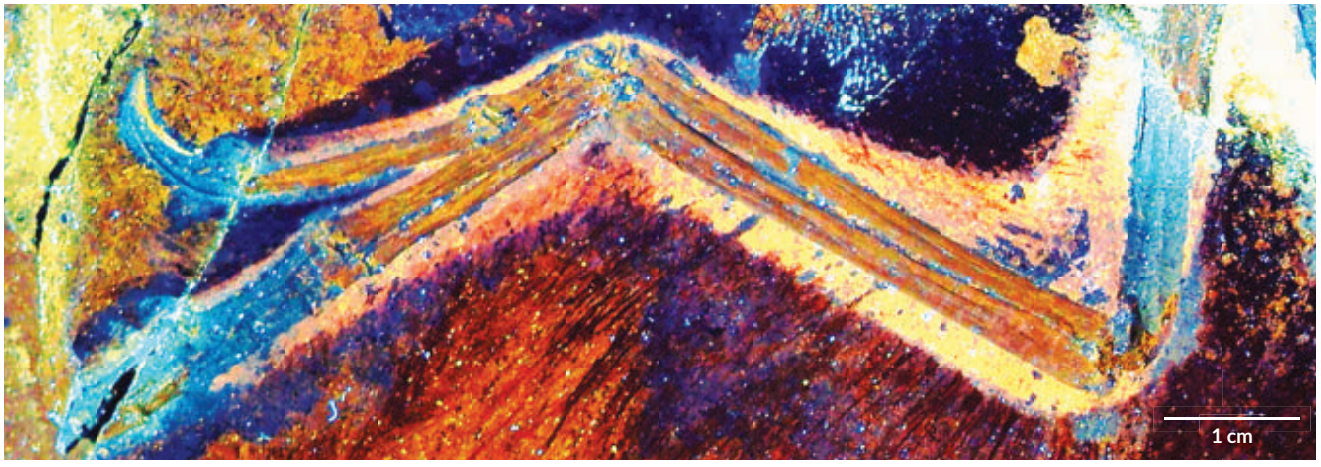
Tie the knot

Chemists created an intricate molecular knot from 192 atoms of carbon, hydrogen, oxygen and nitrogen, ***Meghan Rosen*** *reported in "Molecular knot is most complex yet"* (SN: 2/18/17, p. 8).

Online readers **John Turner** and **David Spector** debated how the knot's tightness might affect its usefulness. **Turner** speculated that molecular knots could be used to trap other molecules, similar to how the active ingredient in Febreze holds odor molecules. **Spector** wasn't so certain. "As tight knots, they would not tend to open to accept desired molecules," he wrote. "They would ... be fairly inert."

Whether or not the knots can trap odor molecules is unclear, **Rosen** says. But study coauthor **David Leigh** of the University of Manchester in England thinks that the technique of the research is what's most useful.

One day, researchers might be able to use it to weave molecular strands into strong, flexible fabrics. Like Kevlar, but better, he says. "We're quite a long way away from that," **Leigh** says. "We're knotting, not weaving, but the principles are the same."



Dino fossils show some skin

What happens when you shoot lasers at a dinosaur fossil? Some chemicals preserved in the fossil glow, providing a nuanced portrait of the ancient creature's bones, feathers and soft tissue such as skin.

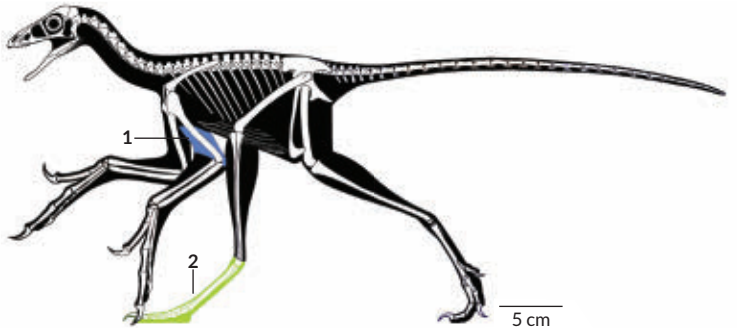
Soft tissue is rarely preserved in fossils, and when it is, it can be easily obscured. A technique called laser-stimulated fluorescence "excites the few skin atoms left in the matrix, making them glow to reveal what the shape of the dinosaur actually looked like," says Michael Pittman, a paleontologist at the University of Hong Kong.

Pittman and colleagues turned their lasers on *Anchiornis*, a four-winged dinosaur about the size of a pigeon with feathered arms and legs. It lived around 160 million years ago during the Jurassic Period. The researchers imaged nine specimens under laser light and used the photos to reconstruct a model of *Anchiornis* that shows an exceedingly birdlike body, the team writes March 1 in *Nature Communications*.

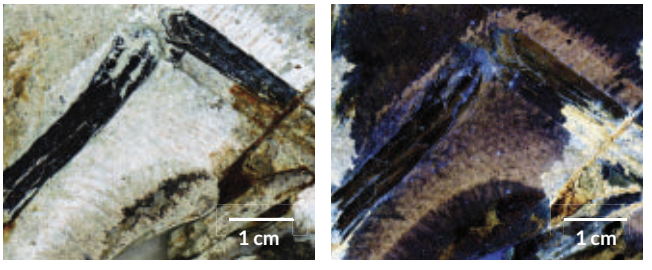
In the crooks of its elbows and wrists (at top and No. 1 at right), the dinosaur had what looks like taut tissues called patagia, a feature in modern bird wings. "The wings ... are reminiscent of the wings of some living gliding and soaring birds," Pittman says. Plus, the images capture minute details like feather follicles and scales, and confirm some characteristics of *Anchiornis* long surmised by scientists: that it had drumstick-shaped legs, pads on the balls of its feet (No. 2 at right) and a slim tail.

Still, it's unclear what geochemicals are actually fluorescing in the fossils because the team didn't perform any chemical analyses to determine the organic compounds or minerals present. "The images are very cool," says Mary Schweitzer, a paleontologist at North Carolina State University in Raleigh. But, she cautions, a few hurdles remain, including testing fluorescence in different fossil types and verifying how skin glows under laser light in modern bird fossils.

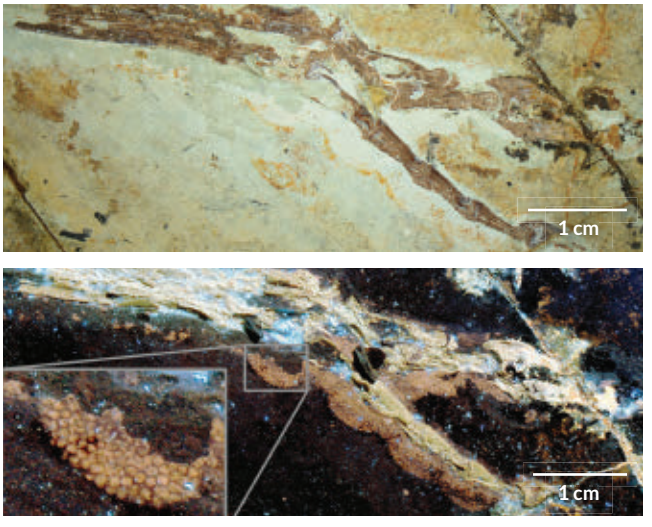
If laser-stimulated fluorescence lives up to its promise, it could help discern fossilized features that are invisible to the naked eye. — *Helen Thompson*



1. *Anchiornis* elbow in white light (left) and laser fluorescence (right)



2. Foot and pads in white light (top) and laser fluorescence (bottom)



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