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People May Sense Earth's Magnetism

RNAs Steal the Spotlight

Depression Drug Raises Questions

Asteroid Spits Dust Plumes

Tundra in Trouble

Climate change is stressing Arctic vegetation

"I THOUGHT I'D TRY THE CONCRETE CANOE AT FIRST, BUT..."

Jennifer Hong
Junior
Mechanical Engineering

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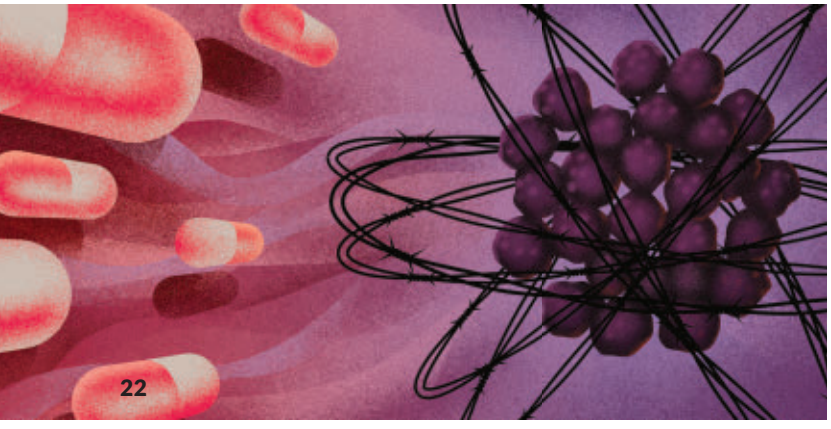

Features

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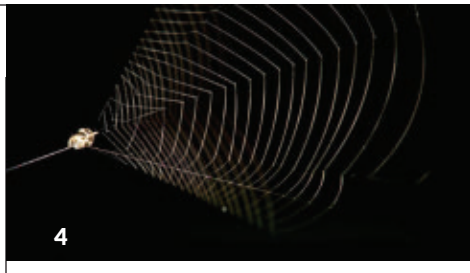

Departments

COVER On Svalbard in the Arctic in 2015, extreme weather killed flowering mountain avens, but purple saxifrage survived. *Rachael Treharne*

FROM TOP: JAMES PROVOST; LAWRENCE E. REEVES; LUKÁŠ JANOŠÍK

The delight of discovering an asteroid that spits

These are wondrous times for space exploration. Just when you think exploring the cosmos couldn't possibly get more fun, another discovery delivers a new "oh wow" moment.

Consider the asteroid Bennu. It's an unprepossessing space rock that drew scientists' curiosity because it is among the most pristine objects in our solar system, and it might provide clues to the origins of life. But checking out Bennu is no trip to Paris; it's about 130 million kilometers from Earth. NASA launched its OSIRIS-REx probe to Bennu in 2016, and it didn't arrive until last December. The spacecraft is currently orbiting its quarry in preparation for an attempt at gathering samples from the asteroid's surface in 2020 and then toting them back to Earth. Estimated delivery date: September 24, 2023. Clearly, asteroid science is not a discipline for those with short attention spans.

So imagine scientists' delight when OSIRIS-REx already had news to share: Bennu is squirting jets of dust into space. It's an asteroid behavior no one had ever seen before. Astronomy writer Lisa Grossman learned all about Bennu's surprise jets while attending the Lunar and Planetary Science Conference in March. She reports that the dusty fountains may be the work of volatile gases beneath Bennu's surface (Page 10). The presence of volatiles would suggest that the rock wandered into the inner solar system relatively recently. But astronomers still have a lot to figure out about Bennu's history, and they couldn't be happier.

In other surprising space rock news from the conference, astronomers analyzing the much-more-distant object dubbed Ultima Thule now think it's an agglomeration of mini-worlds that stuck together in the early days of the solar system — as Grossman terms it, a "Frankenworld" (Page 11). That's just the latest unexpected news from this Kuiper Belt denizen. If you're as space rock obsessed as we are, you may recall that the first fuzzy images from NASA's New Horizons spacecraft, which flew by Ultima Thule on January 1, suggested that the rock looked like a bowling pin or a snowman spinning in space. More recent images reveal not a snowman, but instead two pancakes or hamburger patties glued end to end (*SN: 3/16/19, p. 15*). That has scientists scrambling to figure out what forces could create such an oddly shaped object.

We'll be hearing more about Bennu, Ultima Thule and other residents of our solar system in the months to come. I'm particularly looking forward to news from the Parker Solar Probe, which is tightening its orbit around the sun. I'm the one who is going to have to be patient in this case, though that's not an attribute typically associated with journalists. The spacecraft won't make its closest encounter with the sun until 2024, before ending its mission the following year. But the probe will be reporting in, and we'll be reporting, too, as it makes this historic journey (*SN: 1/19/19, p. 7*).

Open your Web browser or your trusty print magazine and join us for the adventure. We hope you'll enjoy the journey as much as we do.

— Nancy Shute, Editor in Chief

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Excerpt from the April 5, 1969 issue of *Science News*

50 YEARS AGO

Unusual virus is valuable tool

Viruses, which cannot reproduce on their own, infect cells and usurp their genetic machinery for use in making new viruses.... But just how viruses use the cell machinery is unknown.... Some answers may come from work with an unusual virus, called M13, that has a particularly compatible relationship with ... [*E. coli*] bacteria.

UPDATE: M13 did help unlock secrets of viral replication. Some bacteria-infecting viruses, called bacteriophages or simply phages, kill the host cell after hijacking the cell's machinery to make copies of themselves. Other phages, including M13, leave the cell intact. Scientists are using phage replication to develop drugs and technologies, such as virus-powered batteries (*SN: 4/25/09, p. 12*). Adding genetic instructions to phage DNA for making certain molecules lets some phages produce antibodies against diseases such as lupus and cancer. The technique, called phage display, garnered an American-British duo the 2018 Nobel Prize in chemistry (*SN: 10/27/18, p. 16*).

SOAPBOX

Why scientific findings by AI can't always be trusted

WASHINGTON — We live in a golden age of scientific data, with larger stockpiles of genetic information, medical images and astronomical observations than ever before. Artificial intelligence can pore over these troves to uncover potential scientific discoveries much more quickly than people can. But we should not blindly trust AI's scientific insights until these computer programs can better gauge how certain they are in their own results, argues data scientist Genevera Allen of Rice University in Houston.

AI systems that use machine learning — learning by studying data, rather than following instructions — can be trusted with some tasks, Allen says. For example, AI is reliable with work that humans can later verify, like counting moon craters or predicting earthquake aftershocks (*SN: 12/22/18 & 1/5/19, p. 25*).

Genevera Allen is devising ways to measure uncertainty to help AI programs gauge whether their discoveries are accurate and replicable.

More exploratory algorithms that poke around datasets to find previously unknown patterns or relationships "are very hard to verify," Allen said February 15 at a news conference during the annual meeting of the American Association for the Advancement of Science. Deferring judgment to such autonomous systems may lead to faulty conclusions, she warned.

Take precision medicine. Researchers often aim to find groups of genetically similar patients to help tailor treatments. AI programs that sift through genetic data have identified patient groups for some diseases, such as breast cancer. But such effort hasn't worked as well for many other conditions, like colorectal cancer. Algorithms examining different datasets have clustered together conflicting patient classifications. That leaves scientists to wonder which, if any, AI to trust.

These contradictions arise because data-mining algorithms are designed to draw conclusions with no uncertainty, Allen said. "If you tell a clustering algorithm, 'Find groups in my dataset,' it comes back and it says, 'I found some groups.'" Tell it to find three groups; it finds three. Request four, and it gives you four.

What AI should really do, Allen said, is report something like, "I really think that these groups of patients are really, really grouped similarly ... but these others over here, I'm less certain about."

Scientists are used to dealing with uncertainty. But traditional uncertainty-measuring techniques are designed for cases where a scientist has analyzed data that were collected to evaluate a hypothesis. That's not how data-mining AI programs usually work. These systems have no guiding hypotheses and muddle through huge datasets that are generally collected for no single purpose.

Researchers including Allen are designing protocols, however, to help next-generation AI estimate the accuracy and reproducibility of its discoveries.

One of these techniques relies on the idea that if an AI program has made a real discovery — like identifying clinically meaningful patient groups — then that finding should hold up in other datasets. It's generally too expensive to collect new datasets to test what an AI has found. But "we can perturb the [existing] data and randomize the data in a way that mimics [collecting] future datasets," Allen said. If the AI finds the same types of patient classifications, for example, "you probably have a pretty good discovery on your hands," she said. — *Maria Temming*

FROM TOP: TOMMY LAVERGNE/RICE UNIV.; DMYTRO VIKARCHUK/SHUTTERSTOCK

To catch prey, the slingshot spider sends itself and its web flying at record speed.

THE –EST

Spider slingshots itself at extreme speeds

BOSTON — Tasty insects, look out: In an effort to catch prey, a speed-demon spider launches itself, along with its web, at almost 100 times the acceleration of a cheetah. That makes these tiny creatures — called slingshot spiders — the fastest-moving arachnids known, scientists reported March 4 at a meeting of the American Physical Society.

Found in the Peruvian Amazon, slingshot spiders weave conical webs. These webs have a single strand attached to the tip of the cone that the spider reels in to ramp up tension. When the spider senses a potential meal, it releases the web. The spider and web together zing forward, ensnaring the prey. "Just like that, our spider has dinner," biophysicist Symone Alexander of Georgia Tech said.

13
meters per second squared
Cheetah's approximate max acceleration

1,100
meters per second squared
Slingshot spider's approximate max acceleration

High-speed cameras caught the spider in motion, clocking it at a maximum speed of about 4 meters per second — close to the speed of a jogging human. "It's a good thing ... we're not their target," Alexander said of the species, from the Theridiosomatidae family. Other speedy spiders seem slow by comparison, like the Moroccan flic-flac spider, which cartwheels away from danger at about 2 meters per second.

The slingshot spider's maximum acceleration is far more impressive at about 1,100 meters per second squared. Cheetahs, by comparison, accelerate at up to 13 meters per second squared, Alexander said. So the spider puts the fleet-footed cats to shame (*SN: 3/3/18, p. 8*). — *Emily Conover*

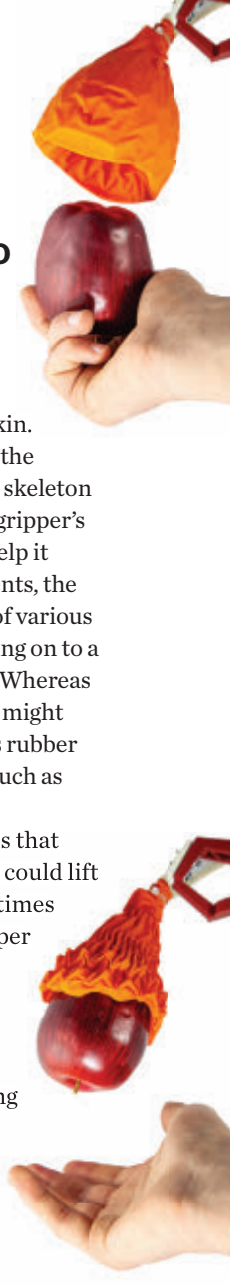
TEASER

Origami design helps a robot lift heavy cargo

A new robotic gripper is a strong "hand" with a soft touch.

The gripper has a silicone rubber skeleton with an origami design, wrapped in an airtight, latex rubber skin. When air is sucked out of the gripper, the skin constricts and forces the origami skeleton to collapse into a narrow funnel. The gripper's ridged interior and rough latex skin help it keep ahold of objects. In lab experiments, the gripper picked up household objects of various sizes and shapes, successfully glomming on to a smartphone and the handle of a mug. Whereas rigid robotic hands lack dexterity and might be liable to crush delicate objects, this rubber gripper gently handles fragile items, such as soft fruits and wine glasses.

And unlike other soft robotic hands that struggle with heavy items, the device could lift about 12 kilograms — more than 120 times its own weight. That allowed the gripper to hoist an electric drill and a bottle of wine. Such a versatile gripping machine could one day work on a factory assembly line or lend a hand around the house. Roboticist Shuguang Li of Harvard University and MIT and colleagues will describe the device's performance in May in Montreal at the IEEE International Conference on Robotics and Automation. — *Maria Temming*



CLOCKWISE FROM TOP LEFT: LAWRENCE E. REEVES; JASON DORFMAN/MIT CSAIL; K.P. DINESH

With a brown back, orange belly and bluish-white spots that help it blend in with the forest floor, the newly described starry dwarf frog stayed hidden from scientists for centuries.

INTRODUCING

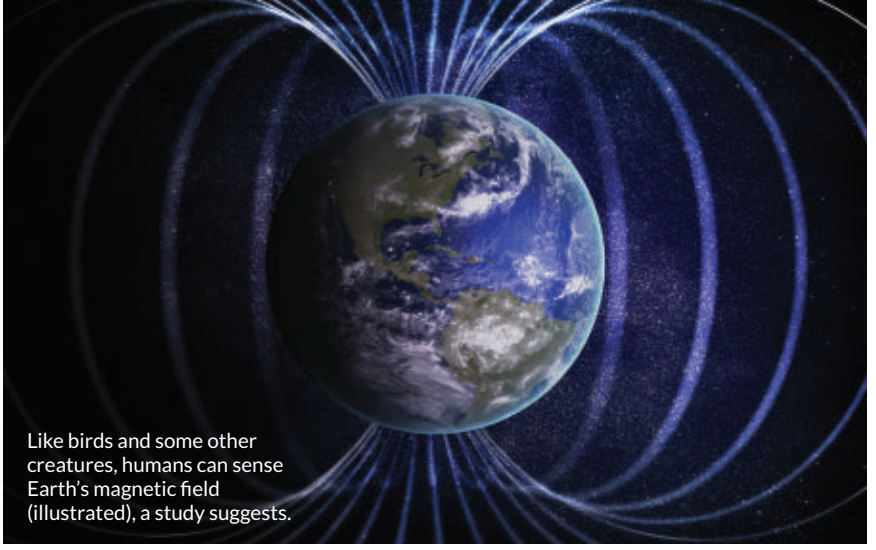
The starry dwarf frog — a species of ancient lineage

A new frog species found in tropical southwest India has been one of a kind for millions of years. Scientists first spotted the species in 2010 while surveying frogs and reptiles in the Western Ghats mountain range, researchers report March 12 in *PeerJ*. The frog hardly stood out — its brown back, orange belly and starlike spots acted as camouflage against the earthy hues and water droplets on the forest floor. About 2 to 3 centimeters long, the frog "can sit on your thumb," says biogeographer Palaniswamy Vijayakumar, who began the work at the Indian Institute of Science in Bangalore and is now a post-doctoral fellow at George Washington University in Washington, D.C. He and his colleagues dubbed it the starry dwarf frog, or *Astrobatrachus kurichiyana*. DNA analysis showed that it's the sole known species of a lineage dating to between 57 million and 76 million years ago. "I had no clue I was holding onto a 50-million-year-old lineage," Vijayakumar says. The frog represents not just a new species and genus but possibly a new family, which the researchers are working to confirm. — *Jeremy Rehm*

BODY & BRAIN

People may sense magnetic fields

Brain waves hint at the ability but offer no clues as to how



Like birds and some other creatures, humans can sense Earth's magnetic field (illustrated), a study suggests.

VCHAL/SHUTTERSTOCK

BY MARIA TEMMING

A new analysis of people's brain waves when surrounded by different magnetic fields suggests that people have a "sixth sense" for magnetism.

Birds, fish and some other creatures can sense Earth's magnetic field and use it for navigation (*SN: 6/14/14, p. 10*). Scientists have long wondered whether humans, too, possess this kind of magnetoreception. Now, by exposing people to an Earth-strength magnetic field pointed in different directions in the lab, researchers from the United States and Japan have discovered distinct brain wave patterns that occur in response to rotating the field in a certain way.

These findings, published online March 18 in *eNeuro*, offer evidence that people subconsciously respond to Earth's magnetic field — although it's not yet clear exactly why or how our brains use this information.

Biophysicist Can Xie says his first impression of the study was, "Wow, I cannot believe it!" Previous tests of human magnetoreception have yielded inconclusive results. This new evidence "is one step forward for the magnetoreception field and probably a big step for the human magnetic sense," says Xie, of Peking University in Beijing.

During the experiment, 26 participants each sat with their eyes closed in a dark, quiet chamber lined with electrical coils. These coils manipulated the magnetic field inside the chamber such that it remained the same strength as Earth's natural field but could be pointed in any direction. Participants wore an EEG cap that recorded the electrical activity of their brains while the surrounding magnetic field rotated in various directions.

This setup simulated the effect of someone turning in different directions in Earth's unchanging field without requiring a participant to move. The researchers compared these EEG readouts with those from control trials where the magnetic field inside the chamber didn't move.

The researchers, neurobiologist and geophysicist Joseph Kirschvink of Caltech and colleagues, focused on alpha waves. Alpha waves generally dominate EEG readings while a person is sitting idle but fade when someone receives sensory input, like a sound or touch.

Sure enough, changes in the magnetic field triggered changes in people's alpha waves. When the magnetic field pointed toward the floor in front of a participant facing north — the direction that Earth's magnetic field points in the Northern Hemisphere — swiveling the field counterclockwise from northeast to northwest triggered an average 25 percent dip in the amplitude of alpha waves. That change was about three times as strong as natural alpha wave fluctuations seen in control trials.

Curiously, people's brains showed no responses to a rotating magnetic field pointed toward the ceiling — the direction of Earth's field in the Southern Hemisphere. Four participants retested weeks or months later showed the same responses.

"It's kind of intriguing to think that we have a sense of which we're not consciously aware," says Peter Hore, a chemist at the University of Oxford who has studied birds' internal compasses but was not involved in the new research. But "extraordinary claims need extraordinary proof, and in this case, that includes being able to reproduce it in a different lab."

If these findings are replicable, they pose several questions — such as why people seem to respond to downward- but not upward-pointing fields. The researchers think they have an answer. "The brain is taking [magnetic] data, pulling it out and only using it if it makes sense," Kirschvink says.

Participants in this study, who all hailed from the Northern Hemisphere, should perceive downward magnetic fields as natural, whereas upward fields would constitute an anomaly, the researchers argue. Magnetoreceptive animals can shut off their internal compasses when encountering weird fields that might lead the animals astray. Northern-dwelling humans may similarly take their magnetic sense "offline" when faced with upward fields.

This explanation "seems plausible," Hore says, but needs to be tested with people from the Southern Hemisphere.

Even accounting for which magnetic changes the brain picks up, researchers still don't know what our minds might use that info for, Kirschvink says. Another lingering mystery is how our brains detect Earth's field. The brain wave patterns may be explained by sensory cells containing a magnetic mineral that has been found in magnetoreceptive trout and in the human brain (*SN: 8/11/12, p. 13*). Future experiments could confirm or eliminate that possibility. ■

Farming cultivated new speech sounds

Shifting to softer foods may have enabled people to say 'f' and 'v'

BY BRUCE BOWER

Humankind's gift of gab is not set in stone, and farming could help explain why.

Over the last 6,000 years or so, farming societies increasingly have replaced tougher-to-chew game meat and wild plants common in hunter-gatherer diets with processed dairy and grain products. Switching to softer foods altered people's jaw structure over time, rendering certain sounds like "f" and "v" easier to utter and changing languages worldwide, scientists contend.

People who regularly chew tough foods experience jaw changes that remove a slight overbite from childhood. But people who grow up eating softer foods retain that overbite into adulthood, say comparative linguist Damián Blasi of the University of Zurich and his colleagues. Computer simulations suggest that adults with an overbite are better able to make certain sounds that require touching the lower lip to the upper teeth, the team reports in the March 15 *Science*.

Linguists classify those speech sounds, found in about half of all current languages, as labiodentals. In reconstructing language change over time among Indo-European tongues, currently spoken from Iceland to India and beyond, Blasi's team found that the likelihood of using labiodentals in those languages rose substantially over the last 6,000 to 7,000 years. That was especially true if foods such as milled grains and dairy products started appearing around that time.

"Labiodental sounds emerged recently in our species and appear more frequently in populations with long traditions of eating soft foods," Blasi said March 12 during a news conference.

Yale University linguist Claire Bowern, who was not involved in the research, agrees. If certain sounds become easier to pronounce, the odds of those sounds getting incorporated into words increases. But changes in how words are actually spoken still may not happen, Bowern says. So evidence of labiodentals' rapid incorporation into many languages comes as a surprise, she says.

Linguists traditionally have thought that humans have always been capable of making all sounds used in the roughly 7,000 languages spoken today. Crucial elements of speech anatomy — such as a larynx, or voice box, positioned low in the neck — evolved in *Homo* species by 500,000 years ago. So when *Homo sapiens* emerged about 300,000 years ago, humans were prepared to talk.

But in 1985, linguist Charles Hockett argued that hunter-gatherer languages virtually never include labiodental sounds. By young adulthood, heavy tooth wear from chewing tough foods results in the upper teeth moving directly on top of the lower teeth, he contended. A resulting "edge-to-edge" tooth arrangement makes it harder to form labiodental sounds, Hockett reasoned. If true, his proposal meant that the introduction of soft foods in farming societies should have safeguarded overbites and raised the likelihood that spoken languages would include labiodentals.

Computer simulations support Hockett's idea. They show that a transition from an edge-to-edge bite to a slight overbite makes it substantially easier to utter labiodental sounds.

What's more, a statistical analysis of languages and lifestyles for more than 2,400 populations around the world found that, on average, hunter-gatherers use about one labiodental sound in their speech for every four spoken by people in societies that produce and process food. A closer examination of hunter-gatherer languages in Greenland, southern Africa and Australia found few instances of labiodental sounds. Historical records indicate that words with labiodental sounds were borrowed during contacts with people from industrialized nations, the researchers say.

A tendency for some commonly mispronounced sounds to become widely used can help explain labiodentals' rapid incorporation into many languages, says evolutionary biologist Mark Pagel of the University of Reading in England. If labiodentals became easier to pronounce relatively recently, making them more likely to be spoken by chance, the sounds could have quickly become embedded in lots of native tongues, he speculates.

Robert Corruccini, a biological anthropologist at Southern Illinois University in Carbondale, says the findings are "fundamentally correct." But human overbite increased much more after the Industrial Revolution, which began in England in the late 1700s, than after the introduction of agriculture, he says.

Industrialized food processing and canning — and perhaps the adoption of forks in Western societies, so that food could be held down with a fork, not gripped with the front teeth, while the other hand cut the food with a knife — played big roles in preserving overbites, Corruccini contends. ■

The skull of an ancient hunter-gatherer (left) lacks the slight overbite seen in a skull from ancient Greece (right). Having an overbite in adulthood has been linked to eating soft, processed foods.

FROM LEFT: MIHAI CONSTANTINESCU, INSTITUTUL DE ANTROPOLOGIE; GIANNI TORTOLI/SCIENCE SOURCE

BODY & BRAIN

New antidepressant raises questions

Long-term effects of a drug based on ketamine are unknown

BY LAURA SANDERS

With great fanfare, a new antidepressant entered the U.S. market in March, the first fundamentally new medicine for depression in decades. Based on the anesthetic ketamine, the drug, called Spravato, is intended to quickly help people with severe depression, taking effect within hours or days instead of the weeks that typical antidepressants take. But for all the hubbub, big questions about the drug have gone unanswered.

Some psychiatrists are concerned that the Food and Drug Administration approved the drug based on skimpy data, under less-rigorous standards than required for previous antidepressants. It remains unclear, for example, whether the drug has negative effects when taken long-term or what happens when someone stops taking it.

The data on Spravato raise more questions than they answer, says psychiatrist Alan Schatzberg of Stanford University. "And I think that's unfortunate."

Still, many psychiatrists are relieved to have another drug to try. Spravato "does something that very few things in psychiatry can do — it works for people who didn't respond to other treatments, and it works fast," says psychiatrist Dan Iosifescu of New York University School of Medicine.

Ketamine-based Spravato can quickly ease severe depression for people who have not found success with other treatments.

Old drug, new use

Ketamine, an anesthetic that's been used for decades, comprises two mirror image molecules: esketamine and arketamine. Spravato, a nasal spray developed by Janssen Pharmaceuticals, is made of esketamine. Some people abuse ketamine, in part for the floating sensation it produces. Similar worries about esketamine being used illicitly prompted the FDA to put tight controls over the drug, which can cause hallucinations, sedation and dizziness.

In the weeks since the FDA approved Spravato, receptionists at the clinics of Gerard Sanacora, a translational neuroscientist at Yale School of Medicine, are answering "dozens of phone calls every day" from people eager for Spravato's promise of quick relief. But "this is not a medicine for everybody," says Sanacora, who has consulted for Janssen. Spravato, which is intended to be used with another antidepressant, was approved for use only in people who have not gotten relief from at least two other treatments. Roughly 5 million people in the United States live with this type of severe depression.

Because the drug is liable to be abused, and due to its potential side effects, Spravato can be taken only in a clinic, where patients will be monitored for several hours after their dose.

Those rules were also set because Spravato has largely been tested in people with severe depression and results of its effectiveness have been mixed. So far, three one-month clinical trials have been conducted in which patients were randomly assigned to receive either the drug or a placebo; neither patients nor doctors knew who belonged to which group. In two of the trials, patients didn't get any better on the drug than on the placebo.

In the third trial, which included 224 people, participants had their depression symptoms improve after a four-week stint of taking Spravato twice a week. That improvement held up to standard statistical analyses, but it wasn't huge. The researchers measured depression on a 60-point scale, with lower numbers being better. Over the month of the study, people who took the placebo had scores that dropped by 15.8 points on average; people who took esketamine beat the placebo group by four points, with scores dropping an average of 19.8 points.

In the past, the FDA has required that at least two short-term studies show that an antidepressant was effective. With Spravato, those requirements were loosened, says Erick Turner, a psychiatrist at Oregon Health and Science University in Portland. This time, the extra evidence for the drug's approval came from a longer-term study that kept half of its participants on esketamine and switched half to a placebo. That clinical trial, however, included some of the same people who responded positively to esketamine in the shorter trials. "It's cherry-picking" the study sample, says Turner, who is a member of an FDA advisory committee that approves new psychiatric drugs. He did not participate in Spravato's approval.

Unanswered questions

That longer-term study, which spanned over a year, found that 39 of 86 people, or 45 percent, who had been switched to a placebo after taking esketamine for four months relapsed on their depression scores. In contrast, 24 of 90 people, or 27 percent, relapsed while continuing to receive esketamine. Those relapses in people who switched to a placebo are concerning, Schatzberg says. "Doesn't that say something about coming off the drug? What are we going to do in practice, just keep people on the drug forever?"

Three of the patients who had received esketamine in the trials died by suicide four, 12 and 20 days after the patients' last doses of the drug.

In a March 20 statement to *Science News*, Janssen Pharmaceuticals noted that the suicides took place during a part of the clinical trials that did not include a comparison group of people who didn't receive esketamine. The company says that most of the suicide events were determined to have been caused by the severe depression — not the drug.

Schatzberg disagrees, saying that stopping the drug may very well have had something to do with the suicides. "Are you inducing some sort of dependence? And when you get the people off, they feel lousy and could become suicidal?"

JANSSEN PHARMACEUTICALS, INC.

Scientists think long-term ketamine use might harm the brain. Here, the brain of a person who abused ketamine for four years shows signs of shrinkage (arrow), though this damage could have been caused by other factors.

he asks. "That, to me, is a worry."

What's more, the lack of long-term data on the drug's effects raises hard questions about what to do after esketamine treatment has started. "There is very, very, very little data for what happens after a lot of ketamine use," Iosifescu says.

The data that do exist are concerning. MRI scans of people who have abused ketamine for a long time reveal brain damage (though other factors could be sources of that damage). Animal studies show ketamine-induced brain damage, too. But not much is known about esketamine's long-term effects in people taking it for depression. "If you take ketamine for too long — and it's unclear what too long is — that's going to be a problem," Iosifescu says. "Nobody can really tell you where this boundary is."

Moving ahead

As more is learned about how ketamine and esketamine alleviate depression, scientists may come up with other drugs that are perhaps less concerning. Carlos Zarate Jr., a clinical neuroscientist at the National Institute of Mental Health in Bethesda, Md., helped make some of the early discoveries about ketamine's fast antidepressant effects. These days, he is studying a molecule that's made when ketamine gets broken down in the body. Tests in animals hint that this molecule has rapid antidepressant properties without ketamine's baggage.

But Zarate is circumspect: "We still aren't really sure what the key targets are in depression." Ketamine and esketamine, many scientists suspect, work by spurring brain cells to release a chemical messenger called glutamate, which might spur nerve cell connections to form. But a small study by Schatzberg and colleagues suggested that ketamine's antidepressant effects somehow work through the body's opioid system. That's a contested idea, but it hints that ketamine may be addictive in a way similar to opioids.

For now, clinicians and patients are moving forward without all of the answers. Ultimately, "it's not about being a fan of ketamine or a hater of ketamine," Iosifescu says. "It's about understanding what is it good for." ■

BODY & BRAIN

Sound, light may fight Alzheimer's

Plaques shrank in mice's brains after clicks and flashes

BY LAURA SANDERS

Fast clicking sounds can boost brainpower in mice with signs of Alzheimer's disease. Like flickering lights, these external sounds spur a type of brain wave that seemed to sweep disease-related plaques from mice's brains, researchers report in the March 14 *Cell*.

It's too early to say whether flickers and clicks could help people with Alzheimer's. If so, the treatment would represent a fundamentally new way to target the neurodegenerative disease.

An earlier study by MIT neuroscientist Li-Huei Tsai and colleagues focused on the eyes. Lights that flickered exactly 40 times a second kicked off gamma waves, a brain wave thought to happen during concentration. In mice, the brain waves seemed to somehow reduce amyloid-beta, a protein that piles up in the brains of Alzheimer's patients (*SN: 1/21/17, p. 13*). But A-beta was reduced only in the part of the brain that handles vision — an area not thought to be key to Alzheimer's progression.

Sounds that hum at a rate of 40 clicks per second, or 40 hertz, also spur gamma waves that appeared to clear mice's A-beta, Tsai and colleagues now find. But that happens in a more relevant brain area: the hippocampus, which is involved in memory and affected by Alzheimer's.

A daily hour of fast clicks for a week also improved the memories of mice genetically engineered to have signs of Alzheimer's. Compared with mice that heard randomly spaced clicks, mice that listened to 40-hertz clicks found a hidden platform in a water maze faster and better recognized a previously seen object.

"That's a very exciting finding, that it can actually affect cognition," says neuroscientist Tara Tracy of the Buck Institute for Research on Aging in Novato, Calif.

Sound-triggered gamma waves appear to kick off other beneficial changes, too. Brain levels of a harmful form of tau, another protein implicated in Alzheimer's, dropped, and blood vessels in the brain expanded, perhaps easing A-beta's disposal. Immune cells called microglia also grew more active, attacking A-beta.

When mice were treated with both flickering lights and clicks, the effect was even stronger, Tsai says. There were fewer A-beta plaques across a big stretch of the brain, including the hippocampus and the prefrontal cortex, an area important for complex thinking. And microglia swarmed into a feeding frenzy. "Microglia pile up on each other, all congregated around the amyloid plaques," Tsai says.

It's not yet clear how increasing gamma waves led to these effects. "How is this particular stimulation affecting all of these properties?" Tracy asks.

Also unknown is whether results from mice that mimic a rare and aggressive form of Alzheimer's apply to people. Tsai has cofounded a company, Cognito Therapeutics, that is testing the light-and-sound approach in older people with mild to moderate cognitive impairment. So far, Tsai says, "we haven't seen any undesirable effects." ■

C. WANG ET AL/FRONTIERS IN NEUROANATOMY 2013

ATOM & COSMOS

Bennu spits streams of dust into space

Scientists have never seen this activity on an asteroid before

Asteroid Bennu is shown from multiple views in these photos taken by OSIRIS-REx.

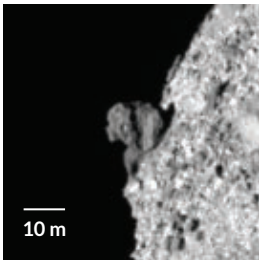
BY LISA GROSSMAN

Like the "Peanuts" character Pig Pen, the near-Earth asteroid Bennu moves around in a cloud of its own dust.

NASA's OSIRIS-REx has watched Bennu spit out plumes of dust 11 times since the spacecraft arrived at the asteroid in December 2018. And some of that dust is caught in orbit around the asteroid, scientists announced March 19 at the Lunar and Planetary Science Conference. It's the first time astronomers have spotted such activity on an asteroid.

"We did not expect to see this," said OSIRIS-REx principal investigator Dante Lauretta of the University of Arizona in Tucson. "We are probably seeing a new kind of activity at asteroid Bennu."

While this result has planetary scientists excited, the overall news from Bennu is mixed. OSIRIS-REx's primary mission is to collect dust from the asteroid in 2020 and bring it back to Earth in 2023, in hopes that the rubbly, water-rich asteroid holds clues to the origins of life in the solar system (*SN: 1/19/19, p. 20*). But that job may prove tricky. In a series of seven studies released March 19 in *Nature* journals, the OSIRIS-REx team reports that the space rock is a minefield of boulders much bigger than the craft was designed to navigate.



Bennu has more than 200 big boulders (one shown) strewn across its surface. These rocks pose a challenge for the OSIRIS-REx mission.

"It's not necessarily completely unexpected," says planetary scientist Daniella DellaGiustina, also of the University of Arizona. "But it does pose a harder challenge than we had planned for."

OSIRIS-REx arrived at the asteroid on December 3, when the rock was about 130 million kilometers away from Earth (*SN Online: 12/3/18*). To researchers' surprise, OSIRIS-REx's navigation cameras picked up several bright spots floating near the asteroid on January 6.

Analyzing the spots revealed that they were eruptions of dust particles from Bennu's surface. The particles were ejected at speeds between a few centimeters per second and 3 meters per second. Some of the dust is flying off into space, but some is getting caught in orbit around Bennu, Lauretta said.

"I'm amazed," says planetary scientist William McKinnon of Washington University in St. Louis, who is not part of the OSIRIS-REx team. "I've never heard of this before. That's the coolest thing so far."

Lauretta and colleagues aren't sure what causes the plumes. One idea is that Bennu's subsurface contains volatile gases, which escape from the rock as the sun heats them and push out plumes of dust in the process. If so, Bennu may have reached its position relatively recently, though it's unclear exactly when. Because the asteroid was probably born farther from the sun in the asteroid belt between Mars and Jupiter, Bennu probably would have lost those volatiles had it wandered into the inner solar system a long time ago, the scientists say.

The team doesn't think that the dust poses a danger to the spacecraft. But Bennu's surface might.

The plan was for the craft to briefly land in a region at least 50 meters wide, where a vacuumlike instrument would collect dust particles no larger than 2 centimeters across. But there are no clear regions that are wide enough on Bennu's surface. Most of the asteroid is a boulder field, and the widest areas of small, sandy particles span just 20 meters. The team is working on adjusting its plans to successfully grab the goods from a smaller area.

"We do have sampleable material on this asteroid," DellaGiustina says. "It's not a wonderful sandy asteroid full of these centimeter-scale particles that we were hoping for, but it is a workable situation."

Another asteroid sample return mission may offer more hope. The Japanese Hayabusa2 mission is also exploring a boulder-covered asteroid, called Ryugu (see Page 11). And Hayabusa2 seems to have taken a sample of material on February 21 (*SN Online: 2/22/19*). "That gives us a lot of confidence," says DellaGiustina. The OSIRIS-REx team plans to meet with the Hayabusa2 team to see what lessons can be learned. ■

FROM TOP: NASA, JHUAPL, SWRI, ESA; D.S. LAURETTA *ET AL*/*NATURE* 2019

ATOM & COSMOS

Ultima Thule may be a Frankenworld

Astronomers are unraveling the distant space rock's origins

BY LISA GROSSMAN

Ultima Thule's history may be written in the sum of its parts.

New analyses suggest that the tiny space rock formed from a rotating cloud of even smaller rocks that collapsed into two individual objects. Those objects then gently collided in the early days of the solar system, creating the distant double-lobed world, researchers reported March 18 at the Lunar and Planetary Science Conference.

NASA's New Horizons spacecraft flew by Ultima Thule, officially known as MU69, on January 1. The first images that the spacecraft sent back suggested a snowman-shaped world, with a larger lobe that the team dubbed "Ultima" and a slightly smaller bulb called "Thule" (*SN: 2/2/19, p. 7*). But subsequent images showed that the lobes look more like flat pancakes or hamburgers than spherical snowballs (*SN: 3/16/19, p. 15*).

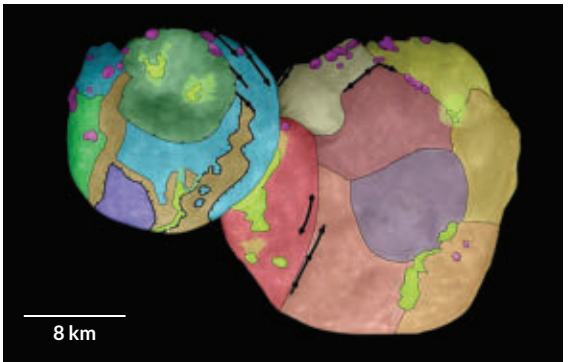
The first map of the space rock's geology may help explain that flatness. The map shows distinct mounds on both lobes whose borders are still visible today, planetary scientist Jeff Moore said at the meeting. Moore, of NASA's Ames Research Center at Moffett Field, Calif., and colleagues think that those mounds represent small or medium-sized rocks that organized themselves into a rotating disk before merging into two separate lobes that then collided. That rotation could have spread out material in a lobe, flattening it. "The disk was spinning ... and that's why we have the hamburger shape," Moore said.

Planetary scientist William McKinnon of Washington University in St. Louis agrees, though he adds that "this has not been proven." McKinnon presented computer simulations of the final collision between Ultima and Thule that showed that the two must have been moving at about 2 meters per second when they collided. That's like a person walking into a wall at a brisk pace, McKinnon said.

That gentle crash, along with the Frankenstein body, suggests that planetesimals like Ultima Thule form from clouds of dust and rock clumping together under the force of their own gravity. Before New Horizons, it wasn't clear if such protoplanets formed from cloud clumping or from small rocks slowly sticking together to form larger ones over time.

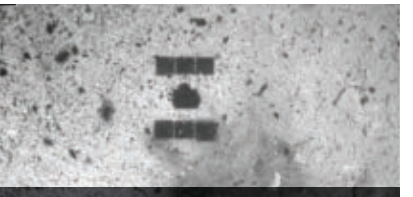
Planetary scientist David Nesvorny of the Southwest Research Institute in Boulder, Colo., says it's "plausible" that clouds of rotating pebbles could have coalesced into Ultima Thule's two lobes. He and colleagues suggested in 2010 that collapsing clouds of small rocks in the Kuiper Belt — the distant zone of cold, primitive space rocks beyond Neptune's orbit where Ultima Thule lives — could form close pairs of objects.

But the idea may not explain Ultima Thule's flatness. "In my simulations back in 2010, I produced a lot of spheres," Nesvorny says. Other researchers will now have to do new simulations to find out whether these rotating disks can lead to flat pancakes, he says. ■



In this preliminary map of Ultima Thule's geology, each color represents what appears to be a different section of the space rock. Some researchers hypothesize that these sections are the pieces of rock that came together to form Ultima Thule.

FROM TOP: JAXA, UNIV. OF TOKYO, KOCHI UNIV., RIKKYO UNIV., NAGOYA UNIV., CHIBA INST. OF TECHNOLOGY, MEIJI UNIV., UNIV. OF AIZU, AIST; NASA, JHUAPL, SWRI, ESA



The Hayabusa2 spacecraft (shadow visible here) took this picture of the asteroid Ryugu on February 22.

MEETING NOTE

Ryugu probably came from one of two other asteroids

The asteroid Ryugu is a chip off the old block. Planetary scientists from the Japanese Hayabusa2 spacecraft team have narrowed down the near-Earth asteroid's parent body to one of two larger, more distant asteroids: Polana and Eulalia.

"Based on links to those specific asteroids, we can talk about the longer history of Ryugu," Seiji Sugita of the University of Tokyo said March 19 during a news conference at the Lunar and Planetary Science Conference.

Ryugu's rubble-pile nature and small size, about 900 meters across, suggest that the asteroid formed after the breakup of a larger body hundreds of millions of years ago. Based on its orbit, astronomers think Ryugu came from the inner part of the solar system's main asteroid belt, between Mars and Jupiter. But it was hard to narrow down the origins any further until Hayabusa2 arrived at the asteroid in 2018. The spacecraft showed that Ryugu is uniformly dark, one of the darkest known objects in the solar system. Its color best matches that of main belt asteroids Polana and Eulalia, Sugita said.

The real test will come when Hayabusa2 returns asteroid samples to Earth in 2020, and scientists can determine the space rock's age (*SN: 1/19/19, p. 20*). An older Ryugu would suggest that the more ancient Polana is the parent; a younger sample would point to Eulalia. — *Lisa Grossman*

GENES & CELLS

Ban on gene-edited babies proposed

Temporary moratorium would allow for further scientific testing

BY TINA HESMAN SAEY

Eighteen researchers, including two CRISPR pioneers, are calling for a temporary ban on creating gene-edited babies.

"We call for a global moratorium on all clinical uses of human germline editing — that is, changing heritable DNA (in sperm, eggs or embryos) to make genetically modified children," the statement's cosigners, who come from seven countries, wrote in the March 14 *Nature*.

Among the signatories are CRISPR pioneers Feng Zhang of the Broad Institute of MIT and Harvard University and Emmanuelle Charpentier of the Max Planck Unit for the Science of Pathogens in Berlin.

The proposed moratorium would last about five years to give time for public education and debate about experiments. The delay would buy time for scientists to further test and refine CRISPR/Cas9 and other gene-editing tools to make them safer. The moratorium would also be voluntary, with a country pledging individually not to allow clinical trials for creating gene-edited children. Countries would make independent decisions on how long such a ban should last.

Gene editing of embryos, eggs and sperm would still be allowed for research purposes, but they couldn't be used to establish a pregnancy. Researchers could still use gene editors to treat genetic diseases in adults and children, provided that any changes couldn't be passed on to the next generation.

Some scientists and ethicists have previously called making gene-edited babies "irresponsible." A 2017 report commissioned by the U.S. National Academies of Sciences and Medicine (*SN: 3/18/17, p. 7*), plus two international conferences on genome editing in 2015 and 2018 (*SN: 12/26/15, p. 12*; *SN: 12/22/18 & 1/5/19, p. 20*), concluded that heritable gene editing is not ready for clinical use and should wait until the technology matures and there's public consensus on it.

The big difference now is the term "moratorium," says bioethicist Alta Charo of the University of Wisconsin–Madison Law School. "In which case, there is no real daylight, only a dictionary, between the authors of the *Nature* essay and the reports and summit statements made to date."

Still, those previous admonitions didn't stop Chinese scientist Jiankui He from editing embryos that resulted in the birth of two babies last year. Other researchers who knew about He's plans didn't stop him.

"Given that both conferences declared as irresponsible this kind of experiment, but in fact, it went ahead, says that we needed a little bit more than just clucking at the end of things," says Paul Berg, a molecular geneticist at Stanford University School of Medicine.

Berg, who helped author the new proposal, admits the call is mostly a matter of semantics but argues that word choice matters. "If everyone is saying it would be irresponsible to do it, then why not be explicit and say it should not be done?"

Other scientists aren't sure the proposed moratorium will stop rogue scientists from copying He's actions. "I don't think someone will say, 'Oh, someone said moratorium, I really can't do that now,'" says Stephan Guttinger, a philosopher of biology at the London School of Economics and Political Science.

But Russ Altman, a bioengineer at Stanford University, says it may be easier to get a moratorium to stick after He's breach. "It will be harder to find a harbor of safety" for researchers who violate the ban, Altman says. "Now a ban will have a bigger weight of scientific credibility and would be more likely to be obeyed."

A moratorium, he says, would have "the force of moral authority," even if it doesn't have legal weight. ■

Editor's Note: Feng Zhang is on the Board of Trustees of Society for Science & the Public, which publishes Science News.

Among wild chimpanzees, breaking open nuts with a stone hammer is seen only in Africa's westernmost groups.

LIFE & EVOLUTION

Chimp traditions are under threat

Human encroachment may endanger cultural behaviors

BY SUJATA GUPTA

From deep inside chimpanzee territory, the fieldworkers heard loud bangs and shouts. Hidden video cameras later revealed what the chimps in the Boé region of Guinea-Bissau were up to. Males were throwing rocks at trees and yelling.

Researchers don't fully understand why the apes engage in this rare behavior. And scientists may not have much time to sort out what's going on.

Africa's chimpanzees are under threat from deforestation and poaching. Those and other human activities may also be affecting chimp behaviors, Ammie Kalan and colleagues report online March 7 in *Science*. These behaviors include ones that many primatologists view as evidence of chimp culture — behaviors that are learned socially and transmitted through generations.

Such traditions as cave dwelling, using sticks to dig for honey and cracking nuts with stones are far less likely to occur in areas most impacted by humans, compared with more remote chimp territories, the researchers found in a large analysis of chimp behavior.

"Everyone thinks that if populations are declining... there would be some loss in the transmission chain that leads to

cultural diversity in animals," says Kalan, of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. "We're the first to really show this."

Her group set out to test the idea that disturbances, including population loss, resource depletion and habitat fragmentation, limit opportunities for social learning to occur. As a result, certain cultural traditions will die out before the species itself.

Starting in 2010, Max Planck researchers began installing automated video cameras at 46 chimpanzee sites in 15 countries and, with the help of citizen scientists, sifted through millions of short clips to identify thousands of chimp videos. The team also surveyed those sites for signs of tool use, feeding remains and fecal samples to see what the animals were eating.

The researchers also combed through about 450 studies from 1951 to 2017 that documented chimp behavior. The final analysis included 144 chimpanzee communities and 31 potentially cultural behaviors, such as using moss as a sponge, using sticks to fish for algae and, of course, hurtling rocks at trees.

The team then sought to quantify the human impact on each chimp community with data from a project that uses satellite images to estimate the impact of infrastructure, human population density, forest cover and remoteness. With a resolution of 1 square kilometer — chimp communities typically span 25 to 100 square kilometers — those images provide a detailed snapshot of the chimps' living situations.

The 31 chimp behaviors were 88 percent less likely, on average, to occur in the areas more affected by human activities compared with the least affected areas. The findings don't directly prove that human activity affected chimp behavior, but the results do support the disturbance hypothesis, says primatologist Carel van Schaik of the University of Zurich, who proposed the idea in 2002.

His own recent work with orangutans suggests that such behaviors can be vital to survival, with the loss of key individuals leading to rapid losses in skills. Culture is not some kind of luxury for the great apes, he says. It's "an intrinsic and essential part of their local adaptation."

Primatologist Andrew Whiten of the University of St. Andrews in Scotland agrees that culture can be crucial to survival, especially for endangered species. "Animal culture matters for conservation," he says. He coauthored a paper in the March 8 *Science* that looks at modes of cultural transmission across the animal kingdom — including among chimps, whales, birds and elephants — and the often dire consequences of breaking those knowledge chains.

Kalan and colleagues are urging conservationists to create preserves around chimp communities that show unique behaviors. Such sites could protect chimpanzee behavioral diversity, Kalan says. ■

LIFE & EVOLUTION

Some male bees pitch in to babysit

Hanging around a nest may be a way to father some young

BY SUSAN MILIUS

Scientists have discovered the first known case of male bees babysitting, and it turns out that these males often aren't biological dads but hopeful stepdads of the young.

Females of a small Mediterranean bee, *Ceratina nigrolabiata*, dig out the pith of plant stems to make a nest and lay eggs. These bees have no colony of daughter-workers. Without that help, mom must collect nectar and pollen to feed her young. But these are no latchkey larvae.

In 78 nests that researchers watched for 90 minutes, an adult male bee stayed in the nest's entrance, rump outward, while the mom was out foraging. A male blocked a menacing ant that researchers put at the entrance in all of 41 attempted attacks. More than half the time, males pushed the ant out of the nest, says behavioral ecologist Michael Mikát of Charles University in Prague.

When mom buzzes back with food, she scratches against the male's rump to get into the nest. Then he goes back to being a dad door, or rather, a stepdad door. In 265 nests sampled, only 29 percent of the babysitting males had fathered even one of the offspring they were guarding, Mikát and colleagues report online March 11 in the *Proceedings of the National Academy of Sciences*.

This behavior isn't selflessness. The longer a male hangs around a female and her nest, the more likely he is to sire one of her young, the researchers found.

Female *C. nigrolabiata* bees can mate at multiple points throughout the nesting season, unlike honeybees. So a male hanging around while a female is building her nest and laying eggs can still end up with one or more offspring. In terms of evolution, care for the offspring arises as a "side effect" of males looking to mate with a female while guarding her against rivals, Mikát says. Even so, males rarely stay with the same female for the entire time a nest develops.

A male *Ceratina nigrolabiata* bee (one shown inside the stem) eager to mate with a female will watch her young while she is foraging.

LUKÁŠ JANOŠIK

Animal behaviorist Stephen Trumbo of the University of Connecticut's campus in Waterbury notes that other insects have also evolved two-parent care. Some small bark beetles, for example, drill a hole in a tree, where a male and female grow fungal food and raise young. Like the bee nest, the farmstead has just one entrance. Trumbo wonders if even an elaborate nuclear family like that could have started as happenstance babysitting of hopeful males. ■

Today the Tibetan Plateau in central and eastern Asia sits at an average elevation of 4.5 kilometers above sea level.

EARTH & ENVIRONMENT

Tibetan Plateau isn't as old as thought

World's 'roof' reached current height after 25 million years ago

BY CAROLYN GRAMLING

A plant fossil discovered in rocks from the Tibetan Plateau and a new analysis of the area's geochemistry are rewriting the uplift history of the region dubbed the "roof of the world." And this research suggests that the story of the rise is far more complicated than just raising the roof.

Previous studies had suggested that the plateau reached its current height, about 4.5 kilometers above sea level, on average, by at least 40 million years ago. But chemical evidence left in the region's rocks indicates the rise couldn't have happened before about 40 million years ago, researchers report in the March 1 *Science*.

Another team reports that as recently as 25 million years ago, the region wasn't yet a flat, windswept plateau. Instead, the area was a diverse landscape of steep mountains surrounding a deep valley where palm trees grew, the team says March 6 in *Science Advances*.

Scientists want to pinpoint the timing of the rise in large part because the Tibetan Plateau has had such a profound effect on climate. The plateau altered atmospheric patterns, causing the onset of monsoons in South Asia and the drying out of Asia's interior, says paleoclimatologist Svetlana Botsyun of the University of Tübingen in Germany. In fact, the plateau is so tall that it affects the atmosphere globally, altering temperature, precipitation, humidity and cloud cover, she says.

About 55 million years ago, the Indian subcontinent rammed northward into Asia, and the land between them buckled. The Himalaya mountain range was born, and the Tibetan Plateau north of the mountains was pushed upward.

One method to estimate how long that uplift took is paleoaltimetry, which uses oxygen isotopes to estimate changes in elevation over time. At higher elevations, the ratio of oxygen-16 to oxygen-18 in rainfall is higher than at lower elevations. Previous studies of oxygen isotopes preserved in carbonate rocks, along with the rocks' ages, suggested that the plateau must have been more than 4 kilometers high by at least 40 million years ago.

Botsyun and colleagues call that estimate into question. Factors other than elevation — such as changes in atmospheric carbon dioxide concentrations or different sources of the water that becomes rain — also affect oxygen isotope ratios in rainfall, Botsyun notes.

Those factors were at play in the Eocene, about 56 million to 34 million years ago. The epoch had much higher atmospheric CO_2 levels than today, a wide, shallow sea covered parts of China, and India wasn't quite where it is now.

Botsyun's team took these factors into account in a series of computer simulations to re-create atmospheric circulation during the Eocene and then recalculated the oxygen isotope ratios. "We can't tell when the uplift [did] happen," Botsyun says. But the results suggest that, by 40 million years ago, the plateau was no higher than 3 kilometers above sea level.

That timing gels with the age of a fossilized palm tree leaf found in the central Tibetan Plateau. Paleobotanist Tao Su of the Chinese Academy of Sciences in Mengla and colleagues dated the fossil to about 25 million years ago. Based on the ability of the plant's living relatives — all tropical and subtropical species — to tolerate cold, the team concludes that, at the time, the region couldn't have been more than about 2.3 kilometers above sea level.

The team also suggests that the region wasn't a high, flat plateau yet. Instead, the palm tree lived in a valley surrounded by high mountain ranges to the north and south. That conclusion is based on simulations of past climate that varied the topography of the region and incorporated previous estimates of temperature based on leaf fossils at sites near where the palm tree fossil was found.

What we think of as the Tibetan Plateau is actually a jigsaw of tectonic blocks of land, each with its own elevation history, says Robert Spicer, one of Su's collaborators. By the time India began its collision, parts of what is now the plateau were already as high as 4.5 kilometers above sea level, says Spicer, an earth scientist at the Open University in Milton Keynes, England.

The valley in which the tree lived existed from about 60 million to at least 20 million years ago, he says. Other fossil finds suggest that the valley was home to a diverse subtropical ecosystem. But as the collision of India and Asia went on, the land continued to rise, and sediment eroded from the mountains filled in the valley, forming a tall, flat plateau, he says.

The fossil- and isotope-derived elevations agree on a key point: The central part of what's now the Tibetan Plateau rose to its current height later than once thought, Spicer says. But to really understand the history of the plateau, paleoaltimetry needs to incorporate the geologic history of the region, he adds. "You need to get the topography right. If you have the wrong Tibetan geometry, you cannot produce realistic results."

Botsyun agrees. Adding in a deep valley landscape to her simulations "would be really interesting," she says. ■

T. SU

LIFE & EVOLUTION

In a first, a fossilized egg is found preserved inside an ancient bird

About 110 million years ago in what is now China, a sparrow-sized bird died with an egg still inside her body. Crushed and flattened by pressure over time, it is the first unlaid bird egg known to be preserved in a fossil, researchers report March 20 in *Nature Communications*.

Paleontologists led by Alida Bailleul of the Key Laboratory of Vertebrate Evolution and Human Origins in Beijing noticed something odd when they looked closely at the fossil: The bird had a strange sheet of tissue between her pubic bones. Examining the tissue under a microscope revealed that it was part of an egg.

All was not well with this bird, a new species named *Avimaia schweitzerae*, and her egg. The eggshell has two layers, not the usual one, suggesting that the egg remained too long in the abdomen. And the egg's layers are very thin. In modern birds, particularly small birds under extreme stress, these symptoms can indicate a deadly condition in which a bird can't lay the egg. The team suggests that the unlaid egg may have ultimately killed the mother. — *Carolyn Gramling*

A. M. BAILLEUL ET AL/NATURE COMMUNICATIONS 2019

This ancient bird, *Avimaia schweitzerae*, died about 110 million years ago with an unlaid egg (arrow) inside her abdomen.

ATOM & COSMOS

Big solar storm hit Earth in 660 B.C.

One of the strongest solar storms ever to hurtle toward Earth blasted the planet in 660 B.C., researchers report online March 11 in the *Proceedings of the National Academy of Sciences*.

The sun's shifting magnetic field can release bursts of charged particles into space. In the most extreme solar storms, called solar proton events, these charged particles are sped up by interactions with other solar emissions: solar flares or coronal mass ejections. Even Earth's protective magnetic field can't deflect such swift, energetic particle streams.

To look for these events in the distant past, researchers hunt for tree rings or ice cores with spikes in cosmogenic radionuclides, which form when cosmic rays interact with molecules in Earth's atmosphere.

In 2017, scientists identified a sudden increase in the radionuclide carbon-14 in tree rings dating to about 660 B.C. But a carbon-14 spike could also signal a supernova or a solar flare. In the new study, a team led by geologist Paschal O'Hare, now at Heathgate Resources in Adelaide, Australia, has found the radionuclides beryllium-10 and chlorine-36 in two Greenland ice cores dating to the same time.

The relative abundance of the radionuclides in the ice suggests that the 660 B.C. event was about 10 times as powerful as a 1956 event, the strongest solar storm recorded by modern instruments. The only known solar storm to rival the ancient storm's power occurred in A.D. 774–775. — *Carolyn Gramling*

MATTER & ENERGY

Atomic clocks put Einstein's special relativity to the test

The ticktock of two ultraprecise clocks has proven Einstein right, once again.

A pair of atomic clocks made of single ions of ytterbium kept pace with one another over six months, scientists report in the March 14 *Nature*. That reliability supports a principle known as Lorentz symmetry. The principle is the foundation for Einstein's special theory of relativity, which describes the physics of voyagers dashing along at nearly the speed of light.

Lorentz symmetry states that the rules of physics should remain the same whether you're standing still or moving at a breakneck speed, and no matter what direction you're facing.

The two ytterbium ions (positively charged atoms) absorbed and emitted light at a particular frequency, functioning like the ticking of a clock hand. The ions, which were oriented in different directions, rotated as the Earth turned, making a full cycle each day. If the ticks had varied based on the ions' orientation in space, the experiment would have revealed a daily variation in the relative frequencies from the two clocks — a violation of Lorentz symmetry. But the clocks agreed within about a tenth of a quadrillionth of a percent, confirming with about 100 times the precision of previous tests that Lorentz symmetry holds. — *Emily Conover*

MATTER & ENERGY

Tiny electronics reach a record low

BOSTON — Today's nanoelectronics weather forecast: positively frigid.

Tiny electronic chips have been cooled to a record low temperature, dipping below a thousandth of a kelvin for the first time ever, scientists reported March 6 at a meeting of the American Physical Society.

Nikolai Yurttagül of Delft University of Technology in the Netherlands and colleagues incorporated into the chips tiny bits of metal that act like magnetic refrigerators. When the team ramped magnetic fields up and down, the metal helped cool the chips' electrons to less than half a thousandth of a kelvin.

Getting electronic chips to supercold conditions should bolster certain applications, such as quantum computing, in which scientists make calculations by harnessing the physics of the atomic world. Warm conditions cause particles to jostle, muddling their quantum properties. Many quantum computers are cooled, typically by devices known as dilution refrigerators that can reach a few thousandths of a kelvin. But even lower temperatures could allow particles to retain their quantum properties for longer. — *Emily Conover*

ARCTIC BROWNING

Warming trends bring insects, extreme weather and wildfires to land that had been going green

By Hannah Hoag

In southern Alaska in 2012, geometrid moths and other insects heavily defoliated alder bushes and other shrubs (brown patches in this aerial photo).

U.S. FOREST SERVICE

The Chugach people of southern Alaska's Kenai Peninsula have picked berries for generations. Tart blueberries and sweet, raspberry-like salmonberries — an Alaska favorite — are baked into pies and boiled into jams. But in the summer of 2009, the bushes stayed brown and the berries never came.

For three more years, harvests failed. "It hit the communities very hard," says Nathan Lojewski, the forestry manager for Chugachmiut, a nonprofit tribal consortium for seven villages in the Chugach region.

The berry bushes had been ravaged by caterpillars of geometrid moths — the Bruce spanworm (*Operophtera bruceata*) and the autumnal moth (*Epirrita autumnata*). The insects had laid their eggs in the fall, and as soon as the leaf buds began growing in the spring, the eggs hatched and the inchworms nibbled the stalks bare.

Chugach elders had no traditional knowledge of an outbreak on this scale in the region, even though the insects were known in Alaska. "These berries were incredibly important. There would have been a story, something in the oral history," Lojewski says. "As far as the tribe was concerned, this had not happened before."

At the peak of the multiyear outbreak, the caterpillars climbed from the berry bushes into trees. The pests munched through foliage from Port Graham, at the tip of the Kenai Peninsula, to Wasilla, north of Anchorage, about 300 kilometers away. In summer, thick brown-gray layers of denuded willows, alders and birches lined the mountainsides above stretches of Sitka spruce.

Two summers ago, almost a decade after the first infestation, the moths returned. "We got a few berries, but not as many as we used to," says Chugach elder Ephim Moonin Sr., whose house in the village of Nanwalek is flanked by tall salmonberry bushes. "Last year, again, there were hardly any berries."

For more than 35 years, satellites circling the Arctic have detected a "greening" trend in Earth's northernmost landscapes. Scientists have attributed this verdant flush to more vigorous plant growth and a longer growing season, propelled by higher temperatures that come with climate change. But recently, satellites have been picking up a decline in tundra greenness in some parts of the Arctic. Those areas appear to be "browning."

Like the salmonberry harvesters on the Kenai Peninsula, ecologists working on the ground have witnessed browning up close at field sites across the circumpolar Arctic, from Alaska to Greenland to northern Norway and Sweden. Yet the bushes bereft of berries and the tinder-dry heaths (low-growing shrubland) haven't always been picked up by the satellites. The low-resolution sensors may have averaged out the mix of dead and living vegetation and failed to detect the browning.

Scientists are left to wonder what is and isn't being detected, and they're concerned about the potential impact of not knowing the extent of the browning. If it becomes widespread, Arctic browning could have far-reaching consequences for people and wildlife, affecting habitat and atmospheric carbon uptake and boosting wildfire risk.

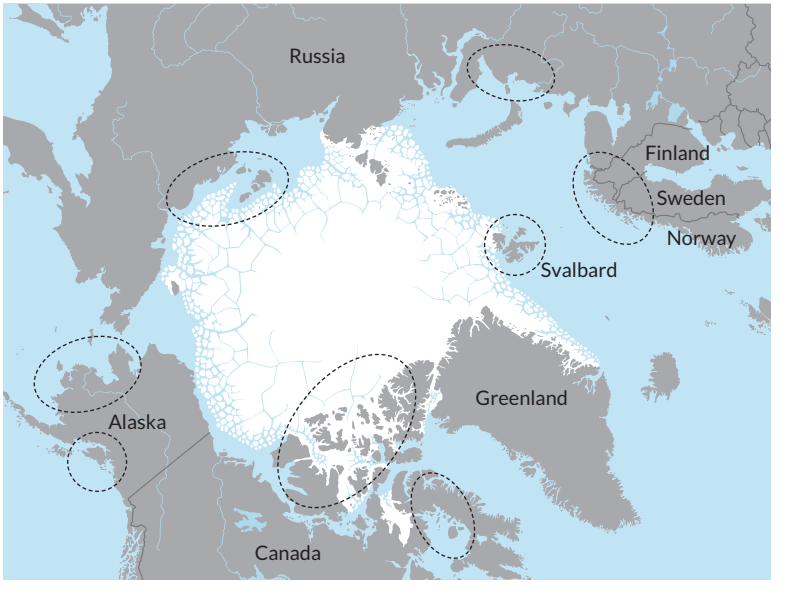
Growing greenbelt

The Arctic is warming two to three times as fast as the rest of the planet, with most of the temperature increase occurring in the winter. Alaska, for example, has warmed 2 degrees Celsius since 1949, and winters in some parts of the state, including southcentral Alaska and the Arctic interior, are on average 5 degrees C warmer.

An early effect of the warmer climate was a greener Arctic. More than 20 years ago, researchers used data from the National Oceanic and Atmospheric Administration's weather satellites to assess a decade of northern plant growth after a century of warming. The team compared different wavelengths of light — red and near-infrared — reflecting off vegetation to calculate the NDVI, the normalized difference vegetation index. Higher NDVI values indicate a greener, more productive landscape. In a single decade — from 1981, when the first satellite was launched, to 1991 — the northern high latitudes had become about 8 percent greener, the researchers reported in 1997 in *Nature*.

Salmonberries are widely harvested during the summer in southern Alaska's coastal regions. The shrubs have been hit hard by moth damage in recent years.

The Arctic ecosystem, once constrained by cool conditions, was stretching beyond its limits. In 1999 and 2000, researchers cataloged the extent and types of vegetation change in parts of northern Alaska using archival photographs taken during oil exploration flyovers between 1948 and 1950. In new images of the same locations, such as the Kugururok River in the Noatak National Preserve, low-lying tundra plants that once grew along the riverside terraces had been replaced by stands of white spruce and green alder shrubs. At some of the study's 66 locations, shrub-dominated vegetation had doubled its coverage from 10 to 20 percent. Not all areas showed a rise in shrub abundance, but none showed any decrease.



Brown among the green As the Arctic warms up, it's getting greener, but some pockets have been going brown instead. Satellite imagery and ecologists on the ground have observed browning in the circled areas on this map.

FROM TOP: CINDY HOPKINS/ALAMY STOCK PHOTO; C. CHANG

From 2002 to 2009, two moth species defoliated as much as a third of the mountain birch trees that stretch across northern Norway, Sweden and Finland. By 2014, some trees had recovered (top) while others had not (bottom).

JAKOB IGLHAUT

In 2003, Howard Epstein, a terrestrial ecologist at the University of Virginia in Charlottesville, and colleagues looked to the satellite record, which now held another decade of data. Focusing on Alaska's North Slope, which lies just beyond the crown of the Brooks Range and extends to the Beaufort Sea, the researchers found that the highest NDVI values, or "peak greenness," during the growing season had increased nearly 17 percent between 1981 and 2001, in line with the warming trend.

Earth-observing satellites have been monitoring the Arctic tundra for almost four decades. In that time, the North Slope, the Canadian low Arctic tundra and eastern Siberia have become especially green, with thicker and taller tundra vegetation and shrubs expanding northward. "If you look at the North Slope of Alaska, if you look at the overall trend, it's greening like nobody's business," says Uma Bhatt, an atmospheric scientist at the University of Alaska Fairbanks.

Yet parts of the Arctic, including the Yukon-Kuskokwim Delta of western Alaska, the Canadian Arctic Archipelago (the islands north of the mainland that give Canada its pointed tip) and the northwestern Siberian tundra, show extensive browning over the length of the satellite record, from the early 1980s to 2016. "It could just be a reduction in green vegetation. It doesn't necessarily mean the widespread death of plants," Epstein says. Scientists don't yet know why plant growth there has slowed or reversed — or whether the satellite signal is in some way misleading.

"All the models indicated for a long time that we would expect greening with warmer temperatures and higher productivity in the tundra, so long as it wasn't limited in some other way, like [by lower] moisture," says Scott Goetz, an ecologist and remote-sensing specialist at Northern Arizona University in Flagstaff. He is also the science team lead for ABoVE, NASA's Arctic-Boreal Vulnerability Experiment, which is tracking ecosystem changes in Alaska and western Canada. "Many of us were quite surprised ... that the Arctic was suddenly browning. It's something we need to resolve."

Freeze-dried tundra

While global warming has propelled widespread trends in tundra greening, extreme winter weather can spur local browning events. In recent years, in some parts of the Arctic, extraordinary warm winter weather, sometimes paired with rainfall, has put tundra vegetation under enormous stress and caused plants to lose freeze resistance, dry up or die — and turn brown.

Gareth Phoenix, a terrestrial ecologist at the University of Sheffield in England, recalls his shock at seeing a series of midwinter time-lapse photos taken in 2001 at a research site outside the town of Abisko in northern Sweden. In the space of a couple of days, the temperature shot up from −16° C to 6° C, melting the tundra's snow cover.

"As an ecologist, you're thinking, 'Whoa! Those plants would usually be nicely insulated under the snow,'" he says. "Suddenly, they're being exposed

because all the snow has melted. What are the consequences of that?"

Arctic plants survive frigid winters thanks to that blanket of snow and physiological changes, known as freeze resistance, that allow plants to freeze without damage. But once the plants awaken in response to physical cues of spring — warmer weather, longer days — and experience bud burst, they lose that ability to withstand frigid conditions.

That's fine if spring has truly arrived. But if it's just a winter heat wave and the warm air mass moves on, the plants become vulnerable as temperatures return to seasonal norms. When temporary warm air covers thousands of square kilometers at once, plant damage occurs over large areas. "These landscapes can look like someone's gone through with a flamethrower," Phoenix says. "It's quite depressing. You're there in the middle of summer, and everything's just brown."

Jarle Bjerke, a vegetation ecologist at the Norwegian Institute for Nature Research in Tromsø, saw browning across northern Norway and Sweden in 2008. The landscape — covered in mats of crowberry, an evergreen shrub with bright green sausagelike needles — was instead shades of brown, red-brown and grayish brown. "We saw it everywhere we went, from the mountaintops to the coastal heaths," Bjerke says.

> "These landscapes can look like someone's gone through with a flamethrower."
>
> GARETH PHOENIX

Bjerke, Phoenix and other researchers continue to find brown vegetation in the wake of winter warming events. Long periods of mild winter weather have rolled over the Svalbard archipelago, the cluster of islands in the Arctic Ocean between Norway and the North Pole, in the last decade. The snow melted or blew away, exposing the ground-hugging plants. Some became encrusted in ice following a once-unheard-of midwinter rainfall. In 2015, the Arctic bell heather, whose small white flowers brighten Arctic ridges and heaths, were brown that summer, gray the next and then the leaves fell off. "It's not new that plants can die during mild winters," Bjerke says. "The new thing is that it is now happening several winters in a row."

Insect invasion

The weather needn't always be extreme to harm plants in the Arctic. With warmer winters and summers, leaf-eating insects have thrived, defoliating bushes and trees beyond the insects' usual range. "They're very visual events," says Rachael Treharne, an Arctic ecologist who completed her Ph.D. at the University of Sheffield and now works at ClimateCare, a company that helps organizations reduce their climate impact. She remembers being in the middle of an autumnal moth outbreak in northern Sweden one summer. "There were caterpillars crawling all over the plants — and us. We'd wake up with them in our beds."

In northernmost Norway, Sweden and Finland in the mid-2000s, successive bursts of geometrid moths defoliated 10,000 square kilometers of mountain birch forest — an area roughly the size of Puerto Rico. The outbreak was one of Europe's most abrupt and large-scale ecosystem disturbances linked to climate change, says Jane Jepsen, an Arctic ecologist at the Norwegian Institute for Nature Research.

"These moth species benefit from a milder winter, spring and summer climate," Jepsen says. Moth eggs usually die at around −30° C, but warmer winters have allowed more eggs of the native autumnal moth to survive. With warmer springs, the eggs hatch earlier in the year and keep up with the bud burst of the mountain birch trees. Another species — the winter moth (*O. brumata*), found in southern Norway, Sweden and Finland — expanded northward during the outbreak. The spring and summer warmth favored the larvae, which ate more and grew larger, and the resulting hardier female moths laid more eggs in the fall.

While forests that die off can grow back over several decades, some of these mountain birches may have been hammered too hard, Jepsen says. In some places, the forest has given way to heathland. Ecological transitions like this could be long-lasting or even permanent, she says.

Smoldering lands

Once rare, wildfires may be one of the north's main causes of browning. As grasses, shrubs and trees across the region dry up, they are being set aflame with increasing frequency, with fires covering larger areas and leaving behind dark scars. For example, in early 2014 in the Norwegian coastal municipality of Flatanger, sparks from a power line ignited the dry tundra heath, destroying more than 100 wooden buildings in several coastal hamlets.

Sparsely populated places, where lightning is the primary cause of widlfires, are also seeing an uptick in wildfires. Scientists say lightning strikes

Three effects

The Arctic is warming more than twice as fast as the rest of the world. The higher temperatures have led to browning in some areas due to:

Extreme weather
Midwinter warming awakens plants, which then freeze as temperatures dive.

Moth infestations
Insects thrive and move into new areas to eat plants.

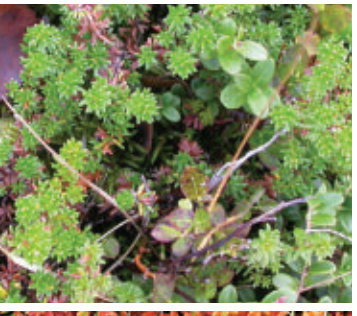
Wildfires
Dry plants plus more lightning leads to blackened land.

C. CHANG

are becoming more frequent as the planet warms. The number of lightning-sparked fires has risen 2 to 5 percent per year in Canada's Northwest Territories and Alaska over the last four decades, earth system scientist Sander Veraverbeke of Vrije Universiteit Amsterdam and his colleagues reported in 2017 in *Nature Climate Change*.

In 2014, the Northwest Territories had 385 fires, which burned 34,000 square kilometers. The next year, 766 fires torched 20,600 square kilometers of the Alaskan interior — accounting for about half the total area burned in the entire United States in 2015.

In the last two years, wildfires sent plumes of smoke aloft in western Greenland (*SN: 3/17/18, p. 20*) and in the northern reaches of Sweden, Norway and Russia, places where wildfires are uncommon. Wildfire activity within a 30-year period could quadruple in Alaska by 2100, says a 2017 report in *Ecography*. Veraverbeke expects to see "more fires in the Arctic in the future."



Top: Healthy crowberry shrubs grow among mountain cranberry in Abisko, Sweden, in September 2005. Bottom: A 2013 midwinter warming event near Tromsø, Norway, melted the snow. By May, these crowberry plants turned reddish brown from severe stress. When this happens, the leaves eventually turn brown, then wilt, turn gray and fall off.

The loss of wide swaths of plants could have wide-ranging local effects. "These plants are the foundation of the terrestrial Arctic food webs," says Isla Myers-Smith, a global change ecologist at the University of Edinburgh. The shriveled landscapes can leave rock ptarmigan, for example, which rely heavily on plants, without enough food to eat in the spring. The birds' predators, such as the arctic fox, may feel the loss the following year.

The effects of browning may be felt beyond the Arctic, which holds about half of the planet's terrestrial carbon. The boost in tundra greening allows the region to store, or "sink," more carbon during the growing season. But carbon uptake may slow if browning events continue, as expected in some regions.

Treharne, Phoenix and colleagues reported in February in *Global Change Biology* that on the Lofoten Islands in northern Norway, extreme winter conditions cut in half the heathlands' ability to trap carbon dioxide from the atmosphere during the growing season.

Yet there's still some uncertainty about how these browned tundra ecosystems might change in the long-term. As the land darkens, the surface absorbs more heat and warms up, threatening to thaw the underlying permafrost and accelerate the release of methane and carbon dioxide. Some areas might switch from being carbon sinks to carbon sources, Phoenix warns.

On the other hand, other plant species — with more or less capacity to take up carbon — could move in. "I'm still of the view that [these areas] will go through these short-term events and continue on their trajectory of greater productivity," Goetz says.

A better view

The phenomena that cause browning events — extreme winter warming, insect outbreaks, wildfires — are on the rise. But browning events are tough to study, especially in winter, because they're unpredictable and often occur in hard-to-reach areas.

Ecologists working on the ground would like the satellite images and the NDVI maps to point to areas with unusual vegetation growth — increasing or decreasing. But many of the browning events witnessed by researchers on the ground have not been picked up by the older, lower-resolution satellite sensors, which scientists still use. Those sensors oversimplify what's on the ground: One pixel covers an area 8 kilometers by 8 kilometers. "The complexity that's contained within a pixel size that big is pretty huge," Myers-Smith says. "You have mountains, or lakes, or different types of tundra vegetation, all within that one pixel."

At a couple of recent workshops on Arctic browning, remote-sensing experts and ecologists tried to tackle the problem. "We've been talking about how to bring the two scales together," Bhatt says. New sensors, more frequent snapshots, better data access and more computing power could help scientists zero in on the extent and severity of browning in the Arctic.

Researchers have begun using Google Earth Engine's massive collection of satellite data, including Landsat images at a much better resolution of 30 meters by 30 meters per pixel. Improved computational capabilities also enable scientists to explore vegetation change close up. The European Space Agency's recently launched Sentinel Earth-observing satellites can monitor vegetation growth with a pixel size of 10 meters by 10 meters. Says Myers-Smith: "That's starting to get to a scale that an ecologist can grapple with." ■

Explore more

■ Gareth K. Phoenix and Jarle W. Bjerke. "Arctic browning: extreme events and trends reversing Arctic greening." *Global Change Biology*. September 2016.

Hannah Hoag is a science journalist and editor based in Toronto.

FROM TOP: J. BJERKE; HANS TØMMERVIK

The Secret Powers of RNA

Overlooked molecules play a big role in human health

By Tina Hesman Saey

DNA is the glamour molecule of the genetics world. Its instructions are credited with defining appearance, personality and health. And the proteins that result from DNA's directives get credit for doing most of the work in our cells. RNA, if mentioned at all, is considered a mere messenger, a go-between — easy to ignore. Until now.

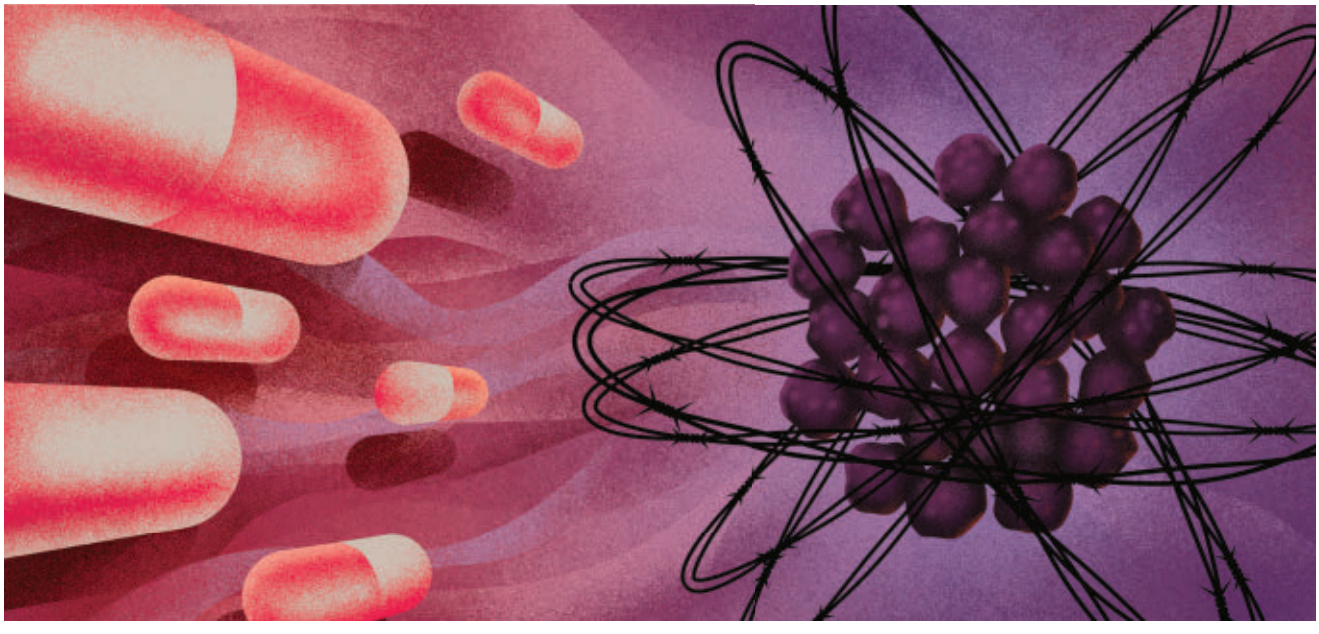
RNAs, composed of strings of genetic letters called nucleotides, are best known for ferrying instructions from the genes in our DNA to ribosomes, the machines in cells that build proteins. But in the last decade or so, researchers have realized just how much more RNAs can do — how much they control, even. In particular, scientists are finding RNAs that influence health and disease yet have nothing to do with being messengers.

The sheer number and variety of noncoding RNAs, those that don't ferry protein-building instructions, give some clues to their importance. So far, researchers have cataloged more than 25,000 genes with instructions for noncoding RNAs in the human genome, or genetic instruction book (*SN: 10/13/18, p. 5*). That's more than the estimated 21,000 or so genes that code for proteins. Those protein-coding genes make up less than 2 percent of the DNA in the human genome. Most of the rest of the genome is copied into noncoding RNAs, and the vast majority of those haven't been characterized yet, says Pier Paolo Pandolfi of Boston's Beth Israel Deaconess Medical Center. "We can't keep studying just two volumes of the book of life. We really need to study them all."

Scientists no longer see the RNAs that aren't envoys between DNA and ribosomes as worthless junk. "I believe there are hundreds, if not thousands, of noncoding RNAs that have a function," says Harvard University molecular biologist Jeannie Lee. She and other scientists are beginning to learn what these formerly ignored molecules do. It turns out that they are involved in every step of gene activity, from turning genes on and off to tweaking final protein products. Those revelations were unthinkable 20 years ago.

Back in the 1990s, Lee says, scientists thought only proteins could turn genes on and off. Finding that RNAs were in charge "was a very odd concept."

Here are five examples among the many noncoding RNAs that are now recognized as movers and shakers in the human body, for good and ill.



Cancer's force field
Some long noncoding RNAs, lncRNAs, protect tumors by fending off anticancer drugs.

ALL ILLUSTRATIONS: JAMES PROVOST

Fan the flame
Some short pieces of RNA, called microRNAs, help ignite pancreatic cancer. Some also help the cancer spread.

lncRNAs

FOILING CANCER TREATMENT

Sometimes anticancer drugs stop working for reasons researchers don't entirely understand. Take the chemotherapy drug cytarabine. It's often the first drug doctors prescribe to patients with a blood cancer called acute myeloid leukemia. But cytarabine eventually stops working for about 30 to 50 percent of AML patients, and their cancer comes back.

Researchers have looked for defects in proteins that may be the reason cytarabine and other drugs fail, but there still isn't a complete understanding of the problem, Pandolfi says. He and colleagues now have evidence that drug resistance may stem from problems in some of the largest and most bountiful of the newly discovered classes of RNAs, known as long noncoding RNAs. Researchers have already cataloged more than 18,000 of these "lncRNAs" (pronounced "link RNAs").

Pandolfi and colleagues investigated how some lncRNAs may work against cancer patients who are counting on chemotherapy to fight their disease. "We found hundreds of new players that can regulate response to therapy," he says.

When the researchers boosted production of several lncRNAs in leukemia cells, the cells became resistant to cytarabine, Pandolfi and colleagues reported in April 2018 in *Cell*. They also found that patients with AML who had higher than normal levels of two lncRNAs experienced a cancer recurrence sooner than people who had lower levels of those lncRNAs.

Researchers are just beginning to understand how these lncRNAs influence cancer and other diseases, but Pandolfi is hopeful that someday he and other researchers will devise ways to control the bad actors and boost the helpful ones.

MicroRNAs

SPARKING A TUMOR'S SPREAD

MicroRNAs are barely more than 20 RNA units, or bases, long, but they play an outsized role in heart disease, arthritis and many other ailments. These pip-squeaks can also lead to nerve pain and itchiness, researchers reported last year in *Science Translational Medicine* and in *Neuron* (*SN Online: 8/13/18*).

Hundreds of clinical studies are testing people's blood and tissues to determine if microRNAs can be used to help doctors better diagnose or understand conditions ranging from asthma and Alzheimer's disease to schizophrenia and traumatic brain injury. Some researchers are beginning to develop microRNAs as drugs and seeking ways to inhibit rogue microRNAs.

So far, the little molecules' most firmly established roles are as promoters of and protectors against cancer (*SN: 8/28/10, p. 18*). Pancreatic cancer, for example, is a deadly foe. Only 8.5 percent of people are still alive five years after being diagnosed with this disease, according to U.S. National Cancer Institute statistics.

Cancer biologist Brian Lewis of the University of Massachusetts Medical School in Worcester and colleagues have learned that some microRNAs spur this lethal cancer's initial attack and help the tumor spread from the pancreas to other organs.

MicroRNAs are mirror images of portions of the messenger RNAs that shuttle protein-making

instructions from DNA to the ribosomes, where proteins are built. The microRNAs pair up with their larger messenger RNA mates and slate the bigger molecules for destruction, or at least prevent their instructions from being translated into proteins. One microRNA might have hundreds of mates, or targets, through which it influences many different body functions.

Lewis studies one gang of six microRNAs, known as the *miR-17~92* cluster, the first group of microRNAs found to play a role in cancer. The six normally help strike a balance between cell growth and death, but an imbalance of these little molecules can push cells toward cancer.

Tumors in pancreatic cancer patients tend to have elevated levels of the cluster. To learn what the microRNAs were doing to goad cancer into taking hold, Lewis and colleagues used a genetic trick to remove the microRNAs from the pancreas in mice that were genetically engineered to develop pancreatic tumors. Early in their lives, mice with and without the microRNA cluster had about the same number of precancerous cells.

But by the time the animals were 9 months old, a clear difference emerged. In mice with the *miR-17~92* microRNAs, nearly 60 percent of the pancreas was tending toward cancer, compared with less than 20 percent in mice lacking the cluster. The finding, reported in 2017 in *Oncotarget*, suggests that the microRNAs aid the cancer's start.

The researchers developed bits of RNA that block some of the cluster members from spurring on the tumor. Using human pancreatic cancer cells grown in lab dishes, Lewis and colleagues found that taking out two of the six cluster members, *miR-19a* and *miR-19b*, stopped cancer cells from forming structures called invadopodia. As their name suggests, invadopodia allow tumors to break through blood vessel walls and other barriers to spread through the body.

Transfer RNA fragments

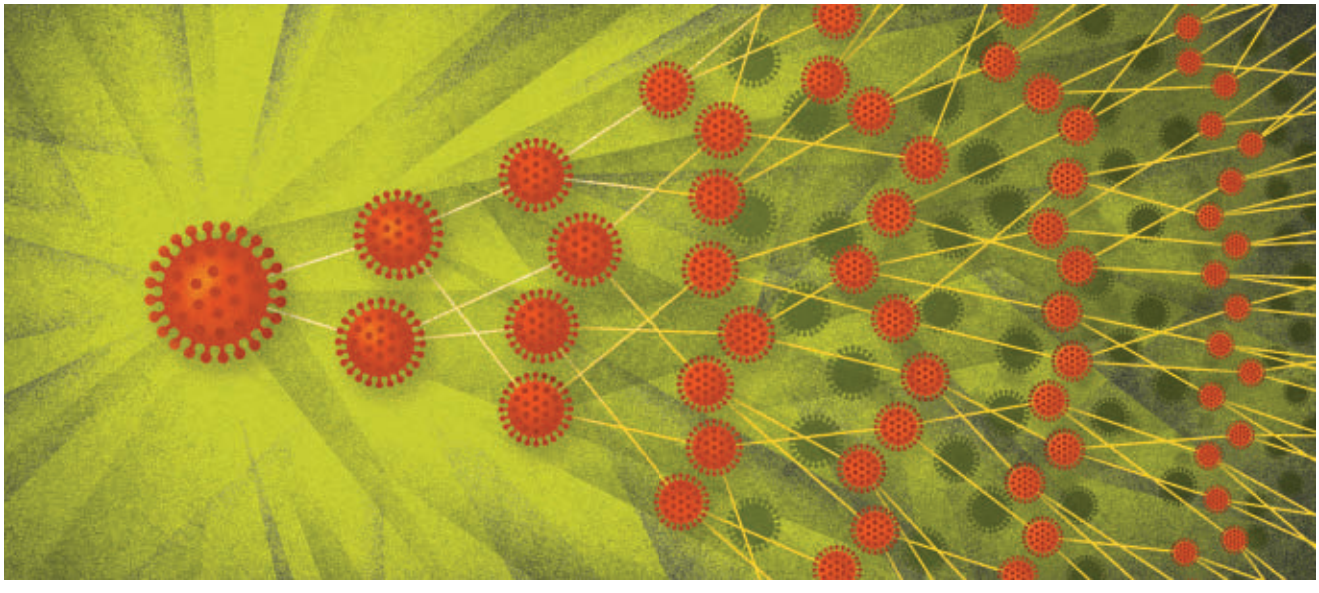
THE VIRUS HELPERS

For some young children and older adults, an infection with respiratory syncytial virus, or RSV, feels like a simple cold. But each year in the United States, more than 57,000 children younger than age 5 and about 177,000 people older than 65 are hospitalized because of the virus, the U.S. Centers for Disease Control and Prevention estimates. The infection kills hundreds of babies and about 14,000 adults over 65 annually.

Slightly higher than normal levels of some microRNAs had been linked to severe RSV infections. But molecular virologist Xiaoyong Bao of the University of Texas Medical Branch in Galveston wasn't convinced that modestly increasing amounts of a few microRNAs could really mean the difference between a child getting a slight cold and dying from the respiratory virus.

She consulted her Texas Medical Branch colleague, cancer researcher Yong Sun Lee, for advice on studying microRNAs. Lee said Bao would need to deeply examine, or sequence, RNA in cells infected with the virus. That was an expensive proposition in 2012 when Bao started the project. "But I squeezed from my [lab's] dry bank account," she says, to pay for the experiment. The investment paid off.

Cells infected with RSV had more of one



Infection on overdrive Snippets of transfer RNAs can spur growth of respiratory syncytial virus, an infection that's most dangerous in the elderly and young children.

Blow it up In cells infected with herpesvirus, production of RNAs copied from a class of transposons called SINEs may slate the cells for death. Killing infected cells may head off the virus's spread.

particular RNA than did uninfected cells. Surprisingly, it was a piece of a transfer RNA. Transfer RNAs, or tRNAs, are the assembly line workers of protein building. tRNAs read instructions in a messenger RNA and deliver the amino acids the ribosome needs to make a protein.

Scientists knew that working tRNAs are essential employees. Fragments, when they were found, were considered leftover bits of decommissioned tRNAs. But the fragments that Bao and colleagues discovered aren't just worn out bits of tRNAs. Each fragment, about 30 bases long, is precisely cut from a tRNA when RSV infects cells. The fragments aid the virus's infection in more than one way. For instance, two fragments help the virus make copies of itself in cells, Bao and colleagues reported in 2017 in the *Journal of General Virology*.

tRNA fragments may also boost the body's susceptibility to a virus. Last year, Bao's group described in *Scientific Reports* how exposure to some heavy metals, via air or water pollution, can produce tRNA fragments that trigger inflammation, which may make people more susceptible to respiratory infections such as RSV.

SINE RNAs

SACRIFICING INFECTED CELLS

Another type of RNA may help protect against infection by certain viruses, including herpesvirus. Virologist Britt Glaunsinger has long marveled at the way viruses manipulate host cells by controlling RNAs in the cell. She became intrigued by transposons, mobile stretches of DNA that can jump from one location to another in the genome. Transposons make up nearly half of all the DNA in the human genome (*SN: 5/27/17, p. 22*).

"We tend to think of [transposons] as parasites and things our own cells are constantly trying to shut down," says Glaunsinger, a Howard Hughes Medical Institute investigator at the University of California, Berkeley. That's because some are relics of ancient viruses. "While they may have initially been bad, some of them may actually be useful to us," she says.

One class of transposons, called SINEs for short interspersed nuclear elements, are peppered throughout the genome. People have more than a million of one type of SINE known as Alu elements. Mice have similar SINEs, called B2s.

When active, SINE transposons make RNA copies of themselves. These SINE RNAs don't carry instructions for building proteins and alone don't enable the transposons to jump around the genome. So researchers puzzled over their role. Glaunsinger and colleagues discovered that some SINE RNAs may protect against viral infections.

Normally, cells keep a tight lock on transposons, preventing them from making any RNA. But in Glaunsinger's experiments, cells infected with herpesvirus "were producing tons of these noncoding RNAs in response to infection," she says. "That sort of captured our interest."

Details of the process are still being worked out, but Glaunsinger and others have discovered that SINE RNA production triggers a cascade of events that eventually kills infected human and mouse cells. Once the RNA production gets going, Glaunsinger says, "the cell is destined to die." Inflammation appears to be an important step in the cell-killing chain reaction. It's all for the greater good: Killing the infected cell may protect the rest of the organism from the infection's spread.

Transposons can't jump piRNAs may help shield the brain from jumping genes, which are suspected of killing brain cells in Alzheimer's disease.

But there's a wrinkle: In mice, at least, one type of herpesvirus benefits from the flood of B2 RNAs in the cells it infects. The virus hijacks part of the inflammation chain reaction to boost its own production, Glaunsinger and colleagues reported in 2015 in *PLOS Pathogens*. "This is an example of the back-and-forth battle that's always going on between virus and host," she says. "Now the ball is back in the host's court."

piRNAs

SHIELDING THE BRAIN FROM JUMPING GENES

Autopsies of people who died with Alzheimer's disease show a buildup of a protein called tau in the brain. That tau accumulation is tied to loss of some guardian RNAs, according to work by Bess Frost, a neurobiologist at UT Health San Antonio.

Frost studies fruit flies genetically engineered to make a disease-causing version of human tau in their nerve cells. Flies with the disorderly tau get a progressive nerve disease that causes movement problems and kills nerves. The insects live shorter lives than normal.

Part of the reason the flies, as well as people with tau tangles, have problems is because some RNAs known to guard the genome fall down on the job, Frost and colleagues discovered. These piwi-interacting RNAs, or piRNAs (pronounced "pie RNAs"), help keep transposons from jumping around. When transposons jump, they may land in or near a gene and mess with its activity.

Usually cells prevent jumping by stopping transposons from making messenger RNA, which carries instructions to make proteins that eventually enable the transposon to hop from place to place. If a transposon gets past the cell's defenses and produces its messenger RNA, piRNAs will step up to pair with the messenger and cause its destruction.

When disease-causing tau builds up in flies (and maybe in people), a class of transposon with a lengthy name — class I long terminal repeat retrotransposons — makes much more RNA than usual. And when flies have the disease-causing version of tau, they also have lower than normal levels of piRNAs, Frost and colleagues reported in August 2018 in *Nature Neuroscience*. "Both arms of control are messed up," Frost says. Brains of people who died with Alzheimer's disease or supranuclear palsy, another tau-related disease, also show signs that transposons were making extra RNA, suggesting that when tau goes bad, it can beat piRNA's defenses.

In search of a work-around, Frost's team found that genetically boosting piRNA production in flies or giving a drug that stops transposon hops reduced nerve cell death in the insects. The researchers are preparing to test the drug in mice prone to a rodent version of Alzheimer's disease. The team is also examining human brain tissue to see if the increase in transposon RNAs actually leads to transposon jumping in Alzheimer's patients. If transposons don't hop more than usual, the finding may suggest that transposon RNAs themselves can cause mischief — no jumping necessary. ■

Explore more

■ Alexander F. Palazzo and Eliza S. Lee. "Noncoding RNA: What is functional and what is junk?" *Frontiers in Genetics*. January 26, 2015.

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The Perfect Predator
Steffanie Strathdee and Thomas Patterson
HACHETTE BOOKS, $28

BOOKSHELF

A personal fight against a bacterial disease

Epidemiologist Steffanie Strathdee and her husband, Thomas Patterson, went to Egypt in 2015 expecting to come home with some photos and souvenirs. Instead, Patterson was hit with his own version of the 10 plagues.

At first, doctors in Egypt thought Patterson had pancreatitis. But his health worsened after treatment, and he started hallucinating. Once flown to Germany, he was diagnosed with a multidrug-resistant bacterial infection in his pancreas. He was then airlifted to a hospital at Strathdee's home institution, the University of California, San Diego. There, Patterson suffered several episodes of septic shock and spent months in a coma.

The Perfect Predator chronicles the couple's encounter with a bacterium that was resistant to every available antibiotic, and the rush to find an alternative treatment to save Patterson's life.

During the ordeal, Strathdee used her scientific training to research solutions and stumbled upon phage therapy. The idea is that even the most resistant bacteria can be defeated by their natural predators, viruses called bacteriophages. The nearly century-old treatment had been all but forgotten in the United States, in large part because of the invention of antibiotics, but was being used in parts of the former Soviet Union.

Doctors needed the right phage, one capable of parasitizing the bacteria infecting Patterson. So Strathdee asked a team of scientists to drop everything and check their phage collections while also hunting for environmental samples for a virus that could be turned into an experimental treatment. Within three weeks, two sets of researchers found phages that were a match. Patterson was treated successfully, and the first phage therapy center in the United States opened last year at UC San Diego.

Strathdee, who did most of the book's writing, provides clear explanations of the science and weaves historical vignettes, such as the early days of research on penicillin, throughout her personal narrative.

The book is a real page-turner, though a few things may give readers pause. The first is the mention of Strathdee's psychic, who appears a few times throughout the book and is later joined by a holistic healer. Then there are "interludes" written by Patterson. Over time, it becomes clear that these snippets are a peek into Patterson's hallucinations, but the book would have been stronger if those passages had been clearly introduced, or left out altogether.

The interludes, and Strathdee's reliance on some unconventional supports, are distracting, but they don't take away from the book's strong foundation in science and skillful storytelling. — *Allie Wilkinson*

Cities
Monica L. Smith
VIKING, $30

BOOKSHELF

Urban living explored

Ancient Rome's Monte Testaccio and modern Tokyo's Tsukiji fish market reveal a lot about the nature of cities. Monte Testaccio is a hill made of broken pottery in the middle of Rome. Around 2,000 years ago, people tossed empty wine and olive oil vessels onto what was then a garbage heap. Tokyo's vast seafood emporium, also known as Toyosu Market, includes passageways where forklifts deposit and remove containers of every sea creature imaginable, as chefs and home cooks bid for the day's catch.

These metropolitan destinations illustrate how mass production and consumption of goods — along with public markets, complex infrastructure and trash — have always characterized cities, archaeologist Monica Smith writes in *Cities*. She argues that cities provide work and leisure opportunities that, once invented around 6,000 years ago, people couldn't do without. Trash was part of the deal, along with poverty and pollution — all of which remain city challenges.

Ancient human traits and behaviors contributed to cities' rapid ascendance, even if it took a few hundred thousand years for agriculture and other cultural developments to spark that urban transition, Smith writes. As a restless, talkative species searching for meaning in the world, people eventually started building gathering spots for religious pilgrimages. One of the earliest such places was Göbekli Tepe in what's now Turkey, dating back 10,000 years or more. Public structures there set the stage for farmers and herders to create the oldest known city, Tell Brak, about 4,000 years later in Syria.

Cities everywhere have been organized in remarkably similar ways to provide jobs, entertainment and other features, the author holds. People have always been drawn to those benefits, both for survival and for excitement, she writes.

Smith offers a spirited defense of conspicuous consumption. Excavations have yielded lots of trash at ancient cities. Changing styles have always fueled a desire to get the latest goods. Many objects were made to be used and thrown out. Heaps of cheap ceramic fast food containers, for instance, have been found at Pompeii and elsewhere. The inventiveness that takes flight in cities is worth the cost of the trash, Smith concludes.

The urban drawbacks of crime and disease get minimal mention. And Smith's arguments seem incomplete without a comparison of cities to hunter-gatherer societies, the venues for most of human evolution. But she plausibly concludes that people will continue to flock to cities, warts and all.
— *Bruce Bower*

CHRIS AYERS PHOTOGRAPHY/SSP

Congratulations to this year's Regeneron Science Talent Search top winners!

Teen scientists win more than $1.8 million at the Regeneron Science Talent Search 2019

Regeneron and Society for Science & the Public announced March 12 the top winners of the Regeneron Science Talent Search 2019, the oldest and most prestigious science and math competition for high school seniors in the United States. The Regeneron Science Talent Search focuses on identifying, inspiring and engaging the nation's most promising young scientists, who are developing solutions that could solve society's most urgent challenges.

Ana Humphrey, 18, of Alexandria, Va., won the top award of $250,000 for her mathematical model to determine the possible locations of exoplanets — planets outside our solar system — that may have been missed by NASA's Kepler space telescope.

Second place honors and $175,000 went to **Samuel Weissman**, 17, of Rosemont, Pa., for his project analyzing the genetic makeup of HIV in two patients on long-term antiretroviral therapy to understand why they continued to have treatment-resistant "reservoirs" of HIV-infected cells.

Third place honors and $150,000 went to **Adam Ardeishar**, 17, of Alexandria, Va., for his project combining a classic math problem called the "coupon collector problem" with extreme value theory.

Fourth Place: **Madeleine Yang** of Beverly Hills, Mich., received a $100,000 award.

Fifth Place: **Carolyn Beaumont** of McLean, Va., received a $90,000 award.

Sixth Place: **Samuel Ferguson** of West Windsor, N.J., received an $80,000 award.

Seventh Place: **Brent Perlman** of Armonk, N.Y., received a $70,000 award.

Eighth Place: **Rachel Seevers** of Lexington, Ky., received a $60,000 award.

Ninth Place: **Vincent Huang** of Plano, Texas, received a $50,000 award.

Tenth Place: **Eshika Saxena** of Bellevue, Wash., received a $40,000 award.

MARCH 2, 2019

SOCIAL MEDIA

Did you hear that?

A new laser technique can send audible messages directly to a listener's ear, **Emily Conover** reported in "Lasers dispatch audio messages" (*SN: 3/2/19, p. 12*). Reddit user **UniversalQuasar** joked about how humans' technological aspirations might play out: "2019: I bet in the future, we'll have human colonization in space. 2050: Apple LaserPods."

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Life after shingles

In "Shingles' sneak attack" (SN: 3/2/19, p. 22), ***Aimee Cunningham*** *described the experience of* ***Nora Fox****, a woman whose bout with shingles nearly 15 years ago left her with a painful condition called postherpetic neuralgia. Fox hadn't found any reliable treatments,* ***Cunningham*** *reported.*

Fox praised *Science News* for our portrayal of shingles-related pain. "The cover is excellent and looks just like I felt," she wrote.

As the story went to press, **Fox** had a surgery during which doctors placed electrodes under the skin near sites of pain. A device lets **Fox** control when stimulation is delivered to those areas. But the treatment, called peripheral nerve stimulation, may not work for all patients with postherpetic neuralgia. There are reports in scientific journals of individual patients experiencing relief from their neuropathic pain after the procedure, **Cunningham** says.

Fox's husband, **Denver C. Fox**, sent *Science News* an update on her pain since the procedure: "There [has] been a significant change to the unbearable pain my wife has endured EVERY afternoon and evening for 14 years, despite trying every possible treatment the MDs knew of." Shortly after the procedure, "her pain is greatly and markedly diminished."

Stone Age throwback

Tests with replicas of a 300,000-year-old wooden spear suggest that Neandertals could have hunted from a distance, ***Bruce Bower*** *reported in "Athletes hurl ancient spears for science"* (SN: 3/2/19, p. 14*).*

Reader **Brenda Gray** suggested that Neandertals' spears could have been used for fighting instead of hunting.

The ancient spear found in Germany, on which the spear replicas were based, came from sediment that also contained stone tools and thousands of animal bones displaying marks made by stone tools, **Bower** says. "Such evidence indicates that the spears were used as hunting weapons. Neandertals could have used wooden spears in different ways, but there is no evidence that I know of for Neandertals using spears in warfare," he says.

Young and restless

Earth's inner core began hardening sometime after 565 million years ago, ***Carolyn Gramling*** *reported in "Earth's inner core is relatively young"* (SN: 3/2/19, p. 13*). The core may have solidified just in time to strengthen the planet's magnetic field, saving it from collapse.*

Reader **John Bunch** thought that the timing of the inner core's solidification "lines up nicely" with the Cambrian explosion, when life rapidly diversified about 542 million years ago. "It leads me to wonder if there may be some cause and effect or some other relationship between the two that's going on here."

That extremely low-intensity magnetic field actually roughly lines up with the Avalon explosion, an earlier proliferation of new life forms called the Ediacaran biota, between about 575 million and 542 million years ago, **Gramling** says. It's an intriguing coincidence that researchers noted.

Earth's magnetic field helps protect the planet from radiation. So a weak magnetic field might somehow be linked with the Avalon explosion. One idea is that increased radiation reaching Earth's surface hundreds of millions of years ago might have increased organisms' mutation rates, **Gramling** says. But there just isn't any evidence to support a causal link at the moment.

Who's dying from fentanyl overdoses?

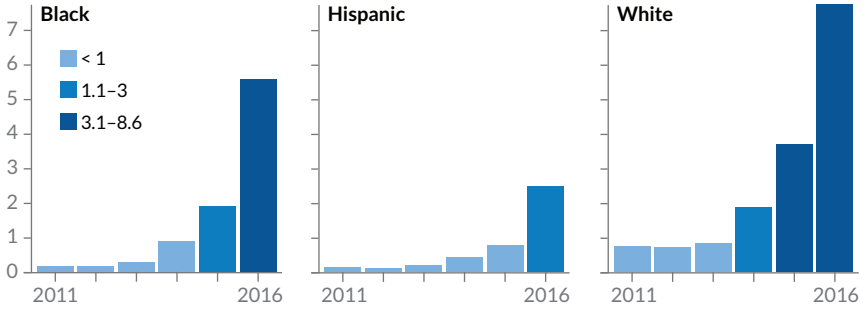
Whites have been hit the hardest in the fentanyl-related drug overdose epidemic in the United States. But data released March 21 by the Centers for Disease Control and Prevention show that blacks and Hispanics are increasingly afflicted.

Non-Hispanic whites experience the majority of deaths involving fentanyl, a synthetic opioid. But death rates among blacks and Hispanics rose faster from 2011 to 2016 (top row, left). The death rate rose 140.6 percent each year, on average, for blacks and 118.3 percent for Hispanics. For whites, it rose 61 percent each year, on average.

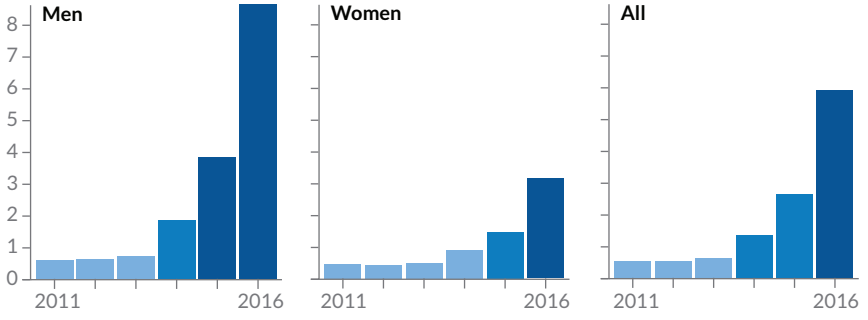
Men also now face higher risks. From 2011 to 2013, men and women died at similar rates. But by 2016, the death rate among men was 8.6 per 100,000 people, nearly three times the rate for women (second row). Overall, in 2011 and 2012, the number of U.S. fentanyl-related deaths hovered just above 1,600. A sharp increase began in 2013, reaching 18,335 deaths in 2016.

There were regional differences, too. Overdose death rates rose most sharply along the East Coast, including in New England and the Middle Atlantic, and in the Great Lakes region (graphs below). — *Cori Vanchieri*

Drug overdose deaths involving fentanyl, by race (2011–2016)
Per 100,000 people



Drug overdose deaths involving fentanyl, by sex (2011–2016)
Per 100,000 people



Drug overdose deaths involving fentanyl, by U.S. region (2011–2016)
Per 100,000 people

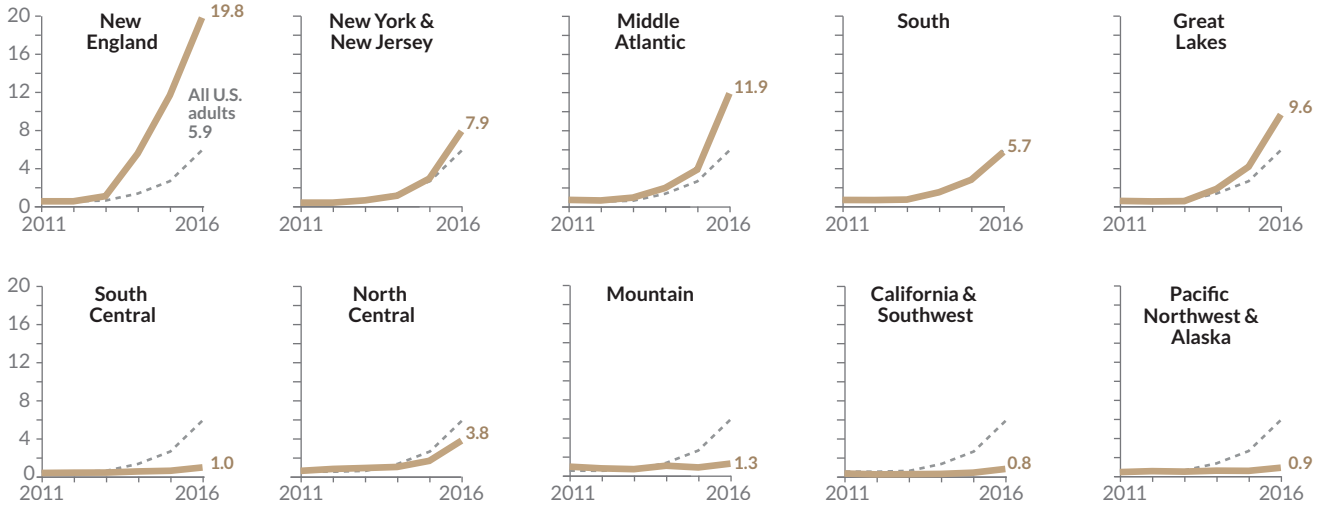


PHOTO: HAILSHADOW/ISTOCK/GETTY IMAGES PLUS; GRAPHS: E. OTWELL; SOURCE: CDC

GEOLOGIC ROAD TRIP OF THE MONTH

FALL CREEK FALLS STATE PARK

Fall Creek Falls State Park, Tennessee's second-largest and most visited state park, sits atop the Cumberland Plateau off TN 30 between Pikeville and Spencer. The park includes 26,000 acres of the Cane Creek watershed, with many steep and narrow gorges. Cane Creek drains the western Cumberland Plateau between its headwaters on Little Mountain, near Sequatchie Valley, to its confluence with the Caney Fork River on the eastern Highland Rim.

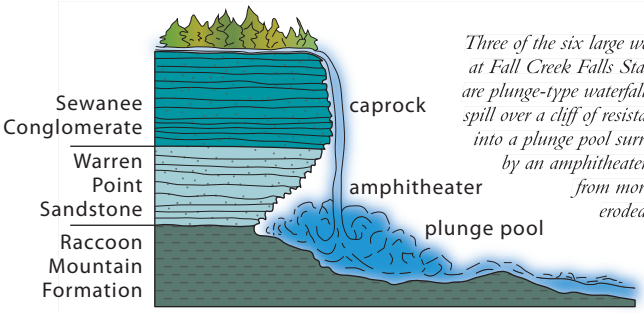
Fall Creek Falls, the centerpiece of Fall Creek Falls State Park, is the highest plunge-type waterfall east of the Rocky Mountains at 256 feet high. Fall Creek Falls (left) and Coon Creek Falls (right) cascade over Pennsylvanian-age Sewanee Conglomerate and Warren Point Sandstone. The amphitheater at the base of the falls occurs at the contact with shales of the underlying Raccoon Mountain Formation. (35.665830N, 85.355830W) —Chuck Sutherland photo

To access Fall Creek Falls State Park from Pikeville, take TN 30 west for 15 miles toward Spencer. Ordovician-age Stones River Group underlies the road for about 0.5 mile west of the turnoff. The Mississippian-age Pennington Formation forms the hills north of the highway and west of the turnoff for TN 402, at the base of the plateau. Sandstone, siltstone, shale, and coal belonging to the Pennsylvanian-age Gizzard Group crop out along the road as it climbs the hill. Near the top, thick-bedded sandstones of the Sewanee Conglomerate form cliffs. The unit, which is well exposed at Shoemate Gap, dips 45 degrees westward along the western limb of the Sequatchie Valley anticline. The steep dip flattens very quickly so that strata nearly lie flat on top of the Cumberland Plateau.

Pennsylvanian-age shale and sandstone of the Vandever Formation of the Crab Orchard Mountains Group underlie the highway between Shoemate Gap and Fall Creek Falls State Park. Rockcastle Conglomerate forms higher areas, while Newton Sandstone underlies major drainages. In many larger drainages, including at the bottom of Cane Creek Gorge west of the park, erosion has cut down to Mississippian-age limestone. Where this is the case, streams disappear into caves that developed in the soluble limestone along stream bottoms. Many of these streams reemerge along the western base of the plateau as springs.

Cane Creek Gorge, with its many tributaries, waterfalls, rapids, and grottoes, is the focus of the park. Cane Creek gradually incised the Cumberland Plateau, beginning about 200 million years ago, through headward erosion. The stream moved farther upstream over time as it naturally eroded in the direction opposite its flow. Headward erosion lengthens and widens a stream valley to include more drainage area, as the stream captures neighboring watersheds. Cane Creek erodes the shales and soluble carbonates that underlie the plateau's resistant caprock. This erosion undermines the caprock, which then breaks and falls off.

Fall Creek, a Cane Creek tributary, falls 256 feet over the resistant Sewanee Conglomerate and Warren Point Sandstone at Fall Creek Falls. Falling water excavates the amphitheater at the contact between the Warren Point Sandstone and the underlying shales of the Raccoon Mountain Formation. Rocks surrounding the falls are highly susceptible to physical weathering processes. Water vapor easily penetrates the porous rocks, and they then expand and contract with the temperature changes, particularly during winter freeze-thaw cycles. This expansion and contraction widens joints in the rocks over time, and eventually rocks break off. This physical process is also part of the stream's headward erosion. Look for the large blocks that litter the bottom of the gorge, evidence of headward erosion in progress; the amphitheater itself will migrate upstream over time. The Base of the Falls Trail provides a close look at the Sewanee Conglomerate and Warren Point Sandstone, as well as a view of the falls from the bottom. There is also an overlook of the falls not far from the parking area.



Three of the six large waterfalls at Fall Creek Falls State Park are plunge-type waterfalls. They spill over a cliff of resistant rock into a plunge pool surrounded by an amphitheater carved from more easily eroded shales.

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