SN
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New Hominid Species Named

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NEXT LEVEL

AI goes gamer to learn how humans think

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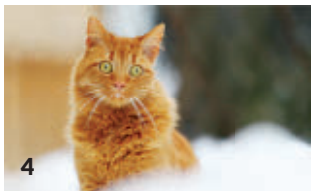
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Departments

COVER By mastering Minecraft and other video games, AI can learn how to navigate, juggle priorities and set goals. *Walter Newton*

FROM TOP: BRIAN TIETZ; DAN ZEN/FLICKR (CC BY 2.0); ANDERSEN_OYSTEIN/ISTOCK/GETTY IMAGES PLUS

Celebrating scientists who ask big questions

Humans are problem solvers. All day, every day, we ask ourselves questions. Should I wear socks with these shoes? Bring a phone charger? Eat the whole sandwich? Finish that assignment or watch YouTube? And that's just an average day. When we apply the tools of science to answering big questions, we can do amazing things.

In this double issue of *Science News*, we profile scientists who are asking big questions. That includes the Silicon Valley entrepreneurs who asked: Can we produce food protein from insects as efficiently as we do from chickens? It turns out that insect ranching is a lot trickier than you'd think. Check out our story, "Down on the (cricket) farm" (Page 28), to see how the team is deploying start-up smarts in an attempt to make insect farming scalable.

Then there's the challenge of training artificial intelligence to learn real-world skills. Algorithms can master games like chess and Go but struggle with the ambiguity and fast-paced interactions of much of human life. To help AI get ahead, scientists are challenging the systems to master popular video games, including Minecraft and StarCraft (Page 34). It's not just fun and games; the goal is to make AI more useful to us in complex tasks like simulating climate change or understanding conversations.

Another pressing problem is how to create batteries for electric cars, cell phones and laptops and for storing energy from solar and wind power. Growing demand is sparking a global hunt for lithium, an element key to making today's lightweight batteries. And the hunt is posing big questions for geologists, who are seeking better ways of finding and extracting lithium, and for countries and communities that want to be sure this new gold rush won't damage the environment (Page 40).

Some questions asked by scientists are so big that they will never be solved in our lifetimes. But one of the great things about being science journalists is reporting on the questions that do get answered, or that get reframed in ways that make us change how we think about the world. That includes the startling experiment that turned up signs of life in a dead pig brain (Page 6); the discovery of what looks to be an unusual ancient hominid species in the Philippines (Page 7); and the study that compared the physiology and DNA of identical twin astronauts Mark and Scott Kelly, which found that life in space pushes the immune system into overdrive (Page 22).

In this issue, we also report on a clever new way to multiply exceedingly large numbers, at least in theory (Page 20), as well as the adventures of a physicist who created a science-based escape room (Page 46). Oh, and cats really do know their names (Page 5). So when they don't respond, they're probably just ignoring us.

Because this is a double issue, subscribers will get the next issue of the print magazine on or around June 8. But fear not; we're reporting on the latest discoveries in science, technology and medicine every day at www.sciencenews.org. Join us there for more, including original videos. And keep asking questions!

— Nancy Shute, Editor in Chief

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DEGREES OF IMPACT

TEXAS TECH UNIVERSITY

Texas Tech University was one of 12 teams, and the only team from Texas, to compete in the Collegiate Wind Challenge created by the U.S. Department of Energy and the National Renewable Energy Laboratory. In May they will return to the Technical Challenge, a scaled down challenge that provides teams the opportunity to expand upon and improve their design. By competing in these challenges, the students gain real-world experience by familiarizing themselves with the industry and gaining an understanding of the workforce they will enter after graduation.

Excerpt from the May 10, 1969 issue of *Science News*

50 YEARS AGO

Part of a whole eye

After an attempted cornea transplant failed, ophthalmologists in Houston, Tex., tried a more daring experiment to restore the vision of 54-year-old John Madden.... They transplanted an entire eye from a donor who had died of a brain tumor.... [Later, the doctor who did the surgery] announced that only the front part of the donor's eye had been transplanted; the back portion of Madden's eye, including the optic nerve and part of the retina, had been preserved.

UPDATE: That partial eye transplant didn't work, but there has been progress in restoring sight to people with some forms of blindness (*SN: 5/30/15, p. 22*). Nearly 185,000 corneas are transplanted globally each year. Whole eye transplants in animals have had mixed success. In 2015, researchers transplanted part of a face, including an eye, from one rat to another. The eye survived. In 2018, researchers saw normal blood flow to the retinas of transplanted eyes in two of four rats, but the rats couldn't see because their optic nerves had been cut.

SOAPBOX

Brains sculpt each other. Why study them in isolation?

Brains have long been star subjects for neuroscientists. But the typical "brain in a jar" experiments that focus on one subject in isolation may be missing a huge part of what makes us human — our social ties.

"There's this assumption that we can understand how the mind works by just looking at individual minds, and not looking at them in interactions," says Thalia Wheatley, a social neuroscientist at Dartmouth College. "I think that's wrong."

To answer some of the thorniest questions about the human brain, scientists will have to study the mind as it actually exists: steeped in social connections that involve rich interplay among family, friends and strangers, Wheatley argues. To illustrate her point, she asked the audience at a March 26 symposium in San Francisco, during the annual meeting of the Cognitive Neuroscience Society, how many people had talked to someone else that morning. Nearly everybody in the crowd of about 100 raised a hand.

> Mind-to-mind interactions lead to something greater than the sum of their parts.

Everyday social interactions may seem inconsequential. But research on people who've been isolated, such as prisoners in solitary confinement, suggests otherwise. In mice, brains deprived of social connection stop working well (*SN: 12/8/18, p. 11*).

"That's a hint that it's not just that we like interaction," Wheatley says. "It's important to keep us healthy and sane."

Part of the tendency toward studying solitary brains stems from a lack of ways to tease apart life's rich social interactions. Functional MRI brain scanners are built for one person at a time, for example, and they usually can't accommodate the movement that comes from talking.

Wheatley and colleagues are getting around this issue by using special headgear that cushions against motion. The team then studies brain activity in pairs of people as they make up a story together over the internet, with one subject in a scanner at Dartmouth and the other in a scanner at Harvard University. This method of hyperscanning may reveal what's special about people working together.

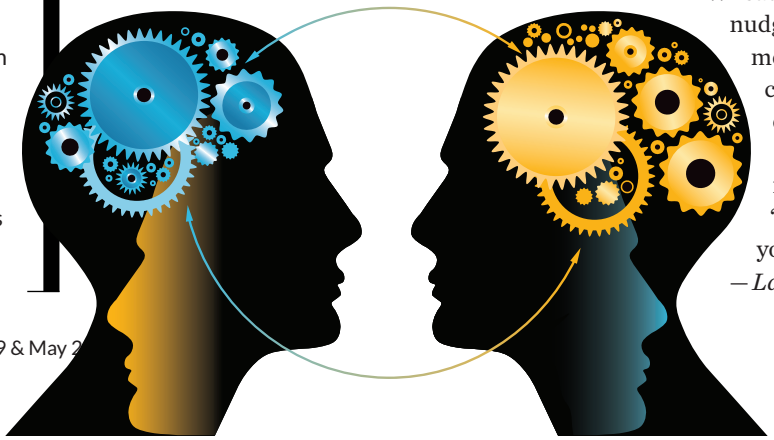
When two people interact this way, "we're creating something that doesn't just come from me, and it doesn't just come from you," Wheatley says. "There's something special about putting our minds together, about putting our heads together, to create something new that couldn't have existed before."

Mind-to-mind interactions, Wheatley suspects, lead to something greater than the sum of their parts — a superbrain, an übermind. (She hasn't yet settled on a term.) Her lab has been working with mathematicians on how to measure any possible additive effect.

Such interactions may become even more important for partners who spend decades together. When a partner dies, the surviving spouse's health often declines fast. Wheatley wonders if that rapid decline might be explained by the sudden change to the partners' shared supermind. "It's like you have taken this other mind as part of you," she says. After one partner dies, "that mind is gone," and the remaining one may be thrown off-kilter, she says.

Wheatley and others hope to nudge neuroscience toward a more holistic view of human cognition. In keeping brain experiments too basic, scientists can "lose the meaning," Wheatley says. "You're missing a lot if you're studying one person."

— Laura Sanders



BRANKOSPEJS/ISTOCK/GETTY IMAGES PLUS, ADAPTED BY E. OTWELL

FOR DAILY USE

Cats may recognize their own names

Whether practical, dramatical or pragmatical, domestic cats (*Felis catus*) can distinguish their own names from other words.

"Many cat owners feel that cats know their names, or the word 'food,'" says Atsuko Saito, a psychologist at Sophia University in Tokyo and a cat owner. But until now, there was no scientific evidence to back that up.

So Saito and her colleagues pounced on the research question, asking cat owners to say four nouns of similar length followed by the cat's name. Cats gradually lost interest with each noun, but then reacted strongly to their names — moving their ears, head or tail, shifting their hind paws or meowing. The results held up with cats living alone or living with other cats in a home or in a cat café, where customers can mingle with cats. When someone other than the owner said a name, the cats still responded more than to other nouns.

One finding did give the team pause. Cats at cat cafés reacted to their names as well as to those of other café cats. Because many people visit cat cafés, and cats' names are often called together, it may be harder for cats to associate their own names with positive reinforcement in these environments, the researchers suggest April 4 in *Scientific Reports*.

As for whether a cat understands what a name is? Well, only the cat knows that. — *Helen Thompson*

This fossilized jawbone, about 69 centimeters in length, belongs to a new species of ancient whale.

INTRODUCING

Peruvian fossils reveal a hooved, otterlike whale

An ancient four-legged whale walked the land on hooved toes and swam in the sea like an otter. The newly discovered species turned up in 2011 in a cache of fossilized bones in Playa Media Luna, a dry coastal area of Peru.

Jawbones and teeth pegged the animal as an ancient whale. More bones followed. "We were definitely surprised to find this type of whale in these layers," says Olivier Lambert, a paleontologist at the Royal Belgian Institute of Natural Sciences in Brussels. The jaw, tooth and spine features, described online April 4 in *Current Biology*, don't match any other whale in the fossil record, setting the creature apart as a new species, dubbed *Peregocetus pacificus* (meaning "the traveling whale that reached the Pacific Ocean").

At 42.6 million years old, the fossilized whale skeleton is the oldest found in the Americas. About 4 meters long, the animal was roughly the size of a small beluga whale or a Volkswagen Beetle. Big, possibly webbed feet and long toes would have allowed *P. pacificus* to dog-paddle or swim freestyle. The whale's vertebrae suggest the tail functioned like a paddle, as seen in modern beavers and otters. With tiny hooves and strong legs and hips, the animal could walk on land. But "it was definitely a better swimmer than walker," Lambert says. — *Helen Thompson*

HOW BIZARRE

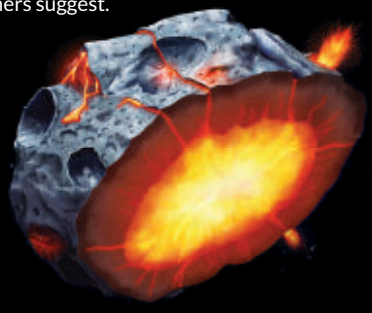
Metal asteroids maybe had iron volcanoes

Imagine an asteroid spewing molten iron. That's ferrovolcanism, a newly proposed type of planetary activity.

Metal asteroids are thought to be iron-rich cores left bare after fledgling planets suffered catastrophic collisions. Exposed to space, a naked core would have cooled from the outside, forming an iron crust denser than the molten material underneath, says a team of planetary scientists from the University of California, Santa Cruz. The same kind of density mismatch drives Earth's volcanoes, with more buoyant material rising through cracks in the crust.

Another ferrovolcanism theory involves an iron core containing bits of rock and sulfur within a rocky crust. As the core cooled, pockets of iron-rich liquid with dissolved sulfur would have hardened more slowly than the surrounding material. Those pockets, more buoyant than the rock above, would force their way up and out, says planetary scientist Brandon Johnson of Brown University in Providence, R.I.

The two theories were presented March 21 at the Lunar and Planetary Science Conference in The Woodlands, Texas. A NASA mission to metal asteroid Psyche will check in 2026 for signs of such activity in the object's past. — *Lisa Grossman*



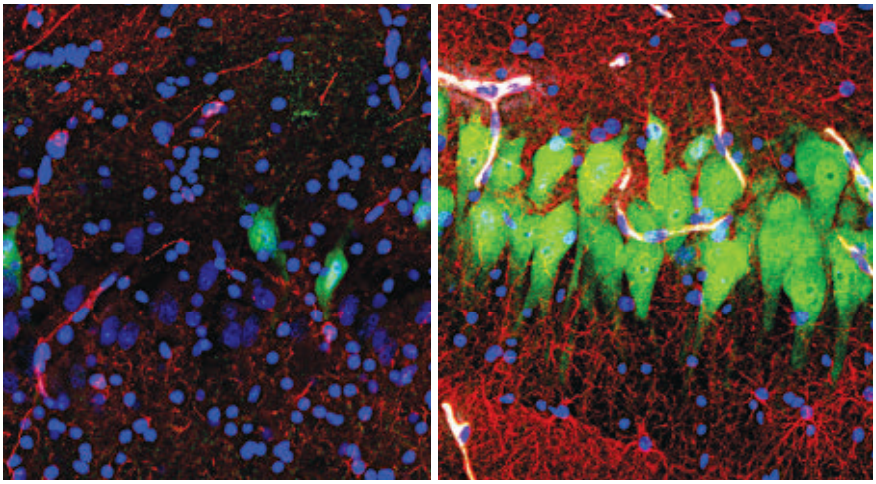
Long ago, molten iron could have erupted from the metal asteroid Psyche (illustrated in cross section) in a process dubbed ferrovolcanism, researchers suggest.

FROM TOP: DAN ZEN/FLICKR (CC BY 2.0); O. LAMBERT; ELENA HARTLEY

BODY & BRAIN

Dead pig brains show signs of life

Artificial fluid kept nerve cells oxygenated, fed and active



Ten hours after death, cells in a pig brain normally deteriorate (left). But a new system called Brain*Ex* kept nerve cells (green) and support cells called astrocytes (red) healthy (right).

BY LAURA SANDERS

Cellular activity has been restored to pig brains hours after the animals' death — an unprecedented feat. This revival, achieved with a sophisticated system of artificial fluid, took place four hours after the pigs' demise at a slaughterhouse.

"This is a huge breakthrough," says ethicist and legal scholar Nita Farahany of Duke University, who wasn't involved in the research. "It fundamentally challenges existing beliefs in neuroscience. The idea of the irreversibility of loss of brain function clearly isn't true."

The results, reported in the April 18 *Nature*, may lead to better treatments for brain damage caused by stroke or other injuries that starve brain tissue of oxygen. The achievement also raises significant ethical puzzles about research on brains that are not alive, but not completely dead either.

> "The idea of the irreversibility of loss of brain function clearly isn't true."
>
> NITA FARAHANY

In the study, the brains showed no signs of the widespread neural activity thought to be required for consciousness, but individual nerve cells were still firing. "There's this gray zone between dead animals and living animals," says Farahany, who coauthored a perspective piece in *Nature*.

The experiments were conducted on pigs that had been killed in a food processing plant. These animals were destined to become pork. "No animals died for this study," the authors of the new work write in their research article.

After decapitation, about 300 pig heads were put on ice and transported to a Yale University lab, where researchers surgically removed the brains. Four hours postmortem, researchers put 32 of these brains in an artificial system known as Brain*Ex* — a chamber with specially designed blood replacement fluid that pumps through the blood vessels, delivering oxygen, sugar and other sustaining ingredients at body temperature to keep the brains operating.

During six hours in the Brain*Ex* system, these dead brains showed signs of activity. Oxygen and sugar went into the brain tissue, and carbon dioxide came out. That suggested the brains were still busy metabolically. Some of the nerve cells in the prefrontal cortex and hippocampus, key brain areas for complex thinking, appeared healthy under a microscope. And nerve cells could still fire off signals, studies on individual cells in brain slices showed. In contrast, brains that weren't in the Brain*Ex* system deteriorated.

The results suggest that brains, perhaps even human ones, are much more resilient than once thought. "That's the punch line," says study coauthor Nenad Sestan, a neuroscientist at Yale. The technique offers a new way to study animal brains in labs, experiments that might yield insights into countering human brain damage caused by strokes or other injuries, he says.

The study is also notable for what it did not observe — coordinated widespread brain activity that could be detected by electrodes on the brains' surfaces. That sort of activity can indicate some level of awareness. If the scientists had observed such signals, the experiment would have been stopped immediately, says study coauthor Stephen Latham, a bioethicist at Yale. "If it does happen, we're going to have to regroup because it would pose this unique problem of creating some kind of experience or awareness in an organ that's completely isolated from any living being," he says.

In the Brain*Ex* system, the fluid was designed to contain a compound that blocks neural activity; researchers suspected that too much nerve cell action would be harmful to the brains. The scientists don't know whether removing that compound would have allowed more complex patterns of activity, or whether such signals would eventually emerge after more time in the fluid.

Brain*Ex* isn't close to being ready to be used on human brains, scientists say. Still, the research raises the possibility that similar approaches could one day restore some function to human brain tissue.

Rules for experiments involving living people are strict, Christine Grady, a bioethicist at the National Institutes of Health in Bethesda, Md., said in an April 16 news briefing. "Once a human dies and their tissue is in a laboratory, there are many fewer restrictions on what can be done," Grady said. New abilities to preserve dead tissue will spur people to think about "whether or not there need to be new rules about how we deal with those tissues," whether they come from a pig or a person. ■

STEFANO G. DANIELE, ZVONIMIR VRSELJA, SESTAN LAB/YALE SCHOOL OF MEDICINE

HUMANS & SOCIETY

Fossils suggest a new hominid species

Homo luzonensis lived at least 50,000 years ago in the Philippines

BY BRUCE BOWER

A new member of the human genus has been found in a cave in the Philippines, researchers report.

Fossils with distinctive features indicate that the hominid species inhabited the island now known as Luzon at least 50,000 years ago, according to a study published in the April 11 *Nature*. That species, which the scientists have dubbed *Homo luzonensis*, lived at the same time that controversial half-sized hominids named *Homo floresiensis* and nicknamed hobbits were roaming an Indonesian island to the south called Flores (*SN: 7/9/16, p. 6*).

In shape and size, some of the fossils match those of corresponding bones from other *Homo* species. "But if you take the whole combination of features for *H. luzonensis*, no other *Homo* species is similar," says study coauthor and paleoanthropologist Florent Détroit of the French National Museum of Natural History in Paris.

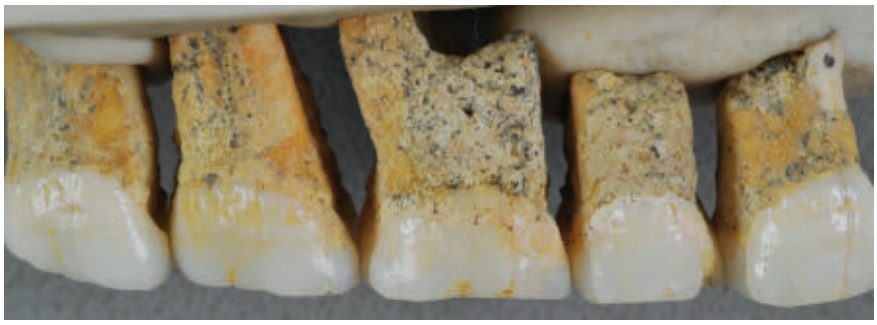
If the finding holds up to further scrutiny, it would add to recent fossil and DNA evidence indicating that several *Homo* lineages already occupied East Asia and Southeast Asian islands by the time *Homo sapiens* reached what's now southern China between 80,000 and 120,000 years ago (*SN: 11/14/15, p. 15*). The result: an increasingly complicated picture of hominid evolution in Asia.

Excavations in 2007, 2011 and 2015 at Luzon's Callao Cave yielded a dozen *H. luzonensis* fossils at first — seven isolated teeth (five from the same individual), two finger bones, two toe bones and an upper leg bone missing its ends, the scientists say. Analysis of the radioactive decay of uranium in one tooth suggested a minimum age of 50,000 years. Based on those fossils, a hominid foot bone found in 2007 in the same cave sediment was also identified as *H. luzonensis*. It dates to at least 67,000 years ago.

The fossils reveal an unusual jumble of shapes and sizes. *H. luzonensis* had molars that were especially small, even smaller than those of hobbits, with some features similar to present-day humans' molars. The hominid also had relatively large premolars that, surprisingly, had two or three roots rather than one. Hominids dating to several hundred thousand years ago or more, such as *Homo erectus*, typically had premolars with multiple roots. *H. luzonensis* finger and toe bones are curved, suggesting a tree-climbing ability comparable to hominids from 2 million years ago or more.

It's unclear whether *H. luzonensis* was as small as hobbits, Détroit says. The best-preserved hobbit skeleton comes from a female who stood about a meter tall. Based on the length of the Callao Cave foot bone, Détroit's team suspects that *H. luzonensis* was taller than that, although still smaller than most human adults today.

A distinctive mix of features on these five fossil teeth from the same individual, unearthed in the Philippines, helped researchers conclude that they had found a new hominid species.



CALLAO CAVE ARCHAEOLOGY PROJECT

As with hobbits, *H. luzonensis*' evolutionary origins are unknown. Scientists think that hobbits may have descended from seagoing *H. erectus* groups, and perhaps *H. luzonensis* did too, writes paleoanthropologist Matthew Tocheri of Lakehead University in Thunder Bay, Canada, in a commentary published with the new report. Evidence suggests that hominids reached Luzon by around 700,000 years ago (*SN Online: 5/2/18*). So *H. erectus* may have crossed the sea from other Indonesian islands or mainland Asia to Luzon and then evolved into *H. luzonensis* with its smaller body and unusual skeletal traits, a process known as island dwarfing, Détroit speculates.

But some scientists say it's too soon to declare the fossils a new *Homo* species. Détroit's group, so far, has been unable to extract ancient DNA from the fossils. So "all [evolutionary] possibilities must remain open," says Katerina Douka, an archaeologist at the Max Planck Institute for the Science of Human History in Jena, Germany.

The fossil features that the team interprets as distinctive, for instance, may have resulted from interbreeding between two or more earlier *Homo* species, creating hybrids, not a new species.

Or perhaps a small population of, say, *H. erectus* that survived on an isolated island like Luzon for possibly hundreds of thousands of years simply acquired some skeletal features that its mainland peers lacked, rather than evolving into an entirely new species, says paleoanthropologist María Martinón-Torres.

Those questions make the new fossils "an exciting and puzzling discovery," says Martinón-Torres, director of the National Research Centre on Human Evolution in Burgos, Spain.

If the unusual teeth and climbing-ready hand and foot bones found at Callao Cave occurred as a package among Luzon's ancient *Homo* crowd, "then that combination is unique and unknown so far" among hominids, Martinón-Torres says. Only a more complete set of fossils, ideally complemented by ancient DNA, she adds, can illuminate whether such traits marked a new *Homo* member. ■

ATOM & COSMOS

Meteor showers kick up lunar water

Moon's soil holds moisture, new orbiter observations show

BY LISA GROSSMAN

Meteor showers bring moon geysers. A lunar orbiter spotted extra water around the moon when the moon passed through streams of cosmic dust that can cause meteor showers on Earth.

The water was probably released from lunar soil by tiny meteorite impacts, planetary scientist Mehdi Benna of NASA Goddard Space Flight Center in Greenbelt, Md., and colleagues report online April 15 in *Nature Geoscience*. Those random impacts suggest that water is buried all over the moon, rather than isolated in freezing dark craters — and that the moon has been wet for billions of years.

Samples of lunar soil brought back by Apollo astronauts suggested that the moon is bone-dry. But more recent, remote missions have found water deposits, including signs of frozen surface water in regions of permanent shadow near the moon's poles.

"We knew there was water in the soil," Benna says. What scientists didn't know was how widespread that water was, or how long it had been there.

Benna and colleagues used observations from NASA's LADEE spacecraft, which collected data from lunar orbit from November 2013 to April 2014. LADEE's spectrometers detected dozens of sharp increases in the abundance of water molecules in the moon's exosphere, the tenuous atmosphere of gas molecules that clings to the moon. Twenty-nine of those measurements coincided with known streams of space dust.

When Earth passes through those streams, the dust burns up in the atmosphere, producing annual meteor showers like the Leonids and the Geminids. But because the moon has no true atmosphere, bits of dust from the same streams strike the moon's surface directly, stirring up what lies beneath.

Benna and colleagues calculated that only meteorites heavier than about 0.15 grams released the water. That means the top eight centimeters or so of lunar soil are indeed dry — smaller impacts would have released water if any was there. Beneath that dry coating is a global layer of hydrated soil, with water ice clinging to dust grains.

But the moon is by no means soggy. Squeezing half a ton of lunar soil would yield barely a small bottle of water, Benna says. "It's not a lot of water by any measure, but it's still water." And it's too much water to have arrived at the moon recently, he says. The moon may have held on to at least some of this water since the time of its formation (*SN: 4/15/17, p. 18*).

Future studies could help figure out whether and how that water could be useful for human explorers on the moon.

The finding is "plausible and certainly provocative," says planetary scientist Erik Asphaug of the University of Arizona in Tucson. "It's the kind of paper that is good to see published so we can debate it." ■

ATOM & COSMOS

Planetary remnant defied star's death

Relic orbiting white dwarf may preview solar system's fate

BY MARIA TEMMING

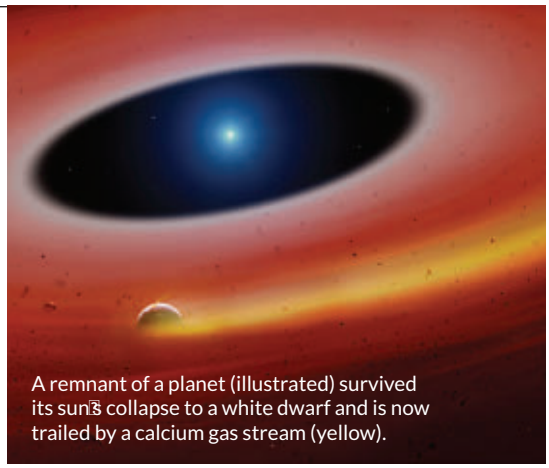
Against all odds, a small planetary body has survived the infernal death of its sunlike star and now orbits the white dwarf that remains.

When most planet-hosting stars run out of hydrogen fuel, they blow out their outer shells of gas, obliterating their inner solar systems and leaving behind a dead star called a white dwarf. Planets orbiting farther out can survive this initial cataclysm, but if those planets move in closer, they also get ripped apart (*SN Online: 10/21/15*) and gobbled up by the dead star's intense gravity (*SN: 9/24/11, p. 10*).

The rare discovery of an intact planetesimal still orbiting close to the white dwarf SDSS J1228+1040, reported in the April 5 *Science*, could offer insight into the fate of solar systems like our own and the chemical makeup of planets.

Astronomers led by Christopher Manser of the University of Warwick in England used the Gran Telescopio Canarias in Spain's Canary Islands to peer at the debris disk surrounding the white dwarf, about 400 light-years from Earth, over two nights in spring 2017 and three nights in spring 2018. Those observations revealed a slight brightening and dimming of certain wavelengths of light in the disk every two hours. That indicated the presence of a cometlike tail of calcium gas trailing a planetesimal as it whips around its star.

The gaseous jet stream may be generated by the white dwarf's radiation blasting calcium off the planetesimal, or by the planetesimal vaporizing calcium dust as it plows through surrounding rubble,



A remnant of a planet (illustrated) survived its sun's collapse to a white dwarf and is now trailed by a calcium gas stream (yellow).

MARK GARLICK/UNIV. OF WARWICK

Manser says. This hardy hunk of rock hugs its star extremely closely, orbiting just one three-hundredth of the distance from the sun to Earth. Since it is able to survive the intense gravity without being shredded, the planetesimal is probably a dense, iron-rich object just a few hundred kilometers across — possibly the core of a planet whose outer layers have been stripped away, the researchers suggest. ■

GENES & CELLS

Genetic score predicts obesity

Critics say that forecast tools must also account for lifestyle

BY TINA HESMAN SAEY

There's a new way to predict whether a baby will grow into an obese adult.

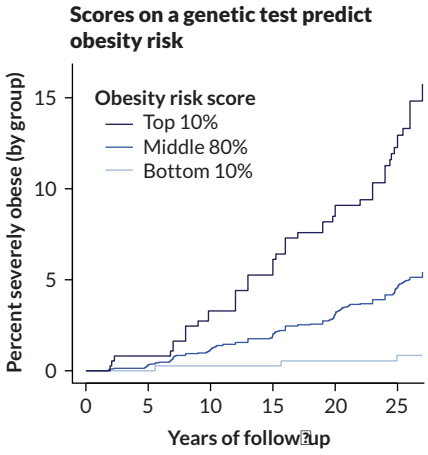
Combining the effect of more than 2.1 million genetic variants, researchers have created a genetic predisposition score that the scientists say predicts severe obesity. By middle age, people with scores in the highest 10 percent weighed, on average, 13 kilograms (about 29 pounds) more than those with the lowest 10 percent of scores, the team reports in the April 18 *Cell*.

The finding may better quantify the role of genes in obesity than previous prediction scores but still fails to account for lifestyle, which may be more important in determining body weight, other researchers say.

Still, the research shows that "your genetics really start to take hold very early in life," says cardiologist Amit Khera of Massachusetts General Hospital and the Broad Institute of MIT and Harvard. Weight differences showed up as early as age 3, and by age 18, those with the highest obesity risk scores weighed 12.3 kilograms more on average than those with the lowest scores, Khera and his colleagues found. Some people with high scores had normal body weights, but those people may have to work harder to maintain a healthy weight than others, he says.

People with the highest scores were 25 times as likely to have severe obesity — a body mass index greater than 40 — as those with the lowest scores. BMI is a measurement of body fat based on height and weight. A BMI of 18.5 to 24.9 (calculated as kilograms per meters squared of height) is considered healthy. BMIs of 30 and above are considered obese.

The nearly 13-kilogram difference between people dealt a good genetic hand versus those dealt a bad one equals about five BMI points, Khera says. "Five points is a lot," he adds. "That's what takes you from normal to obese, from obese to severely obese." High scores were also associated with increased risk of heart disease, diabetes, high blood pressure and stroke.



Separate paths People with the highest 10 percent of scores on a genetic test for obesity risk were more likely to develop severe obesity than those with lower scores.

But other scientists are skeptical that the score is an accurate predictor of obesity risk.

"I'm not convinced at all," says Ruth Loos, a genetic epidemiologist at the Icahn School of Medicine at Mount Sinai in New York City. Genes are responsible for about half of people's susceptibility to obesity, but lifestyle factors such as diet and exercise are equally or even more important, she says. "Even if you have a genetic score that perfectly captures that 50 percent of genetics, you still will not be able to predict anyone's future risk of obesity." Without figuring in the lifestyle factors, she says, "you will never be accurate."

Together, the 2.1 million genetic variants used in the study account for less than 10 percent of genes' contribution to obesity, making the score a blunt tool that could lead to inaccurate predictions, Loos says. For instance, the scores of 3,722 people in the Framingham Offspring/CARDIA study group, one group of people that the researchers used to test the genetic score, suggested that 371 of the highest scorers would become severely obese. But only 58 of them did. "The score said bluntly, if you're in the top decile, you'll become severely obese," Loos says. "So you basically scared people who were not supposed to be scared."

On the flip side, the score would have failed to warn 171 of the 229 people who became severely obese in the Framingham/CARDIA group that they would gain so much weight, Loos says. "If you simply use the score and don't account for lifestyle, you'll be wrong many times."

Khera and colleagues hope that the score will help erase the stigma associated with obesity and shed some light on the biology behind the condition. Although people with high genetic risks may have a harder time avoiding weight gain or losing weight, they also might be the people who benefit most from weight-control drugs or other measures, Khera says.

Endocrinologist and geneticist Mark Goodarzi of Cedars Sinai Medical Center in Los Angeles worries that giving people a prediction of looming obesity could backfire. That has already happened in at least one study. People who were warned that their genes predisposed them to obesity ate more after learning of the propensity, he says. "I think they figured, 'I'm doomed. I'm going to be obese anyway. Why fight it?' " Other studies have showed no change in people's behavior after learning their genetic risks, he says.

It is not clear how doctors might use the score in treating patients, says A. Cecile Janssens, an epidemiologist at Emory University in Atlanta. "You should at least say in the discussion, 'If we identify the people in the highest 10 percent, we can do X, Y and Z with these people, which we wouldn't do with everyone else,' " she says.

And instead of focusing on severe obesity, Janssens says, it might be more useful to be able to predict whether overweight people might become obese in order to prevent that transition. "You can [more] easily lose a few pounds than 30 or 40 pounds," she says. ■

A.V. KHERA *ET AL*/*CELL* 2019

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EARTH & ENVIRONMENT

Tiny microplastics fly far on the wind

Airborne plastic bits can land more than 95 kilometers away

BY CAROLYN GRAMLING

Plastic pollution from Paris doesn't necessarily stay in Paris.

Tiny bits of plastic that originated in cities were carried by wind to a remote mountain location over 95 kilometers away, a study finds. It's the first demonstration that microplastics, ranging from a few nanometers to 5 millimeters in size, can travel far through the atmosphere.

Even more startling is how much microplastic fell from the sky in such a remote location, the researchers say. The rain of microplastics in some far-flung places may rival that of some large cities.

"We found them somewhere they shouldn't be," says atmospheric and environmental scientist Deonie Allen of EcoLab in Castanet-Tolosan, France.

Allen and colleagues set up two types of atmospheric deposition collectors at the Bernadouze meteorological station, in the Pyrenees Mountains between France and Spain. About 365 microplastic particles per square meter per day, on average, were deposited at the site, the team reports online April 15 in *Nature Geoscience*. That's a rate that "is similar to what's happening in Paris," Allen says.

But the size and relative composition of the plastics differed from those found in previous studies in Paris or Dongguan, China. The dominant particles in those cities were slender fibers larger than about 100 micrometers and composed of polypropylene or polyethylene terephthalate, called PET. Such fibers often originate in clothing or other textiles.

At the Pyrenees site, however, most of the plastic bits were smaller than 25 micrometers and consisted mostly of polystyrene and polyethylene fragments, common in many packing materials.

Polystyrene is susceptible to degradation by weathering or by solar ultraviolet rays, making worn-down bits more easily transportable by wind. At the Pyrenees site, higher wind speeds as well as brief bursts of intense rain or snow appear to be linked to higher deposition rates.

A simulation of wind speeds and directions suggested that the plastics traveled at least 95 kilometers to reach the site. But the plastics probably came from farther, Allen says, because no highly populated industrial cities lie in that region.

"Unfortunately, [the study] confirms the ubiquitous contamination of our environment by microplastics," says Johnny Gaspéri, an environmental scientist at the Université Paris-Est Créteil. ■

EARTH & ENVIRONMENT

Lab study reveals volcanic secret

Pyroclastic flows' dual layers explain long-distance travel ability

BY MARIA TEMMING

Dumping tons of volcanic material down a lab flume may finally have revealed how searing mixtures of hot gas and rock travel so far from volcanic eruptions.

These pyroclastic flows can travel tens to hundreds of kilometers over rough terrain and even uphill (*SN: 7/7/18, p. 32*). Despite being made of gritty volcanic rock, "they seem to have as much friction with the ground as if they were made of water," says Alain Burgisser, a geologist at the University Savoie Mont Blanc in France. The driving force behind these flows "has always been a mystery."

Now, lab experiments and computer simulations suggest that in pyroclastic flows, a dense layer of material glides across the ground atop a low-friction layer made largely of air. These findings, reported online April 8 in *Nature Geoscience*, may lead to more accurate forecasts of the speed and spread of these flows.

Simulating avalanches of volcanic material called pyroclastic flows in the lab shows how these currents cover so much ground.

ANDERSEN_OYSTEIN/ISTOCK/GETTY IMAGES PLUS

Gert Lube, a volcanologist at Massey University in Palmerston North, New Zealand, and colleagues created mini pyroclastic flows by piling volcanic material into a giant hopper and heating the rock up to 130° Celsius. When the researchers dumped the hot volcanic material down a 12-meter chute, a dilute layer emerged at the bottom of the flow, topped with a layer of more densely packed volcanic matter. This sparse underlying layer develops because, near the bottom of the flow, material right next to the ground moves much more slowly than the material slightly above.

This difference in flow rate creates low air pressure close to the ground, so gas from higher-pressure areas migrates downward, creating an air-rich base layer. Particles in the top of the flow glide along this airy cushion like disks on an air hockey table and so travel long distances.

Computer simulations indicated that this friction-defying phenomenon occurs in life-size pyroclastic flows, too. ■

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Emus (an adult shown with a chick) and related birds may have lost the ability to fly because of changes in DNA that regulates genes.

GRAEME CHAPMAN

GENES & CELLS

Birds' flight loss tied to regulatory DNA

Gene controls, not altered proteins, perhaps grounded ratites

BY TINA HESMAN SAEY

Evolutionary tweaks to DNA that bosses genes around may have grounded some birds.

New genetic analyses show that mutations in regulatory DNA caused ratite birds to lose the ability to fly up to five times over their evolution, researchers report in the April 5 *Science*. Ratites include emus, ostriches, kiwis, rheas, cassowaries, tinamous and extinct moa and elephant birds. Only tinamous can fly.

Regulatory DNA governs when and where genes are turned on and off. It doesn't contain instructions for making proteins. Researchers have long debated whether big evolutionary changes, such as gaining or losing a trait like flight, occur mostly because of mutations to protein-making genes or mainly from tweaks to regulatory DNA.

Revealing the importance of regulatory DNA in evolution could shed light on how closely related species with the same genes, such as chimps and humans or moas and tinamous, can develop vastly different looks and abilities.

Scientists have stressed the importance of protein-coding changes affecting the evolution of various traits in many organisms. For instance, a study of flightless Galápagos cormorants suggested that mutations in a single gene shrank the birds' wings (*SN: 6/11/16, p. 11*).

In general, mutations that alter proteins are likely to be more damaging than changes to regulatory DNA, and thus easier to spot, says evolutionary geneticist Camille Berthelot of the French national medical research institute INSERM in Paris. A protein may be involved in many processes throughout the body. "So everywhere this protein is [made], there's going to be consequences," she says.

By contrast, many pieces of DNA may be involved in regulating a gene's activity, and each may work in only one or a few types of tissue. That reduces the damage that changing one regulatory segment might have. At the same time, it's harder to see when regulatory DNA is actually involved in big evolutionary changes, says Megan Phifer-Rixey, an evolutionary geneticist at Monmouth University in West Long Branch, N.J. Those pieces of DNA don't all look alike and may have changed a lot from species to species.

Evolutionary biologist Scott Edwards of Harvard University and colleagues got around that problem by deciphering the genetic instruction books, or genomes, of 11 species of birds, eight of them flightless. The team then lined up those genomes alongside already completed genomes from birds including ostriches, North Island brown kiwis, and Emperor and Adélie penguins as well as white-throated tinamous and 25 other flying bird species.

The researchers were looking for regulatory DNA that hadn't changed much during the birds' evolution, an indication that the DNA performs an important function. Among 284,001 shared, relatively unchanging stretches of regulatory DNA, the researchers found 2,355 that had accumulated more mutations than expected in ratite birds, but not in other bird lineages. The plethora of mutations indicates that those bits of regulatory DNA are evolving faster than other parts of the genome and may have lost their original functions. The team concluded that at least three and possibly as many as five branches on the ratite family tree independently lost the ability to fly.

Those regulatory DNA bits tended to be near genes involved in limb development, indicating that they might tweak gene activity to produce smaller wings. The team tested the ability of one regulatory DNA bit, called an enhancer, to turn on a gene in embryonic chicken wings. A version of the enhancer from elegant-crested tinamous — which can fly — turned on the gene, but a version from the flightless greater rhea didn't. That suggests that changes in the enhancer might have disabled the wing-development function, leading to flightlessness in rheas.

One hypothesis for why most ratites are flightless is that the ancestor of all the species had lost the ability to fly, and tinamous later regained it. "We simply don't think that's very plausible," Edwards says. Rather, the ancestor of ratites probably could fly and tinamous retained that ability, while related birds lost the ability, mostly because of changes in regulatory DNA, he says. "My hunch is that it's relatively easy to lose flight."

The researchers also found that over 200 protein-coding genes were building up mutations faster than expected in flightless ratites, but those genes tended to be related to metabolism rather than shrinking wings. Those changes aren't as important for loss of flight as regulatory DNA changes, the researchers conclude.

Luisa Pallares, an evolutionary biologist at Princeton University, is not convinced. Both regulatory DNA changes and protein-coding changes happen and may be equally important in shaping evolution, she says. ■

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HUMANS & SOCIETY

Not all poor neighborhoods are alike

Exposure to lead and violence can affect kids' upward mobility

BY SUJATA GUPTA

Chicago's newly elected mayor, Lori Lightfoot, pledged in her victory speech on April 2 to "make Chicago a place where your zip code doesn't determine your destiny." Turning that pledge into reality will require addressing more than poverty, according to a study that followed the lives of thousands of children in the city.

Kids from low-income neighborhoods that are beset by high rates of violence, incarceration and lead exposure earn less money, on average, in adulthood than equally poor children from less hazardous neighborhoods. Children from these grittier neighborhoods are also more likely to become pregnant as teenagers or to be jailed in their 20s or 30s than children from less "toxic" communities, researchers report in the April 16 *Proceedings of the National Academy of Sciences*.

"One thing that's particularly painful about poverty right now is you're getting hit from all these different angles," from higher local crime and violence to more environmental contaminants like lead, says coauthor Robert Manduca, a Harvard University sociologist.

Both black and white children who grew up in these toxic communities suffered the long-term effects. But citywide, black children were more exposed to the hazards than white kids. Chicago's neighborhoods remain largely segregated, and predominately black neighborhoods tend to have higher crime and pollution levels than otherwise comparable white neighborhoods, the team says.

In particular, the results show that if a black boy had grown up with the same hazards present in a poor white neighborhood, his odds of being jailed by adulthood would have dropped from about 12 to 6 percent. And his annual income in his 30s would have been about $4,200 higher. A black girl's likelihood of teen pregnancy would drop from 54 to 44 percent.

The work builds on studies over the last five years involving 20 million U.S. kids born from 1978 to 1983. Those studies, led by Harvard economist Raj Chetty, showed that a child's future income is strongly associated with the neighborhood he or she grew up in as well as the child's race. But Chetty also found large variations in future incomes among kids raised in equally poor neighborhoods.

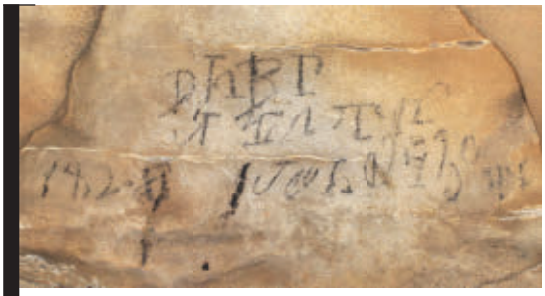
Manduca and Harvard sociologist Robert Sampson explored why some poor children fare better than others. The pair focused on children born in the late 1970s and early '80s, in the same age range as those studied by Chetty. But the researchers considered only children whose parents were earning about $27,000 a year in 2015 dollars, to focus on neighborhood conditions and eliminate income as a variable. The team then tracked those kids as they grew older.

From prison data for 1995 to 2000, the sociologists calculated incarceration rates across 754 Chicago census tracts (a census tract has, on average, 4,000 residents and is roughly equivalent to a neighborhood). The team also looked at police complaints about violence for the same time frame. To gauge overall community lead levels, the researchers looked at more than 150,000 blood tests taken from children from 1995 to 1997.

Exposure to high amounts of those three variables helped explain why poor children in one neighborhood grew up to have worse upward mobility — or the ability to raise one's socioeconomic standing — than equally poor children in another neighborhood.

Most previous work aimed at predicting a child's upward mobility has focused narrowly on poverty and race, says sociologist Christopher Wildeman of Cornell University. Looking at a wider range of neighborhood conditions "significantly broadens the research on intergenerational social mobility," he says.

The researchers are now conducting similar analyses in 54 other U.S. cities. ■



A. CRESSLER, B.D. CARROLL *ET AL/ANTIQUITY* 2019

HUMANS & SOCIETY

Cherokee cave writings reveal sacred messages

Shortly before being forced out of their homeland in the 1830s, Cherokee people of the southeastern United States left written accounts on cave walls of secretive rituals. Now researchers have translated some of those messages.

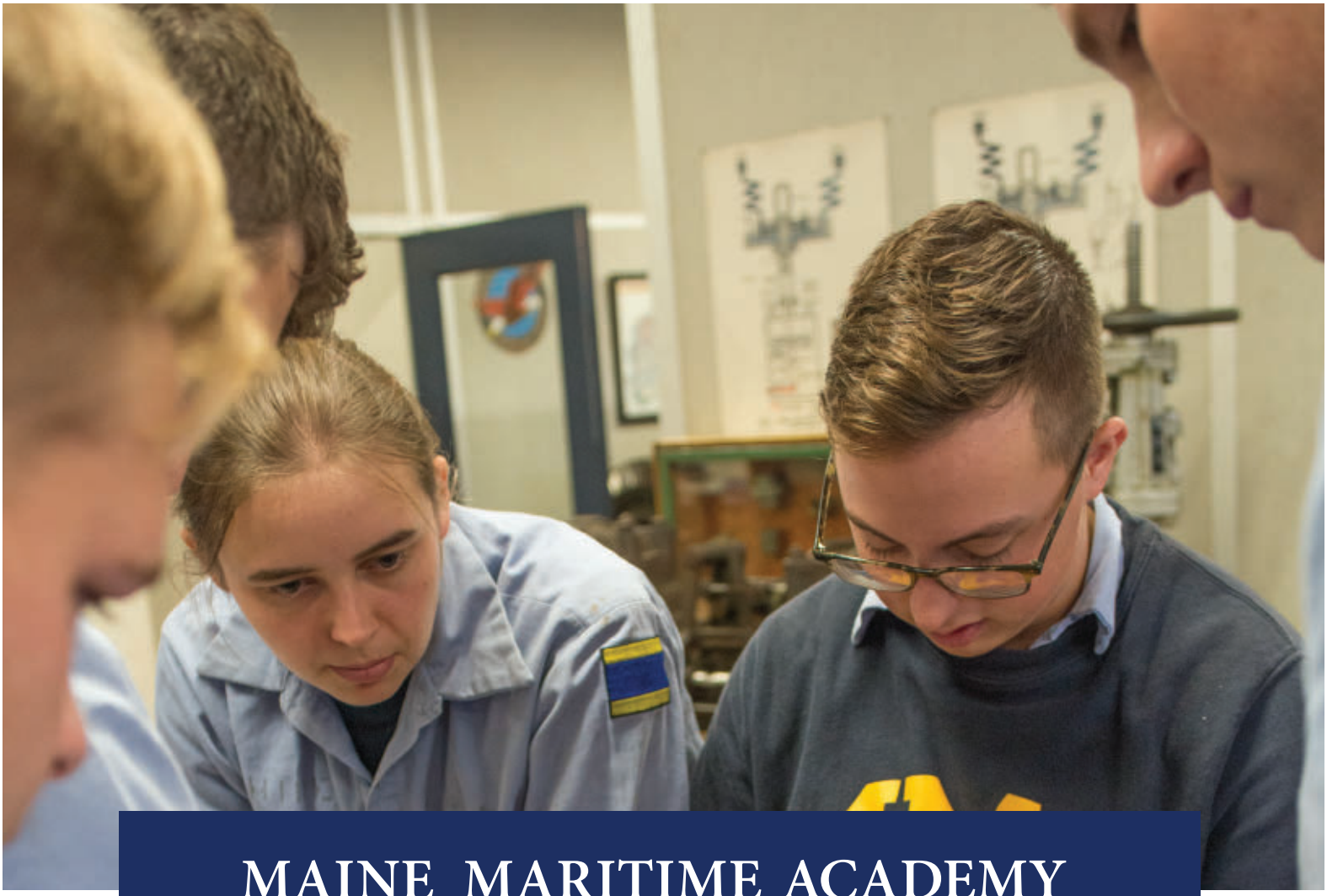
Discovered in 2006, Cherokee inscriptions in Alabama's Manitou Cave describe religious ceremonies and beliefs using written symbols for 85 syllables — enough sounds to replicate the Cherokee spoken language. Cherokee scholar Sequoyah devised this writing system not long before his tribe's banishment down the Trail of Tears, a series of forced relocations of Native Americans to areas to the west.

A team led by archaeologist Beau Duke Carroll of the Tribal Historic Preservation Office of the Eastern Band of Cherokee Indians in Cherokee, N.C., describes in the April *Antiquity* what the writing says.

One inscription (shown above) translates as, "leaders of the stickball team on the 30th day in their month April 1828." Carroll's team suspects that the word "their" refers to European Americans.

Stickball was, and still is, a version of lacrosse played between pairs of communities to achieve spiritual renewal. The inscription commemorates ritual preparations before a game, the scientists say.

Other inscriptions near the cave's entrance may be religious messages to ancestors or other supernatural beings. The script is written backward, likely because it was intended to be read by residents of what the Cherokee considered to be a spirit world reachable only via the cave, the researchers say. — *Bruce Bower*



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BODY & BRAIN

Stress disorders raise heart disease risk

Large study compares cardiovascular incidence for siblings

BY MAANVI SINGH

People coping with psychological trauma have a heightened risk of developing cardiovascular disease, a large study finds.

Researchers used national health registers to identify 136,637 Swedish patients with no history of cardiovascular disease who were diagnosed with a stress-related disorder — a cluster of mental health conditions, including post-traumatic stress disorder, triggered by acute trauma — from 1987 to 2013. The team compared each of these patients with siblings and with unrelated people of the same age and sex, all of whom had a clear bill of mental and heart health.

During their first year after diagnosis, the patients with a stress-related disorder had a 64 percent higher risk of developing cardiovascular disease than their siblings without a mental health diagnosis, and a 71 percent higher risk than unrelated people, the scientists report.

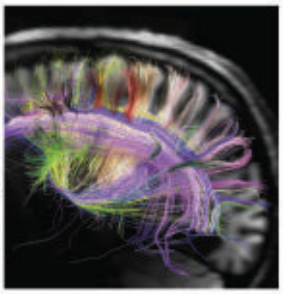
The cardiovascular diseases included heart failure, arrhythmia, stroke, hypertension and heart attack. Those with a stress disorder were most vulnerable during the year following their mental health diagnosis, with nearly seven times the risk of heart failure compared with their siblings. After that first year, patients with a stress diagnosis had a 29 percent higher risk than siblings for all cardiovascular diseases and a 36 percent higher risk than the general population group, researchers report online April 10 in *BMJ*.

"Researchers have been connecting mental health and cardiovascular disease for at least 40 years," says Mary Whooley, a primary care physician and epidemiologist at the University of California, San Francisco who was not involved in the study. But much of the previous research into the link between psychiatric stress and heart health has focused on smaller populations, Whooley says. Often, the focus has been on mostly male veterans with PTSD.

"What's really impressive about this study is the enormous number of patients," she says. More than half the patients with stress-related disorders were women. By comparing siblings, the study was also better able to control for genetic traits and childhood experiences that might contribute to a person's risk of developing cardiovascular disease.

"The large majority of humans are at some point in their lives exposed to trauma," says Huan Song, an epidemiologist at the University of Iceland in Reykjavík who led the study. People lose loved ones, survive accidents and natural disasters and witness violence. "Medical providers should be aware that these vulnerable populations also suffer heightened risks of various cardiovascular diseases," she says. ■

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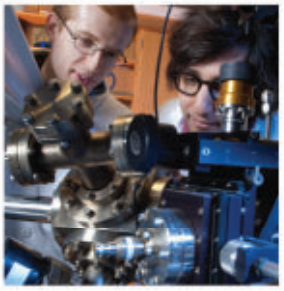


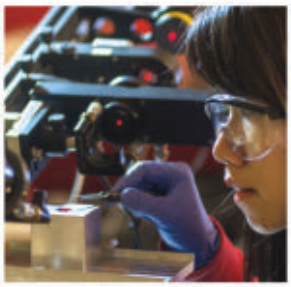
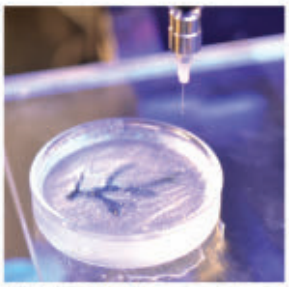

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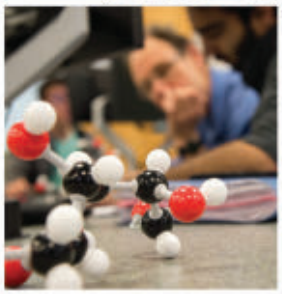

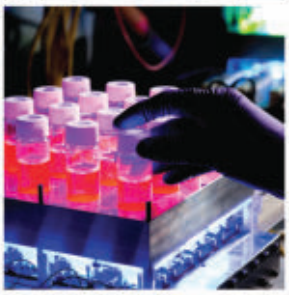

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MATH & TECHNOLOGY

Faster multiplication technique found

Method for big numbers theoretically matches speed prediction

BY EMILY CONOVER

Multiplying 2 x 2 is easy. But multiplying two numbers with more than a billion digits each — that takes some serious computation.

For really big numbers, the grade school multiplication method is too slow to be useful. Now, two mathematicians say that they've found the fastest way yet to multiply extremely large figures.

That feat, described online March 18 at the document archive HAL, has not yet passed peer review. But if the technique holds up to scrutiny, it could prove to be the fastest possible way of multiplying very large whole numbers, or integers, achieving an ultimate speed limit for multiplication suggested nearly 50 years ago.

If you ask an average person what mathematicians do, "they say, 'Oh, they sit in their office multiplying big numbers together,'" jokes coauthor David Harvey of the University of New South Wales in Sydney. "For me, it's actually true."

When making calculations with exorbitantly large numbers, the most important measure of speed is how quickly the number of operations needed — and hence the time required to do the calculation — grows as you multiply longer and longer strings of digits.

That growth is expressed in terms of n, the number of digits in the numbers being multiplied. For the new technique, the number of operations required is proportional to n times the logarithm of n, expressed as O(n log n). That means that if you double the number of digits, the number of operations required will increase a bit faster, more than doubling the time the calculation takes.

But unlike simpler methods, the time needed doesn't quadruple, or otherwise blow up, as the number of digits creeps up, report Harvey and Joris van der Hoeven of the French national research agency CNRS and École Polytechnique in Palaiseau. That makes products of bigger numbers more manageable to calculate.

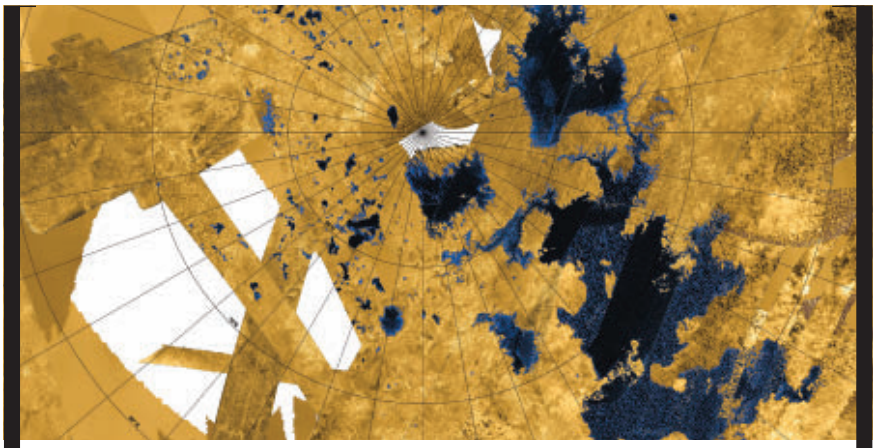
The previously predicted max speed for multiplication was O(n log n), so the new result meets that limit. Although an even speedier technique might be possible, most mathematicians think this is as fast as multiplication can get.

"I was very much astonished that it had been done," says theoretical computer scientist Martin Fürer of Penn State. He discovered a multiplication speedup in 2007 but gave up on improving it.

The new technique won't be faster than competing methods unless you're multiplying outrageously huge numbers. And it's unclear exactly how big those numbers have to be for the technique to win out — or if it's even possible to multiply such big numbers in the real world.

In the new study, the researchers considered numbers with more than roughly $10^{2148570911044552519406350450594173419 52}$ digits when written in binary (encoded with a sequence of 0s and 1s). But the mathematicians didn't actually perform any of these multiplications, because that's vastly more digits than the number of atoms in the known universe. So there's no way to do such calculations on a computer. Even if each bit were so small that it were encoded by a single atom, there wouldn't be enough atoms to represent such huge numbers, much less multiply them. Instead, the team proved theoretically that the method would be speedier than others, at least for large quantities.

It's still possible that the method could work for smaller, but still large numbers, perhaps leading to practical uses, Fürer says. Multiplication of colossal numbers is useful for certain detailed calculations, such as finding new prime numbers with millions of digits (*SN Online: 1/5/18*) or calculating pi to extreme precision. ■



JPL/CALTECH/NASA, ASI, USGS

ATOM & COSMOS

Three lakes disappear on Saturn's moon Titan

Three lakes on Saturn's moon Titan have up and vanished. Previous evidence indicated that Titan's hydrocarbon-filled lakes (shown in blue above) shrink during the moon's summer. But data from the defunct Cassini spacecraft show some lakes disappearing. These phantom lakes offer new insight into the only solar system body other than Earth known to host a hydrological cycle, researchers report April 15 in *Nature Astronomy*. Planetary scientist Shannon MacKenzie of the Johns Hopkins University Applied Physics Laboratory in Laurel, Md., and colleagues found the lakes by comparing Cassini data from two seasons of Titan's year, which lasts 29.5 Earth years. In winter, radar data indicated that all three lakes were filled with liquid. But by spring, all three appeared to have dried up. *Maria Temming*

One teacher shares her blueprint for student success in science fairs

Jeanne Richardson attending the Advocate Training Institute.

Students, project boards, judges, nerves and excitement — all the makings of a science fair, but how does it all come together? We recently talked to Jeanne Richardson, a science teacher from Graham Junior High School in Texas who recently launched a science fair at her school.

Jeanne was named a Society Advocate in 2018. Through the program, Jeanne mentors a cohort of eight underserved students in an after-school club called the *Science Research Team*. She guides these students in their science research and helps them to apply to science competitions, giving them a chance to fulfill their potential.

Jeanne decided to take her Advocate duties one step further and organized the school district's first sanctioned science and engineering fair for *all* grades to participate in.

What were some of the planning challenges?
I learned quickly that requiring other teachers to participate is not the best approach. They all have great ideas to offer and it's better to ask for their input. After assembling a team of teachers, we had over 100 projects in our first sanctioned science fair.

How have other teachers supported you in making the science fair possible?
My Lead Advocate from the Society for Science & the Public has been such a great mentor during this process. She has listened and offered great advice.

What changes have you seen in your students since their participation?
CONFIDENCE. I have watched these students who asked in the beginning, "Why did you pick me?" grow in confidence during the year. They now have the attitude of being the lead scientists in our school because they are a part of the *Science Research Team*.

What is your hope for the future of your students?
My biggest hope is that every one of my students will understand the world they live in a little better, and hopefully care enough to try to make it a better place.

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Astronaut Scott Kelly (left) spent a year in space while his identical twin brother, Mark Kelly (right), remained on Earth in a study on how spaceflight affects the human body.

BODY & BRAIN

Twins reveal space's physical effects

Astronaut comparison finds genetic, cognitive differences

BY JEREMY REHM

For nearly a year, U.S. astronauts and identical twins Scott and Mark Kelly lived lives as separate as Earth and space, literally. While Mark enjoyed retirement in Tucson, his brother floated in microgravity aboard the International Space Station, 400 kilometers above the planet.

Ten science teams studied the twins' physiology, memory abilities and genes before, during and after Scott's 340 days in space. NASA's Twins Study, published in the April 12 *Science*, confirms that lengthy space travel triggers stressors that can manipulate genes, send the immune system into overdrive or impair mental reasoning abilities and memory. Whether these stressors have long-term health repercussions is still unclear.

This is "the most comprehensive view that we've ever had of the response of the human body to spaceflight," says Susan Bailey, a radiation cancer biologist at Colorado State University in Fort Collins who led one of the research teams.

Shortly after entering space in March 2015, Scott took blood samples that were sent back to Earth. Tests revealed chemical markers on more than 1,000 of his genes that weren't in his preflight samples or samples from Mark. The presence of these markers, called epigenetic tags, which are involved in turning genes on or off, can be caused by environmental factors and are reversible. Most affected were genes regulating the repair of DNA and the length of telomeres, the tips of chromosomes, Bailey's team found.

Measurements of Scott's telomeres showed that they had surprisingly grown 14.5 percent longer. The team had expected telomeres to be shortened in the low-gravity, radiation-bathed environment of space. Within 48 hours of his March 2016 return to Earth, though, his telomeres shrank and eventually returned to their preflight length. Several months later, some telomeres were even shorter, the group reports in *Science*.

"That could be where he might be at increased risk," Bailey says. Telomere shortening has been linked to aging and health risks such as cardiovascular disease and cancer (*SN: 12/15/12, p. 13*).

Genes most frequently switched into active mode in those early spaceflight blood samples were those involved in regulating the immune system. That indicates that, while a body is in space, "the immune system is on almost a high alert as a way to try and understand this new environment," says functional genomicist Christopher Mason of Cornell University. His group looked at what genes were affected by spaceflight.

Scott's chromosomes also went through many structural changes, another team found. Chromosome parts were swapped, inverted or even merged — changes that can lead to infertility or certain types of cancer. "These are natural, essential stress responses," says geneticist Michael Snyder of Stanford University, whose group looked for shifts in the twins' metabolisms and protein abundances. Scott's chromosomal changes were probably exacerbated by high-energy particles and cosmic rays in space, Snyder says.

Most of the changes Scott experienced reversed to the preflight state once he returned to Earth. But not all. For instance, 91 percent of the genes that had changed activity in space returned to normal six months later while the rest stayed in space mode. In addition, his immune system was still on high alert, DNA repair genes were overly active and some of his chromosomes were still topsy-turvy. Tests on short-term memory and logic problems showed that his cognitive abilities had declined from preflight levels.

Whether these results are definitely from spaceflight is unclear, partly because the observations are from only one individual. "Bottom line: There's a ton we don't know," Snyder says.

More answers may come from upcoming missions. In October, NASA funded 25 new projects that each could send up to 10 astronauts on yearlong space missions. But to really learn how the space environment impacts health, longer trips are needed. A Mars mission would take a total of about 30 months and go beyond Earth's magnetic field, which shields against DNA-damaging radiation from solar flares and cosmic rays.

Only astronauts on the lunar missions have gone beyond Earth's magnetic field, and for only a handful of days. No one has spent as long as a year in that unprotected environment, let alone 2.5 years.

One way to avoid such lengthy space exposures could be to develop propulsion technologies that can get astronauts to faraway locations more quickly, says Markus Löbrich, a radiation biologist at Technische Universität Darmstadt in Germany who was not involved in the research on the Kelly brothers.

While NASA's Twins Study is impressive, the work underlines the fact that we are not yet ready for longer-term space travel, Löbrich says. For NASA to be able to send people to Mars, he says, "they really will need to think about countermeasures" to the radiation. ■

NASA

Free Lesson Plans NEXT GENERATION: Cord Blood

CORD BLOOD STEM CELLS

Since 1988, there have been more than 35,000 cord blood transplants worldwide. Cord blood is currently used to treat over 80 different diseases including sickle cell anemia, lymphoma and leukemia.

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Intel ISEF 2019 Symposia
Special presentation by
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World-renowned neuroscientist, Dr. Young will discuss his ground-breaking research using cord blood to potentially treat spinal cord injuries.

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MATTER & ENERGY

If coaxed, bacteria can make the toughest kind of spider silk

Bacteria are helping to make engineered silk that rivals the strength and stretchiness of a spider's stiff dragline silk, the type from which the arachnids dangle.

Pound for pound, dragline silk is stronger than steel. Engineers have tried for decades to create a synthetic mimic from genetically modified bacteria, yeast and even goats — with limited success. Part of the challenge is that those organisms slice the long string of repeating DNA that they are given to serve as the blueprint for dragline silk. So researchers precisely separated the repeating DNA into bits and inserted each repeating piece into an *E. coli* microbe. These smaller pieces were less likely to be further altered within the bacteria, and each microbe produced a short strand of silk. The researchers added a chemical tag to the end of each strand that glued individual fibers together.

The material's tensile strength, or resistance to being pulled apart, was 1.03 gigapascals (about the same as for natural dragline silk), and its toughness measured 114 megajoules per cubic meter, compared with about 100 megajoules for spider silk. Engineered strands could stretch 18 percent before breaking, the same as spiders' dragline silk. "We can now use bacteria to produce something as good as nature," says synthetic biologist Fuzhong Zhang of Washington University in St. Louis, who presented the research April 2 in Orlando, Fla., at the American Chemical Society's annual meeting. *Jeremy Rehm*

The silk that spiders dangle from is one of nature's toughest materials, but scientists haven't been able to copy it — until now.

MATTER & ENERGY

Graphene foam stays squishy at lowest temperatures

A graphene-based foam is the first material to remain soft and squishy even at deep cryogenic temperatures.

Most materials become stiff and brittle in extreme cold. But the new foam stays superelastic even when it's subjected to the temperature of liquid helium: about −269 Celsius. A material that remains pliable at such low temperatures could be used to build devices for use in space, researchers report online April 12 in *Science Advances*.

Inside this foam, oxygen atoms connect micrometers-wide patches of the 2-D, carbon-based material graphene to create a meshlike structure. The resulting material is flexible in deep cryogenic conditions because, even at such low temperatures, sheets of graphene are easily bendable and resistant to tearing, and the carbon-oxygen bonds that link these sheets remain strong.

Materials scientist Yongsheng Chen of Nankai University in Tianjin, China, and colleagues compressed samples of the material repeatedly at different temperatures. At −269 C, the foam behaved just as it did at room temperature, bouncing back to almost full size even after being compressed to one-tenth its original thickness. The foam kept this resilience even when heated to about 1000 C and flattened hundreds of times. *Maria Temming*

GENES & CELLS

Some people may have genes that hamper a drug's HIV protection

ORLANDO, FLA. Some people's genes may stop an antiretroviral drug from protecting them against HIV. The drug, called tenofovir, is used for preventing as well as treating an HIV infection. But prevention effectiveness has been mixed, with studies reporting success rates between 78 and 92 percent. It wasn't clear why the drug didn't protect everyone.

Rare genetic variants can prevent tenofovir from becoming active in the body, pharmacologist Namandjé Bumpus of Johns Hopkins University School of Medicine reported April 8 at the 2019 Experimental Biology meeting. People who have HIV or who are at risk of contracting HIV, such as someone whose partner has the virus, take an inactive form of the drug that must be activated in the body in a two-step process. Scientists knew enzymes called kinases are required but until recently weren't sure which of the body's many kinases convert the drug to its active form.

An enzyme called adenylate kinase 2 attaches one phosphate atom to the drug, and another enzyme, creatine kinase, tacks on a second phosphate to spur the drug to action, Bumpus and colleagues discovered. Variants of the kinases are rare: Only 18 adenylate kinase 2 variants were found among 906 people tested. Separately, the researchers tested whether the variants affected the ability of adenylate kinases to activate tenofovir. Of 477 people taking the drug, seven people with variants predicted to disable the enzyme didn't have the active version of tenofovir in their blood, hinting that the variants do affect the drug's effectiveness. *Tina Hesman Saey*

BODY & BRAIN

Common food additive may make flu vaccine less effective

ORLANDO, FLA. A common food additive may make it more difficult to fight the flu. Vaccinated mice that got food containing tert-butylhydroquinone, or tBHQ, took three days longer to recover from the flu than mice that ate tBHQ-free food. The unpublished result hints that the additive may make flu vaccines less effective, toxicologist Robert Freeborn of Michigan State University in East Lansing reported April 7 at the 2019 Experimental Biology meeting.

The additive helps stabilize fats and is used as a preservative for a wide variety of foods, including some cooking oils, frozen meat products (especially fish fillets) and processed foods such as crackers, chips and other fried snacks.

In separate experiments, unvaccinated mice eating tBHQ had more virus RNA in their lungs than mice that didn't eat it. The tBHQ eaters also had inflammation and increased mucus production deeper in their lungs than usual, Freeborn and colleagues found. *Tina Hesman Saey*

KUNTALSAHA/ISTOCK/GETTY IMAGES PLUS

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موسسة الملك عبدالعزيز ورجاله للموهبة والإبداع
King Abdulaziz & his Companions Foundation for Giftedness & Creativity

موهبة

Promoting Passion for Science & Knowledge for the Gifted

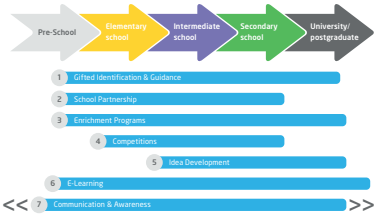
King Abdulaziz and his Companions Foundation for Giftedness & Creativity (known as "Mawhiba" meaning Giftedness) was established in 1999 as a non-profit foundation to support the long term vision of the Kingdom of Saudi Arabia (KSA) for developing giftedness and creativity in KSA. The foundation contributes in building a National Framework for Giftedness & Creativity by identifying and nurturing gifted students by a variety and array of programs and initiatives in STEM domains.

"We will bring together creative and talented people from all over the world to create something different"

HRH Mohammed Bin Salman Al-Saud,
Crown Prince, Deputy Prime Minister
The launch of NEOM project - October 24,2017

Our Mission
We contribute to building a national framework for giftedness and creativity, we provide distinguished care to the gifted, and we promote passion for science and knowledge.

Our Vision
For the Gifted and Creative to Become the Most Important Contributors to the Nation and its Prosperity.



1) Gifted Identification & Guidance:
The "National program for gifted identification" is one of the main gates for gifted students to access Mawhiba programs. It is a joint project between Mawhiba, Ministry of Education, and National Center for Assessment. It ensures sound, fair and unbiased selection procedures of gifted students and contributes in building a national database for gifted students in all regions and cities of KSA. Mawhiba's tests are yearly administered in grade 6 ,3, and 9 in the entire kingdom. This initiative also guides gifted students academically and professionally through the Guidance Program, which helps gifted students who wish to study abroad, and support them in developing a clear academic and professional career.

2) School Partnerships:
An initiative developed to create high-quality educational environment for primary and secondary gifted students to help them reach their full potential. Following identification the gifted students would be offered scholarships to join distinct Mawhiba partnership schools, which are carefully selected and encouraged to develop and to raise their standards in order to qualify. In return, these schools would commit to deliver the Mawhiba enhanced curriculum to Mawhiba students with the option to provide the same acceleration to their own students as well. Support is provided to the schools in the form of continuous teacher professional development, regular assessments, annual tests in the supplemental curriculum, as well as conducting parent orientation workshops. After school STEM programs are also conducted to expand and serve larger number of students and increase opportunities for early identification.

3) Enrichment programs:
An initiative intended to offer enrichment-type programs to supplement the regular school program. Enrichment programs consist of:

a) **Local summer programs**: A range of residential and non-residential three week summer programs that are designed for students entering grade 3 through to grade 11. The programs are offered on the campus of Saudi universities, research centers, leading companies and distinguished schools. They consist of challenging STEM-related academic subjects and advanced activities and skills which promote all personal aspects: intellectual, psychological, social or physical to help students explore and develop their full potential.

b) **International summer programs**: Mawhiba provides a challenging learning experience to optimize academic potential, for 10th and 11th grade students who are English proficient to take part in one of a number of international "off-the-shelf" summer programs for gifted individuals offered at top-tier universities in the US, Canada, UK and Ireland. To complement the conventional international summer programs and make them available to a greater number of students, Mawhiba international summer programs developed a joint venture project with international partners to conduct equivalent international programs in KSA.

4) Competitions
A) **National Olympiad for Scientific Creativity (Ibdaa)**: The National Olympiad for Scientific Creativity "Ibdaa" is a science competition organized by Mawhiba in collaboration with the Ministry of Education.
The idea is based on a pre-college science competition targeted for the age group: 12-7th grade students and complies with ISEF 22 scientific categories. It is considered as the Kingdom's largest pre-college science competition that empowers the next generation of scientists, engineers, and entrepreneurs. This competition develops students' abilities in science research and encourages learning and self-development through science fairs and provides a competitive environment which challenges students' interests and abilities.

b) **Science International Olympiads**: These competitions are worldwide annual international high-quality competitions, held for more than 50 years and are considered an arena for identifying future scientists. Mawhiba selects and trains students (grade 7-12) to enter and participate in international Olympiads in Math, Physics and Chemistry and Science. The students benefit from after school support and residential seasonal training during school holidays. Over time, the training concentrates on the most promising students who will be selected to represent KSA in international competitions. This is a multi-year commitment to help students reach their full academic potential and increases their chances to being accepted in top universities.

5) E-Learning:
E-learning aims to support distance learning, acceleration, enrichment, outreach and interactive e-content for students from 4th to 12th grade. The intention is to develop an integrated eLearning system to provide effective learning experiences that engage and inspire the learner. Mawhiba is in the process of adapting its existing enhanced curriculum and teacher guidebooks into open courseware, adding some interactivity, for the benefit of any student or teacher.

6) Idea Development:
Mawhiba developed an on-line service to support would-be young inventors with scientific curiosity and innovative thinking skills. Inventors would pose ideas on-line which are evaluated by a panel of experts. Mawhiba also offers advice and support in how to apply for patents.

7) Awareness and Communications:
An initiative designed to create awareness for Giftedness & Creativity and engage stakeholders. It also aims to create awareness and excitement in participation in Mawhiba programs. Mawhiba developed its web presence and launched its portal as an online gateway to reach a wide audience (www.mawhiba.org) and developed a scientific content for giftedness & creativity targeting students, parents and educators. The portal provides a tool for student and teacher registration to sign-up for Mawhiba programs. The portal features a number of interactive services such as a consultation service named "Shawer" that provides personalized Q&A responses for any psychological, educational or social issues related to giftedness or creativity.

8) Translation and Research
In recognition of its responsibility to spread and promote the culture of giftedness and creativity in the society, Mawhiba established a "Translation Project" with the aim of supporting the movement of translation into Arab world for books of internationally renowned experts in the field of giftedness and creativity.
Mawhiba launched this project under the name of ". Mawhiba launched this project under the name of " Mawhiba Scientific Publications", where the 35 translated books are published in series form and are provided in an electronic version through its portal. Mawhiba also conducts scientific research and policy development in the field of gifted education. Mawhiba has carried out many important research, such as Proposed National Policy for Giftedness and Creativity in KSA, Gifted and Creativity Index, Needs of Gifted Students in Saudi Arabia, and Nurturing giftedness in Higher Education. In addition, Mawhiba provides its advisory services to researchers in the field of Giftedness and creativity.

Achievements:
a) The International Olympiad

Mathematics | Chemistry | Physics | Junior Science

Since 2010, KSA has awarded the following international Olympiad medals:

204 International Medals
44 Honorable Mentions

In the Mathematics Olympiad, KSA ranked first in the Arab world and in the top third internationally.


Chemistry International Olympiads 2017
Thailand
2 Silver Medals
2 Bronze Medals

Mathematical International Olympiads 2017
Brazil
2 Silver Medals
2 Bronze Medals
Honourable mentions

Physics International Olympiads 2017

Indonesia

- 2 Silver Medals
- 1 Bronze Medals
- Honourable mentions

International Junior Science Olympiad 2017

Netherlands

- 3 Bronze Medals

b) The National Olympiad for Scientific Creativity "Ibdaa"
Intel ISEF Participation from

Intel ISEF Participation from
2007 - 2017
No. of Awards

Total

36
Grand Awards

18
Special Awards

Categories

- Molecular and cell biology
- Material and Bioengineering
- Chemistry and Biochemistry
- Medicine and Health Sciences
- Plant Sciences
- Environmental Sciences
- Energy and transportation
- Environmental Management
- Materials science
- Social and Behavioral Sciences

Intel ISEF 2017

Grand Award
Nadia Almutlak
Materials Science
Enhancing LiFi and Lighting: CsPbBr3 Zero-Dimensional Perovskite and Quantum Dot Based Color Converters

Grand Award
Dana Alkhaldi
Chemical Energy
A Novel Approach for the Preparation of High Efficiency Water Splitting Photocatalysts
Special Award

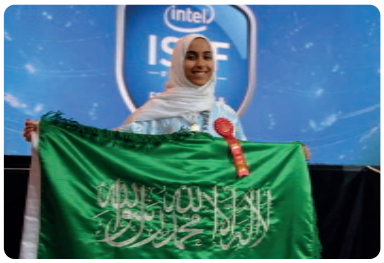
Grand Award
Amaar Amir
Animal Science
The Effect of Expression Patterns of Ammonium Transporters on the Interaction between Corals and Their Symbiotic Din flagellates

Top Award
Sara Alrabiah
Materials Science
Improving Resistive RAMs' Performance by Using Single Crystal MAPbBr3 Perovskite

Special Award
Ruba Alsulami
Environmental Engineering
Green Nanotechnology

NASA names asteroids after Saudi students

The NASA-funded LINEAR Program at MIT Lincoln Laboratory Names Minor Plants after these Saudi Students:
The asteroid (Al-Sheikh 33535) was named after Saudi talented student Fatima Abdel-Moneim Al-Sheikh in recognition of her efforts and excellence in her research in Botany for which she won the second place at Intel International Science and Engineering. Fair (Intel ISEF) 2016.
The asteroid (alhamood 31926) was named after Saudi student Abdul Jabbar Al-Hamood who had received 2 awards and ranked "The best of category and first place in Plant Sciences" at Intel International Science and Engineering Fair (Intel ISEF 2015).



Fatima Abdel-Moneim Al-Sheikh
ISEF 2017

Abdul Jabbar Al-Hamood
ISEF 2016

Making edible insects a consequential part of Western agriculture inspired the tech start-up Ovipost. CEO Trina Chiasson is flanked by chief science officer James Ricci and chief technical officer Tequila Ray Snorkel.

Down on the (Cricket) Farm

Can Silicon Valley entrepreneurs make insects the next chicken?

By Susan Milius

Trina Chiasson was raised in a log cabin, learned to spin plates in Chicago's circus arts community, dreamed up a software company and three years later sold it to a bigger company. Her next challenge: building a business, called Ovipost, that brings better technology to cricket farming.

"I didn't know any cricket farmers growing up, I know you'll be shocked to learn," she says. Yet she's jumped into this new frontier of insect agriculture and, she hopes, a more sustainable food system. It's all about reinventing ranching, but with six legs.

Humans have had thousands of years, including at least 50 years of industrial R&D, to figure out how to raise chickens, pigs and cattle. Today's insect farmers in North America and Europe are racing to catch up, mixing ancient herder–style insights about domesticating wild animals with computer-vision algorithms and robot design.

How to grow enough critters often gets overlooked in the buzz about insects as cuisine. There's far more fuss about whether Westerners will join the rest of the world and swallow a bug. Yet it's the behind-the-scenes inventions and decisions that will determine how environmentally gentle insect farming can be and whether insects become a weekly staple that a lot of people can afford or just a foodie indulgence.

Start□ ps and incubators

Chiasson's cricket leap into farming will at least use her skills with data. Her first start-up company, Infoactive, developed software to turn raw data into easy-to-grasp charts and graphs. After she and a business partner sold the company in 2015 to the data visualization company Tableau Software for an undisclosed sum, Chiasson spent two years researching and strategizing about her next venture. Raised by back-to-the-land parents in Maine, she became a vegetarian around age 11, but now, she says, "I regularly chow down on insects."

Chiasson met her next business partner, entomologist James Ricci, in San Francisco at the world's largest nacho festival. "To see if we could execute on program without killing each other," she says, the two spent a month building a booth promoting edible insects. Their creation debuted at the 2017 Oregon Eclipse festival. The two pulled it off without fatalities, and went on to set up Ovipost in San Francisco.

Chief technology officer Tequila Ray Snorkel describes herself as "200 percent a city kid." Homeschooled in Cincinnati with an interest in physics, she (her preferred pronoun) worked on automated prosthetics in college and then took her mechanical engineering degree to the biotech

> □ didn□ know any cricket farmers growing up, I know you□ be shocked to learn.□
>
> **TRINA CHIASSON**

OPPOSITE PAGE: BRIAN TIETZ

Insect farms, even old-style ones like the Lazy H (now Ovipost) in LaBelle, Fla., are indoor affairs. A daytime visitor can stand outside of buildings that hold many thousands of animals and hear pretty much nothing.

company Synthego in Menlo Park, Calif. She's been known to engineer provocations as well, such as strolling the streets in glitter to interview passersby on sensitive subjects. One outfit Snorkel devised was two pairs of bright yellow pants, the top one re-engineered so pant legs became sleeves. Chiasson saw Snorkel wearing it in a drag show and complimented her creativity — one of the more unusual ways to land a tech job.

Ovipost got an early boost from the iconic Silicon Valley start-up incubator Y Combinator, which nurtured Dropbox and Airbnb. Working out of two shipping containers, one piled on top of the other to make the most of a small footprint at San Francisco rents, the company started by automating the tedious, time-sucking management of cricket egg laying and egg counting. Normally, farmers provide romantically moist peat moss for cricket mating, and count the offspring by coaxing them into measuring containers. Snorkel described it as "like convincing a few thousand tiny toddlers to take a bath." Ovipost developed shortcuts, and for its Y Combinator finale pitch session, the company revealed a million cricket eggs swirling in a snow globe.

Less labor-intensive counting is just a first step in bringing down production costs, which, Chiasson says, "are way too high to be economically feasible in our current food system." Compared with the low cost of raising industrial chickens, she says, producing crickets is "not even close." Those production costs explain why a pound of boneless chicken breast retails for a little more than $3 versus $15 for a pound of food-grade crickets from the Armstrong family farms in Louisiana and Georgia.

When I heard that Ovipost's Silicon Valley tech entrepreneurs had bought an old cricket farm in rural Florida, I was baffled. This move sounded like a pitch for a sitcom, a la *Green Acres*.

The Lazy H has been a cricket farm for about 30 years. It markets live crickets to reptile keepers and pet stores. The farm sits on what's literally named "A Road" (it runs parallel to "B Road") in the small town of LaBelle.

Snorkel the city kid makes the most spirited case for the surprising move: Designing tech for crickets needs crickets. The best way to test new automation tech is to put it into the hands of skilled workers with realistic conditions and volumes. That this testing facility happens to be a real farm paying its own way makes buying into LaBelle "almost a no-brainer," she says.

Swerve

Driving along A Road with its solid walls of greenery, I overshoot the Ovipost mailbox, despite the clear markings. In my head, the word "farm" still begs for a pasture, a fence. But insect farms in the United States are indoor affairs, less Old MacDonald and more server farm.

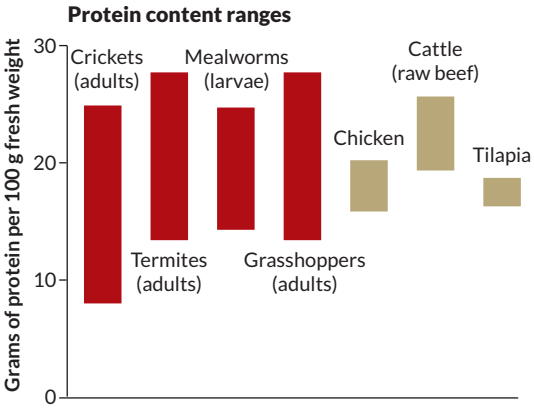
When I nudge the car down a long driveway through yet another great billow of twisted oaks and blunt-leaved shrubbery, I reach a clearing of farm buildings. I can't tell yet, but inside a string of oversized red sheds, creatures by the thousands are grazing, mating, fighting. It's silent ranching, at least in the daytime.

The biggest miniherds at the Lazy H are the house crickets, and Snorkel leads me into a cricket barn. It's a wide, long room with big plastic bins sitting edge to edge in rows down the middle and along the sides. A radio is playing, but I don't hear crickets. (At night, Ricci tells me later, the cricket chorus can get deafening.)

Power protein

Insects compete well with chicken and beef as a protein source, although details depend on what the animals are fed, among other things. Grasshoppers fed bran, high in essential fatty acids, had almost double the protein content of those fed maize.

SOURCES: FAO 2013; H. KIM *ET AL/KOREAN J. FOOD SCI. ANIM. RESOUR.* 2017



FROM TOP: BRIAN TIETZ; T. TIBBITTS

The bins look like giant, sawed-off plastic milk jugs. They were once fertilizer containers, plentiful in agricultural LaBelle and the brainstorm of one of the farm's earlier owners. Each bin could swallow a minifridge without a burp.

Around the inner perimeter of each bin, workers have stuck a wide stripe of slick, brown packing tape. It's the insect farm version of split rail fencing, a stripe that's just too slippery for crickets to cross. These strips need replacing after several weeks, one of many labor sucks at the farm that Snorkel is trying to improve on. The Ovipost crew scoured hardware stores for slippery spray-on coatings that would be much simpler to apply. The winner was a can of Krylon appliance epoxy, available for $3.50.

Now I learn something about innovation — location, location. The spray worked beautifully in San Francisco, Snorkel says, but it needs to be retested here. Florida humidity, the fertilizer bins and many more factors are different. Not until a few sprayed bins have efficiently fenced several generations of crickets would Snorkel deploy her epoxy brainstorm.

Below the fencing, I see stacks of egg separators propped around the edges. These gray, cardboard-like rectangles with deep dents to hold chicken eggs safe and upright have become the industry standard for sheltering crickets. I see crickets tucked into the indents and huddled just under the lips.

Are there maybe ... several hundred crickets in the bin? I ask. A woman working nearby laughs, with maybe a touch of farmer pride. There are thousands in just that one bin. Now I am impressed. Herding crickets this densely takes a cricket whisperer, and her name is Maria Mendieta. She's been at the farm for 17 years and counts as one of its greatest assets. What she does "is magic," Snorkel says. "I can't tell you how to make this work."

Snorkel points out a metal cart heaped with trays, unremarkable as far as I can see, that a man is pushing down one of the aisles between bins. When the Ovipost crew arrived with their Silicon Valley dreams, the thing that really cheered the workers, and certainly improved efficiency, was no more involved than replacing the balky, sticking wheels on this old cart.

In this kind of farming, simple, operational improvements will be just as important as the fancier tech, Snorkel predicts. Back when steam-powered factories were switching to electricity, for instance, a central steam boiler no longer constrained the positioning of the machines. The new electrical equipment added flexibility. Managers who experimented with factory layout saw big improvements in efficiency.

Setting up assembly-line flows and building some simple work stations, Snorkel says, "I definitely feel rooted in the first industrial revolution."

Imagining Tequila Ray Snorkel as a rebooted Henry Ford, I follow her to a cricket breeding area, where females lay eggs in make-do, metal baking pans filled with moist peat moss like lumpy cake mix. From here, the egg pans get moved into what looks like a decent-sized heated closet with flypaper strips curling down from the ceiling. Snorkel points out that the racks holding the pans stand with their feet in little dishes of water

Farms raise crickets in bins, often with stacks of egg separators as shelters (top right). To fence a bin, Ovipost is testing sprays that make the top too slippery for crickets to climb (top left). The company also grows darkling beetles (bottom); their larvae make good reptile food.

ALL: BRIAN TIETZ

Wanda Orengo packs insects into boxes at Ovipost. Caring for and shipping insects to customers is a labor-intensive effort that needs to change if insect protein is to become a common, affordable part of Western diets, the Ovipost group argues. But getting an intuitive feel for crickets still takes human experience.

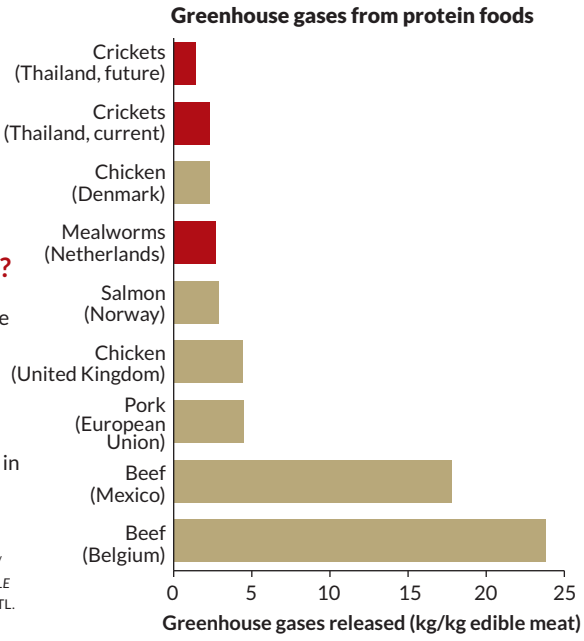
to repel ants. Insect pests bedevil all kinds of farms, but they're a special menace at insect farms because pest control can kill the livestock too.

When I e-mail later to ask what engineering might someday do to cut labor costs, Snorkel imagines "Willy Wonka's cricket farm." In rows of warm, humid tanks stacked higher than a farmer can reach, "a laboratory-crafted little Tide pod of just the right number of eggs for each container hatches out soft white nymphs." These young crickets would grow up on processed human-food waste delivered by conveyor belt and water flowing by in a trough. After a month with no human intervention, the bins would tip onto conveyor belts, sending the insects to be sorted.

Gentler farming?

Growing insect protein could produce fewer greenhouse gases than other forms of meat farming. Details such as what the animals eat make a difference in impact summed across the whole production process.

SOURCE: A. HALLORAN *ET AL/ EDIBLE INSECTS IN SUSTAINABLE FOOD SYSTEMS*, SPRINGER INTL. PUBLISHING 2018



Not the basement

Crickets already thrive in basements without help from humans. Yet I've heard cricket farm consultant Kevin Bachhuber of Madison, Wis., get hearty applause just for the title of his talk: "Crickets are stupid, and will drown themselves if possible."

So how hard is cricket farming? I ask him by phone. "Hard enough that my full-time job is helping other people figure out what went wrong," he says.

Bachhuber started his own farm in Youngstown, Ohio, in 2014, but has since closed it. His was the first to pass U.S. government inspection for growing insects for people to eat. But soon enough, over 19 days, his crickets died, about 6 million of them.

Crickets aren't the easiest or, he thinks, the best-tasting insects, but they're a major seller for many of the 20 to 40 U.S. farms that Bachhuber estimates are selling insects for human food. In early April, his database listed some 540 U.S. businesses related to insect agriculture, and he's sure he's missing some.

The edible insects market was estimated at over $55 million in 2017 by Global Market Insights, of Selbyville, Del., which projects a burst of growth ahead. Interest boomed after a 2013 United Nations' Food and Agriculture Organization report, which made the case for insect farming as a way to meet the protein requirements of an expanding human population.

Farmers count

Insect farming often gets talked about as a single entity in discussions of environmental consequences, but that's even more vague than saying "mammal farming."

PHOTOS: BRIAN TIETZ; GRAPH: T. TIBBITTS

The list of edible insects stretches to over 2,000, and the bugs' demands vary, says entomologist Åsa Berggren of the Swedish University of Agricultural Sciences in Uppsala. Some need meat to eat. Some, such as termites, produce methane, which is a powerful greenhouse gas.

Even in the same insect species at the same stage of life, environmental impact numbers can differ, Berggren and colleagues pointed out in the February issue of *Trends in Ecology & Evolution*. The few shreds of data on farming the house cricket (*Acheta domesticus*) suggest that the animals convert feed to body weight at rates varying from 1.6 (good) to 4.5 (almost as resource-hogging as pigs). What would be really sad, she says, is insect farming missing this chance to take the green and thrifty route.

A better way to judge farm impacts is to sum them all in a life cycle analysis, says Afton Halloran, a sustainable-food consultant based in Copenhagen. However, she knows of fewer than a dozen such analyses, and results differ.

Overall, the analyses suggest that what farmers choose to feed their insects is a big deal, Halloran says. A farmer might nudge the world in a better direction by feeding the microherd something that would normally be thrown away, for example, feeding chicken manure to black soldier fly larvae. Serving a different waste product, say beet pulp, also puts food waste to good use, but it racks up considerable environmental impacts. The larvae don't grow well on the pulp, so they need a lot of it, plus heating to keep their metabolisms revved.

Also grown

Some farms have already diversified beyond crickets. Among its reptile foods, Lazy H raises discoid roaches, one of the few kinds that Florida allows people to cultivate on purpose. "We love the roaches," Chiasson says. They withstand temperature fluctuations and shipping better than the crickets do. "They don't smell as bad," she adds. And when a roach dies in the tank, cleanup is easy: The other roaches eat most of it.

Can't argue with that. The discoids live in a trailer, with worn blond wood paneling. A row of big fertilizer bins lines each side. Snorkel says that at night the whole trailer rustles.

Snorkel, too, clearly loves the roaches, calling them "relatable." She points out some babies, a mature female and something that would make a fine half-moon pendant. It's what's left of a dead roach after the funeral lunch. Then she spots a female on its back, waving her legs. "Contractions," Snorkel explains. Females release a brood of young in a large sac.

So that is how I find myself standing between a Silicon Valley software entrepreneur and a reinventor of the pantsuit in an old trailer waiting quietly for a cockroach to give birth. This is about as far as you can get from Silicon Valley, but you can see the future from here too. ■

COURTESY OF BROOKLYN BUGS

Lobster with roasted waxworms (which are caterpillars, not worms) highlights chef Joseph Yoon's principle of pairing edible insects with people's favorite foods.

Fancy feast

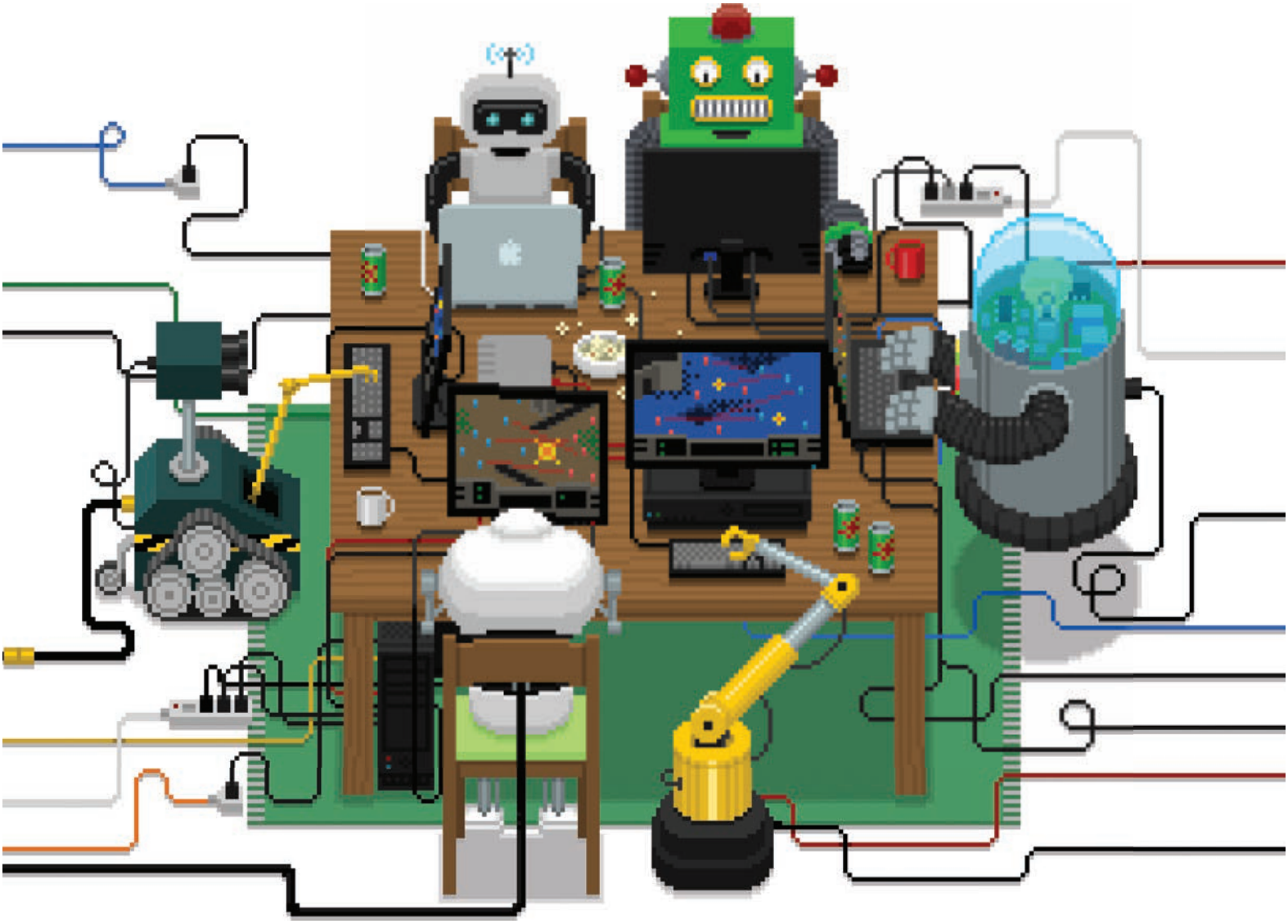
I met the Ovipost innovators in Athens, Ga., at the August 2018 meeting of the North American Coalition for Insect Agriculture. The event gave a glimpse of one possible future in which insects become a prestige protein like shrimp, crab and lobster. Considering how multilegged and armored so much shellfish is, it's intriguing that so many people relish shrimp cocktail, yet cringe at eating a land-based arthropod cousin.

The banquet chef, Joseph Yoon from the insect-eating advocacy group Brooklyn Bugs, goes big and bold. He doesn't disguise the ants, dried scorpions or silkworm larvae; he flaunts them. The insects become luxury highlights for dishes people already love. His eight-course extravaganza began with insect bodies mixed with popcorn and ended with a silky chocolate mousse topped with wasps. People talked about the varied flavors of insects, but for me, it was more about texture — an added crunch or chewiness.

Partisans of insect protein admit that many people won't ever embrace this flamboyant cuisine. But insects could still play a major role as more subtle ingredients. Insect powders, for example, are already muscling into protein bars. Nobody counts legs once they're ground into flour. Farmed insects could also be used to feed farmed fish, an animal we're willing to eat, replacing as much as 25 to 30 percent of food for fish raised in aquaculture, European food specialists estimated in a 2015 review. — *Susan Milius*

Explore more

- Åsa Berggren, Anna Jansson and Matthew Low. "Approaching ecological sustainability in the emerging insects-as-food industry." *Trends in Ecology & Evolution*. February 1, 2019.



AI at Play

When computers take a seat at the game table, they learn real-world skills **By Maria Temming**

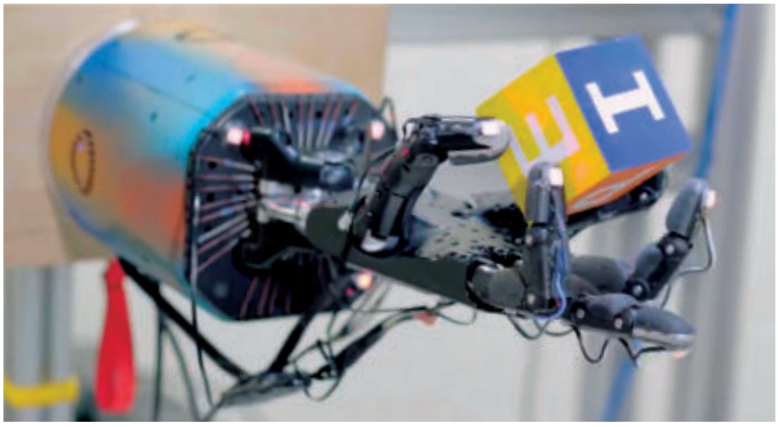
WALTER NEWTON

Dario Wünsch was feeling confident. The 28-year-old from Leipzig, Germany, was about to become the first professional gamer to take on the artificial intelligence program AlphaStar in the rapid-fire video game StarCraft II. Wünsch had been professionally playing StarCraft II, in which competitors command alien fleets vying for territory, for nearly a decade. No way could he lose this five-match challenge to a newly minted AI gamer.

Even AlphaStar's creators at the London-based AI research company DeepMind, which is part of Alphabet, Inc., weren't optimistic about the outcome. They were the latest in a long line of researchers who had tried to build an AI that could handle StarCraft II's dizzying complexity. So far, no one had created a system that could beat seasoned human players.

Sure enough, when AlphaStar faced off against Wünsch on December 12, the AI appeared to commit a fatal mistake at the onset of the first match: It neglected to build a protective barrier at the entrance to its camp, allowing Wünsch to infiltrate and quickly pick off several of its worker units. For a minute, it looked like StarCraft II would remain one realm where humans trump machines. But AlphaStar made a winning comeback, assembling a tenacious strike team that quickly laid waste to Wünsch's defenses. AlphaStar 1, Wünsch 0.

Wünsch shook it off. He just needed to focus more on defense. But in the second round, AlphaStar surprised the pro gamer by withholding attacks until it had amassed an army that once again crushed Wünsch's forces. Three matches later, AlphaStar had won the competition 5-0, relegating Wünsch to the small but growing club of world-class gamers bested by a machine.



Using algorithms originally developed to help five AIs play the game Dota 2, OpenAI researchers built an extremely dexterous robot hand.

Researchers have long used games as benchmarks for AI smarts. In 1997, IBM's Deep Blue earned international acclaim by outwitting chess champion Garry Kasparov (*SN: 8/2/97, p. 76*). In 2016, DeepMind's AlphaGo famously overpowered Go champion Lee Sedol (*SN: 12/24/16, p. 28*).

But board-based contests like chess and Go can only push AI so far. These games are still pretty simple — players take turns and can see every piece's position on the board at all times. When it comes to making an AI that can deal with real-world ambiguity and fast-paced interactions, the most useful tests of machine cognition will probably be found in games played in virtual worlds.

Building AI gamers that can trounce human players is more than a vanity project. "The ultimate idea is to ... use those algorithms [for] real-world challenges," says Sebastian Risi, an AI researcher at IT University of Copenhagen. For

TOP: OPENAI; BOTTOM, ALL: DEEPMIND

In this scene from the video game Starcraft II (left image), professional StarCraft II player Dario W□nsch, who plays as □LiquidTLO□is overpowered by the artificial intelligence AlphaStar, which is wreaking havoc on W□nsch□s base. The AI□s creators at DeepMind cheer as the AI shows its superiority (top right). W□nsch took it in stride when AlphaStar bested him, 5 matches to 0 (bottom right).

instance, after the San Francisco–based company OpenAI trained a five-AI squad to play an online battle game called Dota 2, the programmers repurposed those algorithms to teach the five fingers of a robotic hand to manipulate objects with unprecedented dexterity. The researchers described this work online at arXiv.org in January.

DeepMind researchers similarly hope that AlphaStar's design could inform researchers trying to build AIs to handle long sequences of interactions, like those involved in simulating climate change or understanding conversation, an especially difficult task (*SN: 3/2/19, p. 8*).

Right now, two important things that AIs still struggle with are: coordinating with each other and continually applying new knowledge to new situations. The StarCraft universe has proved to be an excellent testing ground for techniques that make AI more cooperative. To experiment with methods to make AIs forever learners, researchers are using another popular video game, Minecraft. While people may use screen time as an entertaining distraction from real life, virtual challenges may help AI pick up the skills necessary to succeed in the real world.

Arcade education AI can practice different skills in video games to learn how to get along in the real world. Navigational know-how, for example, could help search- and-rescue robots prowl tough terrain, and AIs that know how to manage many workers could help run companies.

Game types that teach AI useful skills for the real world

Type	Racing	First-person shooting	Open world	Real-time strategy
Example games	Forza Motorsport, Real Racing	Doom	Minecraft, Grand Theft Auto	StarCraft
Navigation	✓	✓	✓	
Manage resources/staff	✓			✓
Plot strategy	✓	✓		✓
Fast reaction	✓	✓		✓
Collaboration		✓		✓
Setting goals			✓	
Creativity			✓	
Exploration			✓	✓
Lifelong learning			✓	
Motivation			✓	✓
Juggling priorities			✓	✓

Team play

When AlphaStar took on Wünsch, the AI played StarCraft II like a human would: It acted like a single puppeteer with complete control over all the characters in its fleet. But there are many real-world situations in which relying on one mastermind AI to micromanage lots of devices would become unwieldy, says artificial intelligence researcher Jakob Foerster of Facebook AI Research in San Francisco.

Think of overseeing dozens of nursing robots caring for patients throughout a hospital, or self-driving trucks coordinating their speeds across miles of highway to mitigate traffic bottlenecks. So, researchers including Foerster are using the StarCraft games to try out different "multiagent" schemes.

In some designs, individual combat units have some independence, but are still beholden to a centralized controller. In this setup, the overseer AI acts like a coach shouting plays from the sidelines. The coach generates a big-picture plan and issues instructions to team members. Individual units use that guidance, along with detailed observations of the immediate surroundings, to decide how to act. Computer scientist Yizhou Wang of Peking University in China and colleagues reported the effectiveness of this design in a paper submitted to *IEEE Transactions on Neural Networks and Learning Systems*.

Wang's group trained its AI team in StarCraft using reinforcement learning, a type of machine learning in which computer systems pick up skills by interacting with the environment and getting virtual rewards after doing something right. Each teammate received rewards based on the number of enemies eliminated in its immediate vicinity and whether the entire team won against fleets controlled by an automated opponent built into the game. On several different challenges with teams of at least 10 combat units, the coach-guided AI teams won 60 to 82 percent of the time. Centrally controlled AI teams with no capacity for independent reasoning were less successful against the built-in opponent.

AI crews with a single commander in chief that exerts at least some control over individual units may work best when the group can rely on fast, accurate communication among all agents. For instance, this system could work for robots within the same warehouse.

But for many machines, such as self-driving cars or drone swarms spread across vast distances, separate devices "won't have consistent, reliable

and fast data connection to a single controller," Foerster says. It's every AI for itself. AIs working under those constraints generally can't coordinate as well as centralized teams, but Foerster and colleagues devised a training scheme to prepare independent-minded machines to work together.

In this system, a centralized observer offers feedback to teammates during reinforcement learning. But once the group is fully trained, the AIs are on their own. The master agent is less like a sidelined coach and more like a dance instructor who offers ballerinas pointers during rehearsals, but stays mum during the onstage performance.

The AI overseer prepares individual AIs to be self-sufficient by offering personalized advice during training. After each trial run, the overseer simulates alternative possible futures and tells each agent, "This is what actually happened, and this is what would have happened if everyone else had done the same thing, but you did something different." This method, which Foerster's team presented in New Orleans in February 2018 at the AAAI Conference on Artificial Intelligence, helps each AI unit judge which actions help or hinder the group's success.

To test this framework, Foerster and colleagues trained three groups of five AI units in StarCraft. Trained units had to act based only on observations of the immediate surroundings. In combat rounds against identical teams commanded by a built-in, nonhuman opponent, all three AI groups won most of their rounds, performing about as well as three centrally controlled AI teams in the same combat scenarios.

Lifelong learning

The types of AI training that programmers test in StarCraft and StarCraft II are aimed at helping a team of AIs master a single task, for example, coordinating traffic lights or drones. The StarCraft games are great for that, because for all their moving parts, the games are fairly straightforward: Each player has the singular goal of overpowering an opponent. But if artificial intelligence is going to become more versatile and humanlike, programs need to be able to learn more and continually pick up new skills.

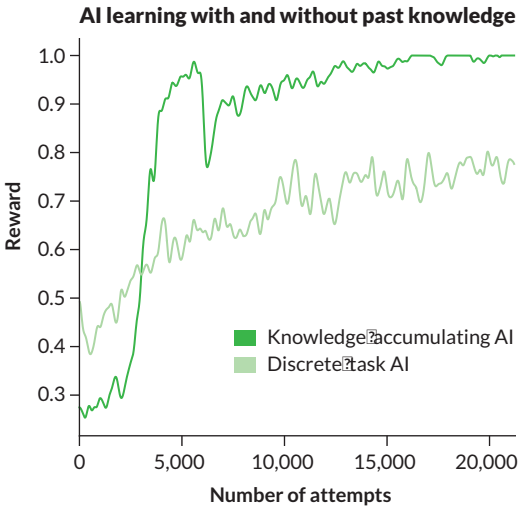
"All the systems that we see right now that play Go and chess — they're basically trained to do this one task well, and then they're fixed so they can't change," Risi says. A Go-playing system presented with an 18-by-18 grid, instead of the standard 19-by-19 game board, would probably have to be completely retrained on the new board, Risi says. Changing the characteristics of StarCraft units would require the same back-to-square-one training. The Lego-like realm of Minecraft turns out to be a better place for testing approaches to make AI more adaptable.

In different environments composed of 3D blocks, Minecraft players can build structures and explore their surroundings (two examples above). Researchers use Minecraft to teach AI skills such as how to set goals and build creative structures.

Unlike StarCraft, Minecraft poses no single quest for players to complete. In this virtual world made of 3-D blocks of dirt, glass and other materials, players gather resources to build structures, travel, hunt for food and do pretty much whatever else they please. Caiming Xiong, an artificial intelligence researcher at the San Francisco–based software company Salesforce, and colleagues used a simple building full of blocks in Minecraft to test an AI designed to continually learn.

Rather than assigning the AI to learn a single task through trial and error in reinforcement learning, Xiong's team staggered the AI's education. The researchers guided the AI through increasingly difficult reinforcement learning challenges, from finding specific blocks to

FROM TOP: CHRISTOPH SALGE ET AL/PROC. OF THE 13TH INTERNAT. CONF. ON THE FOUNDATIONS OF DIGITAL GAMES 2018; LAIGE PENG AND YOSHIMASA TSURUOKA/INFORMATION PROCESSING SOCIETY OF JAPAN 2018



Quick on the uptake A Minecraft-playing AI that knows how to apply past knowledge to learn new skills (dark green) more quickly learns how to perform a new skill successfully. It reached rewards up to 1.0 in fewer attempts than an AI that doesn't rely on old expertise (light green).

SOURCE: T. SHU, C. XIONG AND R. SOCHER/6TH INTERNAT. CONF. ON LEARNING REPRESENTATIONS 2018

stacking blocks. The AI was designed to break each challenge into simpler steps. It could tackle each step using old expertise or try something new. Compared with another AI that was not designed to use prior knowledge to inform new learning experiences, Xiong team's AI proved a much quicker study.

The knowledge-accumulating AI was also better at adjusting to new situations. Xiong and colleagues taught both AIs how to pick up blocks. While training in a simple room that contained only one block, both AIs got the "collect item" skill down pat. But in a room with multiple blocks, the discrete-task AI struggled to identify its target and grabbed the right block only 29 percent of the time.

The knowledge-accumulating AI knew to rely on a previously learned "find item" skill to locate a target object among distractions. It picked up the right block 94 percent of the time. The research was presented in Vancouver in May 2018 at the International Conference on Learning Representations.

With further training, Xiong and colleagues' system could master more skills. But this design is limited by the fact that the AI can only learn tasks assigned by the human programmer during training. Humans don't have this kind of educational cutoff. When people finish school, "it's not like, 'Now you're done learning. You can freeze your brain and go,'" Risi says.

A better AI would get a foundational education in games and simulations and then be able to continue learning throughout its lifetime, says Priyam Parashar, a roboticist at the University of California, San Diego. A household robot, for example, should be able to find navigational work-arounds if residents install baby gates or rearrange the furniture. Parashar and colleagues created an AI that can identify instances in which it needs further training without human input. When the AI runs into a new obstacle, it takes stock of how the environment is different from what it expected. Then it can mentally rehearse various work-arounds, imagine the outcome of each and choose the best solution.

The researchers tested this system with an AI in a two-room Minecraft building. The AI had been trained to retrieve a gold block from the second room. But another Minecraft player had built a glass barrier in the doorway between the rooms, blocking the AI from collecting the gold block. The AI assessed the situation and, through reinforcement learning, figured out how to shatter the glass to complete its task, Parashar and her colleagues reported in the 2018 *Knowledge Engineering Review*.

An AI faced with an unexpected baby gate or glass wall should probably not conclude that the best solution is to bust it down, Parashar admits. But programmers can add additional constraints to an AI's mental simulations — like the knowledge that valuable or owned objects should not be broken — to inform the system's learning, she says.

New video games are becoming AI test-beds all the time. AI and games researcher Julian Togelius of New York University and colleagues hope to test collaborating AIs in Overcooked — a team cooking game that takes place in a tight, crowded kitchen where players are constantly getting in each other's way. "Games are designed to challenge the human mind," Togelius says. Any video game by nature is a ready-made test for how much AI know-how can emulate human cleverness.

But when it comes to testing AI in video games or other simulated worlds, "you cannot ever say, 'OK, I've modeled everything that's going to happen in the real world,'" Parashar says. Bridging the gap between virtual and physical reality will take more research.

One way to keep simulation-trained AI from overreaching, she suggests, is to devise systems that require AIs to ask humans for help when needed (*SN: 3/2/19, p. 8*). "Which, in a sense, is making [AI] more like humans, right?" Parashar says. "We get by with the help of our friends." ■

29
percent
Success rate for an AI that could not use prior knowledge to grab the correct block in Minecraft

94
percent
Success rate for an AI that built on previous knowledge to grab the correct block in Minecraft

Explore more

■ Niels Justesen *et al*. "Deep learning for video game playing." *IEEE Transitions on Games*. February 13, 2019.

C. CHANG

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LOOKING FOR LITHIUM

The lightest metal on the periodic table is key to clean energy's future

By Carolyn Gramling

The future of lithium is electrifying. Cars and trucks powered by lithium batteries rather than fossil fuels are, to many people, the future of transportation. Rechargeable lithium batteries are also crucial for storing energy produced by solar and wind power, clean energy sources that are a beacon of hope for a world worried about the rapidly changing global climate.

Prospecting for new sources of lithium is booming, fueled by expectations that demand for lightweight, rechargeable lithium batteries — to power electric vehicles, cell phones, laptops and renewable energy storage facilities — is about to skyrocket.

300
percent
Global estimated increase in demand for lithium in the next 10 to 15 years

Even before electric cars, lithium was a hot commodity, mined for decades for reasons that had nothing to do with batteries. Thanks to lithium's physical properties, it is bizarrely useful, popping up in all sorts of products, from shock-resistant glass to medications (see Page 44). In 2018, those products accounted for nearly half of the global lithium demand, according to analyses by the Frankfurt-based Deutsche Bank. Batteries for consumer electronics, such as cell phones or laptops, accounted for another 25 percent or so of the demand. Electric vehicles accounted for most of the rest.

That breakdown will soon be turned on its head: By 2025, as much as half of the demand for lithium will be from the electric vehicle industry, some projections suggest. Global demand for the metal is expected to rise at least 300 percent in the next 10 to 15 years, in large part because sales of electric vehicles are expected to increase dramatically. Right now, there are about 2 million electric vehicles on the road worldwide; by 2030, that number is projected to grow to over 24 million, according to the industry research firm Bloomberg New Energy Finance. Electric vehicle giant Tesla has been on a worldwide quest for lithium, inking deals to obtain lithium supplies from mining operations in the United States, Mexico, Canada and Australia.

As a result, lithium prices in global markets have been on a roller coaster in the last few years, with a sharp spike in 2018 due to fears that there just might not be enough of the metal to go around. But those doomsday scenarios are probably a bit overwrought, says geologist Lisa Stillings of the U.S. Geological Survey in Reno, Nev. Lithium makes up about 0.002 percent of Earth's crust, but in geologic terms, it isn't particularly rare, Stillings says. The key, she adds, is knowing where it is concentrated enough to mine economically.

To answer that question, researchers are studying how and where the forces of wind, water, heat and time combine to create rich deposits of the metal. Such places include the flat desert basins of the "lithium triangle" of Chile,

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Flamingos feast on tiny shrimp in the saline lagoons of Chile's Salar de Atacama. Lithium and copper mining operations compete with the protected birds for the region's scant water resources.

150 years of the periodic table
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Argentina and Bolivia; volcanic rocks called pegmatites in Australia, the United States and Canada; and lithium-bearing clays in the United States.

The hunt to find and extract this "white gold" is also spurring new basic geology, geochemistry and hydrology research. Stillings and other scientists are examining how clays and brines form, how lithium might move between the two deposits when both occur in the same basin and how lithium atoms tend to position themselves within the chemical structure of the clay.

Seeking simpler sources

Lithium, in its elemental form, is soft and silvery and light, with a density about half that of water. It's the lightest metal on the periodic table. The element was discovered in 1817 by Swedish chemist Johan August Arfwedson, who was analyzing a grayish mineral called petalite. Arfwedson identified aluminum, silicon and oxygen in the mineral, which together made up 96 percent of the mineral's mass.

The rest of the petalite, he determined, was made up of some sort of element that had chemical properties similar to potassium and sodium. All three elements are highly reactive with other charged particles, or ions, to form salts, are solid but soft at room temperature, have low melting points and tend to dissolve readily in water. Thanks to their similarities, these elements, along with rubidium, cesium and francium, were later grouped together as "alkali metals," forming most of the periodic table's Group 1 (*SN: 1/19/19, p. 18*). Lithium's affinity for water helps explain how it moves through Earth's crust and how it can become concentrated enough to mine.

The basic recipe for any kind of lithium-rich deposit includes volcanic rocks plus a lot of water and heat, mixed well by active tectonics. Worldwide, there are three main sources of lithium: pegmatites, brines and clays.

Most pegmatites are a type of granite formed out of molten magma. What makes pegmatites interesting is that they tend to contain a lot of incompatible elements, which resist forming solid crystals for as long as possible. The rocks form as the magma beneath a volcano cools very slowly. The magma's chemical composition evolves over time. As elements drop out of the liquid to form solid crystals, other elements, like lithium, tend to linger in the liquid, becoming more and more concentrated. But eventually, even that magma cools and crystallizes, and the

Demand for lightweight, rechargeable lithium batteries to power electric vehicles and other modern electronics is expected to climb.

TRAMINO/ISTOCK/GETTY IMAGES PLUS

incompatibles are locked into the pegmatite.

Before the 1990s, pegmatites in the United States were the primary source of mined lithium. But extracting lithium ore, primarily a mineral called spodumene, from the rock is costly. On top of the cost of actual mining, the rock has to be crushed and treated with acid and heat to extract the lithium in a commercially useful form.

In the 1990s, a much cheaper source of lithium became an option. Just beneath the arid salt flats spanning large swaths of Chile, Argentina and Bolivia circulates salty, lithium-enriched groundwater. Miners pump the salty water to the surface, sequestering it into ponds and letting it evaporate in the sun. "Mother Nature does most of the work, so it's really cheap," Stillings says.

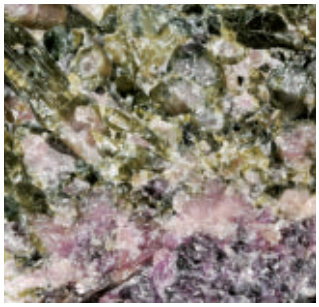
What's left behind after the evaporation is a sludgy, yellowish brine. To extract battery-grade lithium in commercially useful forms, particularly lithium carbonate and lithium hydroxide, the miners add different minerals to the brine, such as sodium carbonate and calcium hydroxide. Reactions with those minerals cause different types of salts to precipitate out of the solution, ultimately producing lithium minerals.

Compared with pegmatite extraction, the process for extracting lithium from the brine is extremely cheap; as a result, brine mining currently dominates the lithium market. But in the hunt for more lithium, the next generation of prospectors are looking to a third type of deposit: clay.

Clays are the hardened remnants of ancient mud, produced by the slow settling of tiny grains of sediment, such as within a lake bed. To get lithium-enriched clay requires the right starting ingredients, particularly lithium-bearing rocks such as pegmatite and circulating groundwater. The groundwater leaches the lithium from the rocks and transports it to a lake where it becomes concentrated in the sediments.

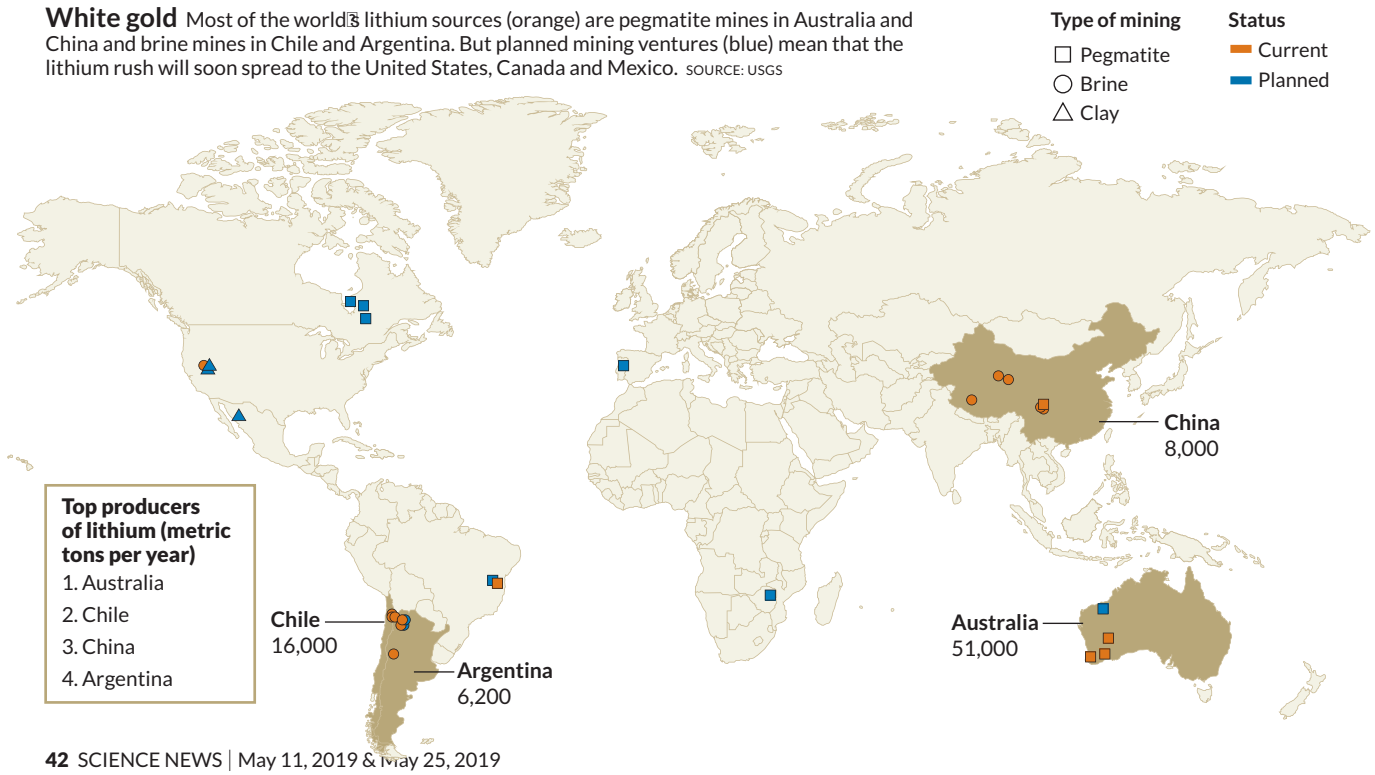
The western United States, it turns out, has all the right ingredients to make lithium-rich clay. In fact, in 2017 in *Nature Communications*, researchers suggested that some ancient supervolcano craters that became lakes, such as the Yellowstone caldera, would be excellent sources of lithium.

Beneath North America lies a shallow pool of magma that feeds the Yellowstone supervolcano. For the last 2 million years or so, Yellowstone volcanism has been located in northwestern Wyoming (and is the centerpiece of Yellowstone National Park). But the Yellowstone hot spot isn't stationary. Over the last 16 million years, as the North American plate has slowly slid to the southwest, it has moved over the stationary, shallow magma body, leaving a pockmarked track of volcanic craters stretching from Nevada to Yellowstone. One of the oldest known Yellowstone craters, called McDermitt Caldera, filled with water, then later dried up, leaving behind a potential treasure trove of lithium-rich clay. Vancouver-based Lithium Americas Corp., which plans to begin mining operations at a site called Thacker Pass within the caldera in 2022, estimates that by 2025, the lake bed could provide as much as 25 percent of the world's lithium.



Pegmatite rocks have large crystals and often contain minerals not found elsewhere, such as lithium-bearing spodumene or petalite.

White gold Most of the world's lithium sources (orange) are pegmatite mines in Australia and China and brine mines in Chile and Argentina. But planned mining ventures (blue) mean that the lithium rush will soon spread to the United States, Canada and Mexico. SOURCE: USGS



GARY PARENT/WIKIMEDIA COMMONS (CC BY 3.0)

In the United States, Stillings says, McDermitt is "one of the very large resources that we know exists." But lithium clays have some hurdles to clear before they can compete with brines. Retrieving the lithium ore requires open-pit mining, which is more expensive than pumping up the brine. And processing the clay to extract lithium carbonate or other industry-ready minerals is also pricey. Lithium Americas and other companies that claim to have developed their own clean, inexpensive extraction processes haven't yet demonstrated that they will be competitive with brine mining.

Several other types of lithium extraction may be on the horizon, Stillings says. Lithium-rich brines can also form in tectonically active geothermal regions, where there is a lot of heat in the subsurface. Geothermal power plants already pump up the superheated water to generate energy, then inject it back into the subsurface. Some facilities are experimenting with extracting other commercially valuable elements from the brine, including lithium, manganese and zinc. Hydraulic fracturing, or fracking, also involves pumping up brines from the subsurface that may contain high levels of dissolved metals, possibly including lithium. Although the lithium may not be present in very high concentrations, the extraction could still be economically worthwhile, if it's a by-product of mining already going on.

Revitalized research

In December 2017, the White House issued an executive order directing the U.S. Department of the Interior to ramp up research on new sources of certain "critical minerals," including ores bearing lithium. Citing the economy and national security, the order instructed government scientists to analyze each link in the minerals' supply chains, from exploration to mining to production, in hopes that new sources could be found within U.S. borders.

The United States isn't alone in the rush to find lithium. China, the European Union and others are on the hunt for new sources. In January, a consortium of EU researchers launched a two-year initiative called the European Lithium Institute to become competitive in the lithium market.

To kick off this new phase in lithium research, Stillings helped convene a symposium at the American Geophysical Union's annual meeting in Washington, D.C., last December. "We would like to understand how lithium cycles through Earth's crust," Stillings says. "Lithium is very soluble; it likes to be in solution. However, we've learned that as it moves through the crust, it does interact with clays."

Lithium isotopes — it has two, lithium-6 and lithium-7 — are one way to track this exchange. "They are like a fingerprint," says Romain Millot, a geologist with the French Geological Survey and the University of Orléans in France. The different masses of the two isotopes influence how they move between water and solid rock: Lithium-6 prefers to leave the water and bind into clay grains, compared with lithium-7. The isotopes are also proving useful at revealing the influences of weathering, water flow and heat on concentrating lithium, Millot says.

Because water is so important for concentrating lithium, researchers are shifting away from a classic "find the ore" framework, says Scott Hynek, a USGS geologist based in Salt Lake City. Instead, "we're taking a more petroleum-like perspective," he says. Scientists are tracking not just where deposits are, but how they might move: where the water flows, where the lithium-rich fluid could become trapped beneath a layer of hard, impermeable rock.

Lithium prospecting is also taking a page from the hydrology playbook, using some classic tools of that trade to track the circulation of groundwater through the subsurface to suss out where lithium-rich deposits might end up. Isotopes of hydrogen, oxygen and helium are used to track how long the groundwater has been traveling through the subsurface as well as the types of rocks that the water has been in contact with.

Faults, for example, can channel subsurface water, and therefore may play a big role in shaping where lithium deposits might form. "It's an unresolved question," Hynek says. "These are big-scale geologic controls on where high-lithium water goes." He presented data at the AGU symposium suggesting that the highest lithium concentrations in a Chilean salt flat known as the Salar de Atacama occur near certain fault lines. That, he says, suggests the faults are helping to channel the groundwater and thereby concentrating the deposits.

Do no harm

One looming problem for lithium mining is that even "clean" energy isn't completely clean. Extracting lithium from its ore and converting it into a commercially usable form such as lithium carbonate or lithium hydroxide can produce toxic waste, which can leak into the environment. Chemical leaks from a lithium mine in China's Tibetan Plateau have repeatedly wreaked havoc on the environment since 2009, killing fish and livestock that drank from a nearby river.

CYPRESS DEVELOPMENT CORP.

Pieces of a sediment core drilled at one potential future mining site in Clayton Valley, Nev., revealed a promising lithium-rich clay.

A multipurpose element

Lithium is useful for a lot more than batteries. Below are some common products and the lithium compounds they contain. *Carolyn Gramling*

Mood stabilizer for bipolar disorder
Lithium has been used as a medication for conditions ranging from gout to mental disorders since the mid-19th century. Taken as lithium carbonate or lithium citrate, lithium has been in widespread use to treat acute mania, an aspect of bipolar disorder, since the 1970s. However, scientists still aren't sure why the treatment works. Due to their smaller size, charged particles, or ions, of lithium may substitute for potassium, sodium or calcium ions in certain enzymes and chemicals in the brain. Substituting lithium may reduce the sensitivity of certain receptors, making them less likely to connect to brain chemicals such as norepinephrine, which is known to be overabundant during mania.

Cosmetics
Lithium stearate acts as an emulsifier, keeping oils and liquids from separating in foundations, face powders, eye shadows and lipsticks. When added to face creams, a soft, greasy, lithium-bearing mineral called hectorite keeps the product smooth and spreadable.

Military, industrial, automotive, aircraft and marine applications
When added to petroleum, lithium stearate creates a thick lubricating grease that is waterproof and tolerant of high and low temperatures.

Shock-resistant cookware and aluminum foil
Compared with the other alkali metals, lithium atoms are small, particularly in their charged state. Lithium ions expand relatively little as they get hotter, so adding some lithium carbonate to glass or ceramics can make those products stronger and less likely to shatter when hot.

Even when Mother Nature is doing much of the work, such as in evaporation ponds, there can be negative effects on the environment. In South America, for example, the problem is water supply. The lithium triangle, which includes Salar de Atacama, is one of the driest places on Earth — and mining consumes a lot of water. And that's producing a worrisome confluence of events. Just at the edges of the Salar de Atacama salt flats is a flamingo nesting habitat: brackish lagoons filled with brine shrimp. "One of the major oppositions to this mining activity is the impact it has potentially on flamingo populations," Hynek says. The same water source in the Andes that feeds the subsurface lithium brine reservoir also, ultimately, fills the lagoons.

Brine mining in the Salar de Atacama consists of pumping salty, lithium-rich water into evaporation ponds (shown). The post-evaporation sludge is treated with minerals such as sodium carbonate to extract the lithium.

HEMIS/ALAMY STOCK PHOTO

In fact, the water table is already dropping in some places in the region, and indigenous communities, as well as both Chilean and Argentinian authorities, are on high alert, Hynek says. "Chilean authorities are worried that [miners] will pump so much that the lagoon water levels will also drop." In February, Chile announced new restrictions on water rights for miners operating in Salar de Atacama.

Who's to blame is the subject of a lot of debate. In addition to the lithium brine mining, copper mines high up in the Andes — where the groundwater originates — are extracting a substantial amount of water from the system. "The flamingos and the indigenous communities are literally stuck in the middle," Hynek adds.

Such big environmental concerns could hamper future prospects for mining in the region. "You're making the brine in the same area where you're sustaining these important biodiversity habitats," says David Boutt, a hydrologist at the University of Massachusetts Amherst.

There is so far little research on how water moves through the subsurface in dry areas with very low precipitation rates, such as South America's lithium triangle, Boutt adds. "There are a lot of questions about where the water is coming from," such as how variable the water flow rate is through the ground. "It can take a very long time for these systems to respond" to perturbations such as groundwater pumping.

The effects of withdrawing the briny waters now might not be felt for perhaps decades. "A concern," Boutt says, "is whether we are going to be waiting 100 years before something bad happens." ■

Explore more

■ Dwight C. Bradley *et al.* "Lithium" in *Critical mineral resources of the United States — economic and environmental geology and prospects for future supply*. K.J. Schulz *et al.* eds. U.S. Geological Survey Professional Paper 1802, December 2017.

GEOLOGIC ROAD TRIP OF THE MONTH

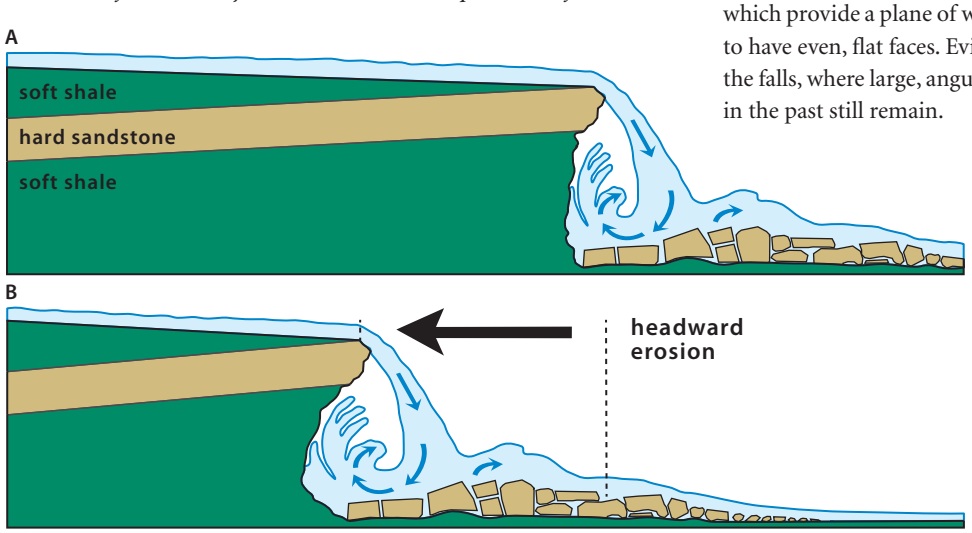
BLACKWATER FALLS

For those wanting to visit Blackwater Falls, turn west on Blackwater Falls Road just west of Davis. The park has two easily accessible viewing platforms. The first is a level, paved walkway from a parking area that offers an elevated view from near the top of the Blackwater River valley. To access the platform, turn left onto Blackwater Lodge Road at the triangle intersection with Blackwater Falls Road. The second platform, accessed using stairs that descend to the lower part of the valley, gives visitors a close-up view of the falls.

The falls are situated in a steep, V-shaped valley that is nearly 500 feet deep. The Blackwater River, named for the water's dark tint from tannic acids released by decaying vegetation, flows over a ledge of Pottsville Sandstone. The falls drop 57 feet to the valley bottom, and the sandstones in both the riverbed and the valley walls contain numerous cut-and-fill channel structures and cross bedding formed by rivers that transported the sand. Deposited during the Pennsylvanian Period, the sand was ultimately lithified into sandstone. Many of the stone steps that lead to the lower platform contain plant fossils, ripple marks, and cross beds.

How was the river able to cut down through the hard Pottsville Sandstone? The answer is found in the soft shales that underlie the sandstone. The river carved a valley in the upstream direction in a process called headward erosion. Shales below the dipping Pottsville Sandstone were eroded to a lower elevation ahead of where the river encountered the Pottsville Sandstone at the surface. As the soft shales were eroded from below they no longer supported the weight of the overlying sandstone, which then collapsed, causing the falls to migrate upstream, or in the headward direction. The collapse of many of the blocks is aided by joints in the sandstone, which provide a plane of weakness and cause the blocks, and the falls itself, to have even, flat faces. Evidence of this ongoing process lies at the base of the falls, where large, angular blocks of sandstone that collapsed sometime in the past still remain.

River channel sandstones of the Pottsville Sandstone at Blackwater Falls State Park form the valley walls and the resistant caprock at the falls.



The effect of headward erosion on soft shales (green) and hard sandstones (brown). The sandstone layer is undercut by the river, causing it to break into blocks and collapse. —Modified from Renton, undated

INTERVIEW

A science-themed escape room gives the brain a workout

Professor Schrödenberg is missing, and evil agents want to use her quantum computing research for nefarious purposes. Stopping them is up to you, but completing your mission will require solving some mind-bending puzzles — based on science.

If you are up for the challenge, you can test your wits at LabEscape, a science-themed escape room at the Lincoln Square Mall in Urbana, Ill. Escape rooms are a popular group activity, in which a team of players is enclosed in a room and must solve puzzles to either escape the room or accomplish a goal within a certain amount of time. LabEscape, created by a bona fide physicist and a crew of physics students, requires no previous scientific knowledge to play. But it does take a willingness to think creatively and work together as a team.

Science News had the opportunity to try out a different version of LabEscape in Boston at a meeting of the American Physical Society in March. In this case, the challenge was to decode the fictional Professor Schrödenberg's password to submit her grant proposal. The tasks necessary to break the code had our small group, consisting of adults and children, scientists and science rookies, running from one side of the room to the other, fiddling with lasers, polarized glasses, thermal imaging cameras and more. Many puzzles required discovering the specific action necessary to reveal a cleverly hidden message — often eliciting excited gasps from our group. Solving one puzzle led to others, until finally, we cracked the code and saved the day.

The puzzles are effective and artistic, and some of the reveals seem almost magical until the purveyors explain the scientific principles behind them at the end of the game. For example, some puzzles required the use of polarized glasses like those used to watch 3-D movies. Those challenges provided an opportunity to discuss the polarization of light — the orientation of light's wiggling electromagnetic waves in a preferred direction. Only waves with the appropriate polarization make it through the lenses. The principle also reveals how 3-D movies work: Different polarizations make it through the right and left lenses, sending a different image to each eye.

As of March, the nonprofit LabEscape has had about 4,500 visitors since it opened in January 2017. LabEscape's creator, quantum physicist Paul Kwiat of the University of Illinois at Urbana-Champaign, has also brought incarnations of LabEscape to scientific meetings and is in discussions with science museums to host the room in the future.

Science News sat down with Kwiat to learn more about his foray into escape rooms. His inspiration, he says, was the first escape room he ever tried, in the summer of 2015 in Lausanne, Switzerland. He did not escape, but he realized that many of the demonstrations he used in lectures could be turned into puzzles to capture the attention of the unsuspecting public and teach scientific principles. The following discussion has been edited for length and clarity. — *Emily Conover*

To unlock hidden messages in LabEscape, players must discover tricks of light. In this example, sugar molecules in the flask rotate light's polarization, or the orientation of its electromagnetic waves, revealing colors that are visible through polarized glasses.

P. KWIAT/LABESCAPE

What are your goals for LabEscape?

The first goal is to show people that science is accessible and relevant to them. The second is to show that science can be fun, because most people don't think of "science" and "fun" without a "not" between them. And third is to have them see that science can be really beautiful, aesthetically. Then there's a meta-goal, which is that it's super important that people have a really good time.

What kinds of teams perform the best?

Curiosity is the thing that people need to do well in an escape room. And that's a case where kids can be really quite good. They're very energetic; they really want to figure things out. The group [at the American Physical Society meeting] that had five high school students and two scientists was clearly superior to all the groups that had only scientists.

What makes a good puzzle?

A good puzzle is hard to do, and when people find out the answer, in some sense it was obvious. Of course, it wasn't really obvious because then you would have just done it. A bad puzzle is when the people running the room tell you no one's ever gotten it without a hint.

What have you learned by watching people solve puzzles?

I hadn't anticipated people's inventiveness. We have a puzzle in which people have to get a key out of a crate. We had a very particular vision in mind of how that should happen. And then people came up with another way to get the key out of the crate, and another way. Now there are 19 ways. It's quite creative, and that's absolutely fabulous for science. You're not following a recipe; you're discovering new things. ■

To learn more about LabEscape, visit **labescape.org**

CONVERSATIONS WITH MAYA

MOON DUCHIN
ASSOCIATE PROFESSOR, TUFTS UNIVERSITY

TUFTS PHOTOGRAPHY

Maya Ajmera, President & CEO of Society for Science & the Public and Publisher of *Science News*, sat down to chat with Moon Duchin, Associate Professor at the Tufts University Department of Mathematics, before she spoke to the Regeneron Science Talent Search 2019 finalists. Moon is an alumna of the Science Talent Search and the International Science and Engineering Fair. She is more recently known for her work applying metric geometry to gerrymandering. We are thrilled to share an edited summary of their conversation.

You are a Westinghouse Science Talent Search 1993 (STS) finalist and International Science and Engineering Fair 1993 (ISEF) alumna. Do you have fond memories of the competitions? How did those competitions affect your career trajectory?

Meeting President Bill Clinton (who seemed larger in person than on TV!) was definitely a memorable part of the Westinghouse STS experience. Also, I felt like I was seeing a lot of the same cohort of kids on the science fair and science program circuit. Many of them also cropped up at Harvard University the next year when I started as an undergraduate, and quite a few are still in my profes- sional circles. So it's also an opportunity to think about who has access to that science fast track. If you're thinking about who's in the room and who's not, then you can be thinking about ways to broaden participation.

You have bachelor's degrees in mathematics and women's studies from Harvard and you have a Ph.D. in mathematics from the University of Chicago. Can you tell us about that journey?

I had a very strong interest in a question about math that was poorly represented in the math curriculum. I really wanted to think about the social aspects of knowledge production in math. What I mean by that is, what counts as a fact in math? Who decides? How does a proof work anyway? What are the dynamics of expertise and authority? And so going into college, it seemed very natural to be a math and philosophy major because I wanted to understand how knowledge works. But philosophy turned out not to be the place where you could ask that question in the way that I wanted – how people in their social formations make the world. So I stumbled on gender studies because the feminist tradition of inquiry engages those same kinds of concerns. Who's in power, and how did they get there? These were the kinds of questions that interested me.

You are known for pushing the boundaries of mathematics to address gerrymandering and fairness in voting systems. Can you explain how that work started and what it entails?

A few years ago I found myself in a position to teach voting theory. It was through teaching that I became more educated about how mathematicians have seen voting as a math problem. I also have close friends in the civil rights legal community and was seeing the other side of the impact of voting theory through them.

Two things sealed the deal for me to actually start actively working on voting systems. First, I was hearing about a desper- ate need for more expert witnesses on quantitative and structural aspects of voting rights litigation. Mathematicians are a big un- tapped pool of brainpower that likes to chew through these kinds of problems. That, for me, was very motivating. Second, I came to realize that there was still a lot of research-level math to do. When you look at redistricting, a lot of the story has been about the shapes of districts. Shape analysis is something that I already did for a living, and when I started out, I assumed that all the tools and ingredients were in place. But I soon realized that there was a lot of room for new ideas that mathematicians could offer to help move the conversation forward. It was the perfect confluence of factors to make me start working on the issue of gerrymandering full-time.

In 2018, Pennsylvania Gov. Tom Wolf enlisted you to analyze the state's congressional districts for fairness. How were you involved in that case?

During January and February 2018, there was a court-ordered scramble to redo the state's congressional district maps, and I was asked to create an analytical framework to understand all the maps proposed by various stakeholders. Pennsylvania has 18 seats in the U.S. House of Representatives. A decent estimate of how many ways we could cut the state into 18 pieces and meet all the rules is maybe 10^{80} or 10^{100} or more. I would venture that you certainly can't hold all those possibilities in your mind at once.

So how are you going to decide what maps are fairest out of that vast wilderness of possibility? I interpreted my role in that kind of question very narrowly. It's absolutely not to pick a map, much less get a computer to pick a map. It's to put some guard-rails on the process so that the maps that are really extreme outliers and provide lots of advantage for one party or racial group can be flagged and made impermissible. And it actually happened. A new map that I rate as very reasonable in its partisan properties was ultimately approved by the state's supreme court, and it has already shaken up the Pennsylvania congressional delegation. I ended up working on the science of redistricting at a really interesting and impactful time.

Last year, you helped lead a summer program on redistricting for 52 students from around the world. Tell us about that experience.

I run a gerrymandering working group called the Metric Geometry and Gerrymandering Group, with Justin Solomon (ISEF 2005–2006, STS 2006), an MIT computer science professor. Together we developed a summer research program called the Voting Rights Data Institute (VRDI), which we hope will be an annual tradition. We bring people from all domains together, including social scientists, geographers, political scientists, law and philosophy students, plus of course mathematicians and coders. It's inspiring to watch the ways that people can do more together than they can do with their own specialty. (You can read about VRDI and some of our other activities at www.mggg.org.)

Moon Duchin poses in front of her Science Talent Search 1993 project, "Applications of Minkowski's Theorem to Classical Number Theory."

SSP

You are a mathematics professor and teach young minds. What do you say to your students, particularly women, who are anxious about math?

One thing I try to get across is that math is really a lot more like other fields than its reputation would allow it when it comes to the fact that ideas can be halfway there. Ideas can be valuable even if they don't totally solve the problems, and it's important to get away from the dogma that if you're not immediately right you must be wrong. I also think for some people it is very meaningful when the math can connect to the social and political world. Those things together can be helpful if you're anxious. Math is incremental so there's lots of room for building up to something big over time, and it's useful!

What advice would you give young people just starting college?

I'm a huge proponent of the American liberal arts model. Some advice I give to people at the college level is to be broad. Don't squander that chance. You have decades to specialize and in this one moment you're pushed to be really broad, so take your interests wherever they go.

What books are you reading right now?

Right now I'm reading two books. One of them is called *The Color of Law*, which is about the history of segregation. It's a really interesting book because it makes the case that the forces behind residential segregation go all the way up in government, and that it was ruthlessly applied and enforced. For someone like me who likes to think about how to draw district lines, it's essential to understand how people got to be located where they are. I think that may be underappreciated, but it is absolutely fundamental. The logic of districts really depends on segregation in some ways, because it's only clustered communities that can be well-captured by compact districts. So those two stories are very intertwined.

The other book I'm reading right now is *Citizen: An American Lyric* by Claudia Rankine. Poetry as social critique!

I am the kind of person who would read and reread and reread a favorite book, especially when I was a teenager. And some of the books that I read obsessively include *The Outsiders* by S.E. Hinton, which is such a great coming-of-age story, and Frank Herbert's over-the-top science fantasy novel *Dune*. *The Outsiders* holds up really well in many ways, maybe *Dune* not so much. But it was science and politics together, so I was sold.

The world faces so many challenges today. What keeps you up at night?

I think about access to power. I think about the direction of the country and its institutions. These days I think about how people like me who speak a technical language can break out of the lecture format and make meaningful interventions. ◆

MARCH 30, 2019

SOCIAL MEDIA

Shell game

There's stiff competition for shells among land-dwelling hermit crabs (one shown below). New research hints that the scent of a dead hermit crab may signal to neighbors that a shell is up for grabs, **Yao-Hua Law** reported in "Hermit crabs are drawn to the dead" (*SN: 3/30/19, p. 10*). Video of the hermit crabs in a frenzy over deathly smells, which *Science News* posted on Instagram, inspired reader **drplockwood** to dub the behavior "musical shells."

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Going green

Researchers found iron oxides trapped in a sample of green Antarctic ice. The compounds may explain why typically blue-hued icebergs can sometimes appear green, ***Jeremy Rehm*** *reported in "Iron may turn icebergs green"* (SN: 3/30/19, p. 12*).* "Since icebergs can drift for thousands of miles, and because iron is a limiting nutrient for algae, I wonder if these bergs are a significant source of iron for algae in temperate latitudes?" reader **Karl Chwe** asked on Facebook. **Chwe** also asked if decreasing numbers of Antarctic icebergs, and therefore reduced iron transport, could impact the amount of algae available to soak up and store carbon dioxide, accelerating climate change.

While it's true that icebergs, especially giant ones, supply some iron to the ocean and support algae, most Antarctic icebergs never make it to temperate regions, **Rehm** says.

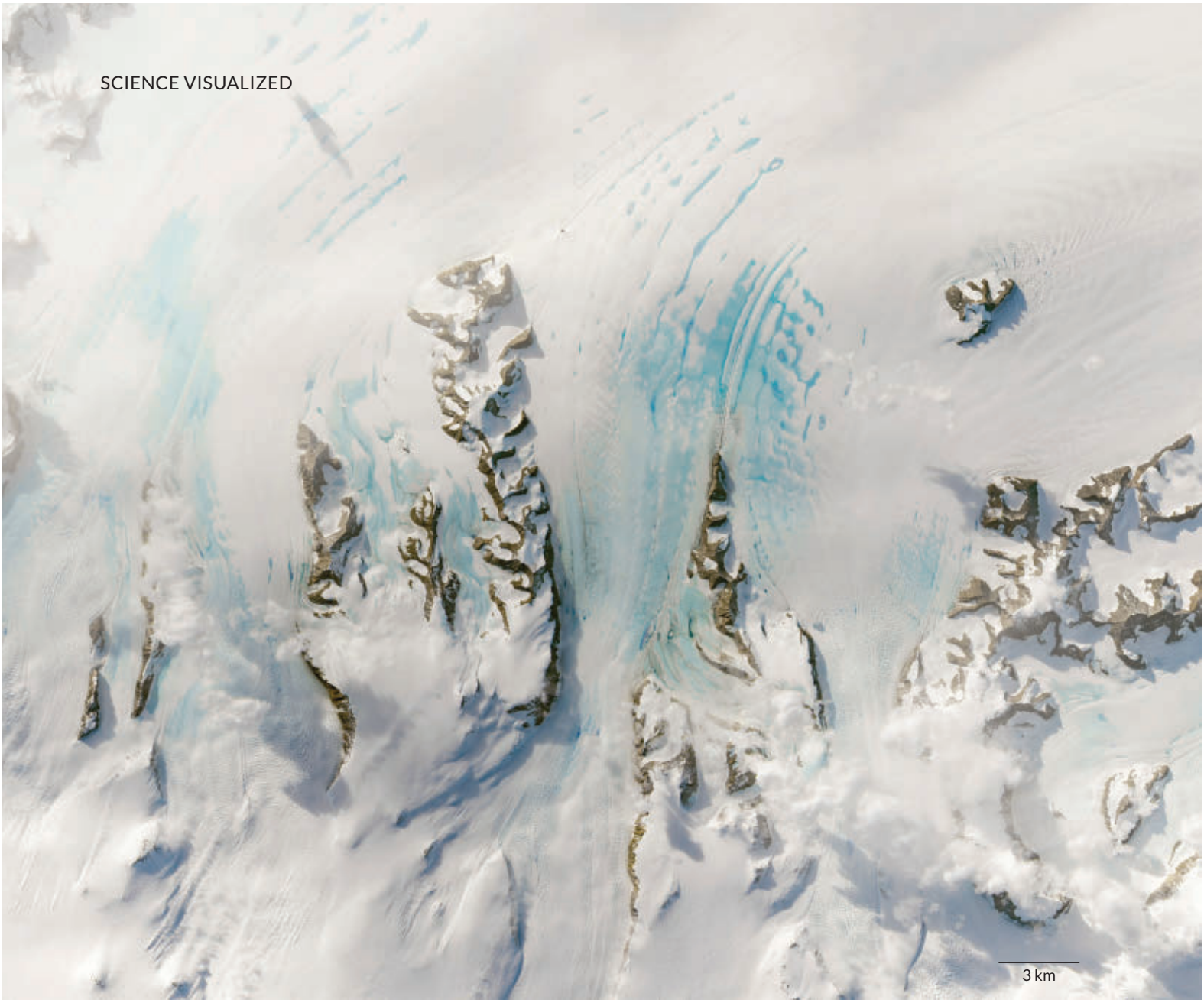
And Antarctica's icebergs may actually be increasing in number, he says. But green icebergs are uncommon. "They account for maybe 3 percent of Antarctic icebergs, based on a survey researchers did from a helicopter," **Rehm** says. "So even if green icebergs do carry iron, it's uncertain they would play a large role in iron delivery, especially outside the Antarctic region."

Search party

Some astronomers are pushing for NASA to make looking for technosignatures, or signs of alien technology, an official goal, ***Lisa Grossman*** *reported in "It's time to start taking the search for E.T. seriously"* (SN: 3/30/19, p. 4*).*
Online reader **Jan Steinman** doubted that human civilization would last long enough to detect technosignatures. The best signs of intelligent life future humans would be able to detect "may be smoke signals" from no farther than the next mountain range on Earth, **Steinman** wrote.

That's an interesting point, and one that astronomers have considered, **Grossman** says. Carl Sagan, a pioneer of the field dedicated to searching for extraterrestrial intelligence, called SETI, made a similar observation in the 1980s when he and four other scientists warned about the possibility of nuclear winter (*SN: 11/12/83, p. 314*).

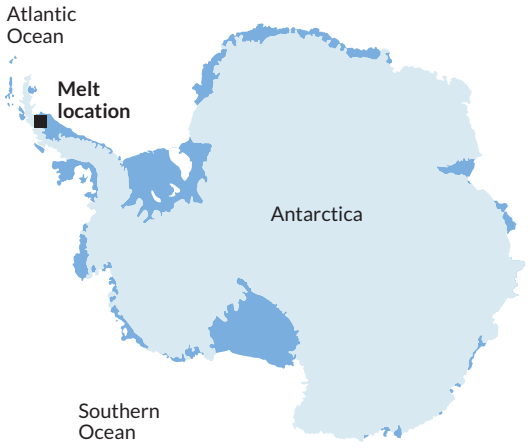
SETI pioneer Frank Drake and colleagues published a study in 2018 that found that even if we find technosignatures, it's likely that the alien civilizations that made them will have already died out (*SN: 4/14/18, p. 9*). "Smoke signals indeed," **Grossman** says.



Untimely melting could be a warning sign

Turquoise pools of snowmelt on the Antarctic Peninsula, including on the Larsen C ice shelf, have recently been forming months after the peak summer melt. Bursts of warm, dry wind cascading over the peninsula's mountain range are largely to blame, scientists report online April 11 in *Geophysical Research Letters*. In this March 2016 satellite image, meltwater on part of Larsen C can be seen at the base of these mountains, one case of this type of wind-induced melting (location indicated on map).

Satellite data and simulations of the peninsula's ice sheet and atmospheric conditions from 1982 to 2017 showed that since 2015, these winds, called foehns, have caused a lot of the region's melting as late as May, well into Antarctica's autumn. Foehns likely cause 60 percent of snowmelt on the northeastern part of the peninsula at that time, says cryospheric scientist Tri Datta of NASA Goddard Space Flight Center in Greenbelt, Md. The melting may have implications for the ice shelf. In 2017, a giant iceberg broke from Larsen C, raising questions about the shelf's stability and how it may contribute to rising seas. —*Jeremy Rehm*



FROM TOP: LAUREN DAUPHIN/NASA EARTH OBSERVATORY; RIDVAN EFE/SHUTTERSTOCK. ADAPTED BY E. OTWELL

“

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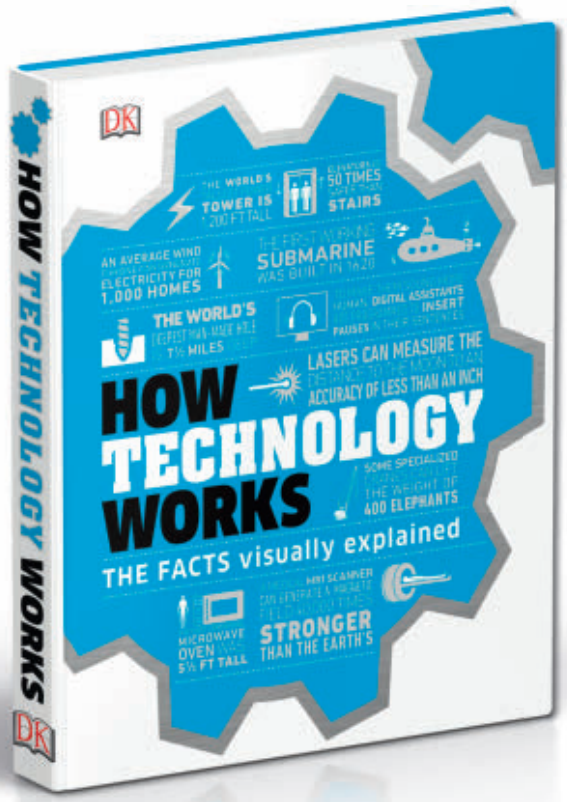

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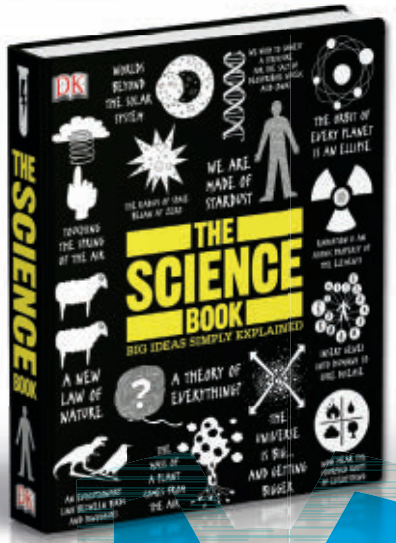

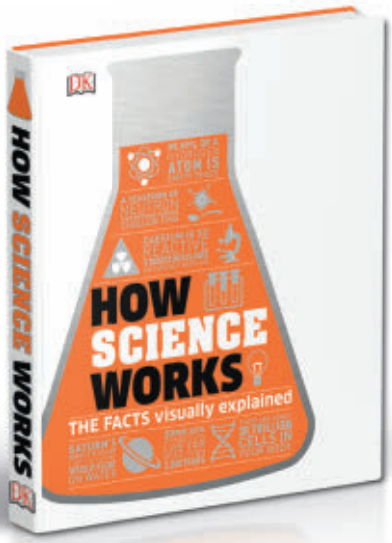

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