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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ JUNE 1, 2024

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COVER Scientists are working to fix faulty and unreliable forensic techniques that can lead to wrongful convictions. *The Red Dress*

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Science and the challenges of evidence-based forensics

Detectives and scientists have a lot in common. Both collect data, develop hypotheses and test their assumptions. And both pursue evidence in the hope of a definitive finding.

Science was key to the exploits of fictional detective Sherlock Holmes, who developed tests to detect poisons and other clues. Another fictional British detective, Dr. John Evelyn Thorndyke, also applied science, using his training as a pathologist to solve crimes, including using X-rays to reveal a murder victim's corpse stashed in an Egyptian sarcophagus. Many more science-minded fictional gumshoes followed, including introverted entomologist Gil Grissom in *CSI: Crime Scene Investigation* and FBI behavioral analyst Jason Gideon in *Criminal Minds*.

We continue to be fascinated by the science of solving crimes—true crime is the most popular genre for top-ranked podcasts. But failures of forensic science to accurately ID perpetrators and exonerate the innocent have become as fascinating as the marvels of scientific sleuthing itself. No doubt Sherlock would argue that science is still the solution. Would he be wrong?

In this issue, we examine where forensics falls short and how scientists are working to fix those failures. It's a challenge, because the work requires both improving the science itself and bettering public understanding of science for a society that includes judges, prosecution and defense lawyers, and jurors.

Despite the shakiness of some of the so-called science, solid, real-deal science can still help make the criminal justice system more accurate and fair. As freelance writer Amber Dance writes, science can't always provide 100 percent certainty, but it can improve the odds that evidence is tested and evaluated properly (Page 22).

In the courtroom, science has led to huge leaps forward. The introduction of DNA evidence in the 1990s overturned many wrongful convictions. It became the gold standard in suspect identification, identifying notorious criminals like the Golden State Killer (SN: 12/22/18 & 1/5/19, p. 22). But it's not infallible; using very small samples of DNA, a mere few cells, makes it harder to get a positive identification. Efforts are underway to add likelihood ratios to this type of evidence, but the technique isn't widely used.

Researchers are also testing ways to improve eyewitness identification. Such approaches include being sure that the officer running a photo lineup doesn't know who the suspect is and inadvertently influence the witness, or ensuring that one person in a lineup doesn't look dramatically different than the others.

I was fascinated by one study that suggested a way to reduce witness bias when showing lineups. Showing pairs of photos and asking which of each pair looked most like the suspect, rather than showing multiple headshots at once, meant witnesses were less likely to assume that one person in the lineup had to be the perpetrator.

But calling a suspect "most likely" may be meaningless in a court where jurors crave certainty, Dance notes. One of the biggest challenges in using science to make the criminal justice system more just is getting the system to accept the caveats and nuance that are inherent to the science itself. Even when it comes to bits of DNA. —*Nancy Shute, Editor in Chief*

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Excerpt from the June 1, 1974 issue of *Science News*

50 YEARS AGO

Animal genes added to bacteria

Genes from animals can be combined with genes from bacteria and be put in a bacterium so that the animal genes can replicate in the bacterium.... The technique consists of constructing DNA "chimeras"—molecules that consist of genes from different sources.... Some day the technique may be used to correct genetic defects.

UPDATE: Chimera experiments have moved far beyond bacteria. Advances in gene-editing technology have helped scientists create mouse embryos with a dash of human cells (*SN: 6/6/20, p. 7*), grow brains that are a mix of rat and mouse cells (see Page 11), and grow mostly human organs in pigs (*SN: 10/7/23, p. 6*). In March, surgeons at Massachusetts General Hospital in Boston transplanted a genetically modified pig kidney into a living person. The kidney had certain pig genes removed and some human genes added to improve the organ's compatibility with the human immune system. The man was discharged from the hospital in April. He died in May from a cause unrelated to the transplant, the hospital said.

RETHINK

Pluto's heart-shaped basin might not hide an ocean after all

A buried asteroid chunk could anchor the Sputnik Planitia formation to Pluto's equator, scientists say.

Rather than a vast ocean, Pluto's heart might be hiding a huge, heavy treasure.

Computer simulations suggest that a 730-kilometer-wide object, slightly larger than the asteroid Vesta, could have slammed into the dwarf planet billions of years ago, formed the famous Sputnik Planitia and left behind a rocky remnant, scientists report April 15 in *Nature Astronomy*.

Sputnik Planitia appeared in images taken by NASA's New Horizons spacecraft as it zipped past Pluto in 2015. The heart-shaped feature, which has roughly the same area as Congo, sits three to four kilometers below the rest of Pluto's surface and is filled with frozen nitrogen.

> The core of an asteroid under Pluto's surface could keep the heart from straying.

"We think it's an impact basin, because that's the easiest way to make a giant hole in the ground," says planetary scientist Adeene Denton of the University of Arizona in Tucson.

Yet the basin's location, across Pluto's equator, is perplexing. Knocking a huge hole in one side of a rotating object, such as a dwarf planet or moon, would lead to unstable wobbles that shift the object's tilt (and thus the hole's location) over millions of years. This is what happened to the moon's Aitken basin, which presently sits near the lunar south pole.

Some scientists have proposed that the impact that created Pluto's heart also created a dense, subterranean water ocean, which has kept Sputnik Planitia situated at the equator (SN: 4/25/20, p. 8). But how the purported ocean could have survived over geologic time has proved challenging. Pluto's surface is a frigid −230° Celsius and even the base of Sputnik Planitia is probably far below water's freezing point. "What if Pluto didn't have an ocean at all?" Denton asks.

To explore this possibility, she and colleagues simulated what would happen if rocky objects of different sizes crashed into Pluto. A space rock about 730 kilometers in diameter is large enough to have a dense, solid core surrounded by lighter-weight materials. As the simulated object plowed into Pluto, the impactor's exterior vaporized but its heavy center remained intact. The core eventually settled below Sputnik Planitia's surface, where it could keep the heart from straying.

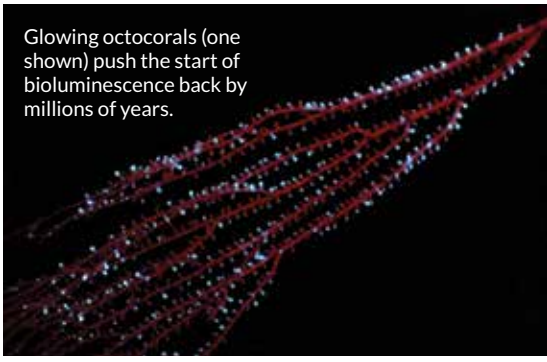
"This is an important idea for us to be thinking about and exploring," says Carver Bierson, a planetary scientist at Arizona State University in Tempe who wasn't involved in the work. Other researchers have raised doubts about cold, tiny Pluto having an ocean, so he's happy to see an alternative model that can explain Sputnik Planitia's properties.

—*Adam Mann*

NASA, JHUAPL, ALEX PARKER/SWRI

THE –EST

Octocorals' glow up goes back half a billion years



Glowing octocorals (one shown) push the start of bioluminescence back by millions of years.

Some 540 million years ago, the deep, dark ocean was aglow with the eerie light of bioluminescent corals, new genetic and fossil analyses suggest. The findings, reported in the April 30 *Proceedings of the Royal Society B*, push the origins of bioluminescence back about 300 million years.

"Our study presents the oldest published record for the appearance of bioluminescence on Earth, and more than doubles the previous record for when bioluminescence first appeared," says biologist Danielle DeLeo of the Smithsonian National Museum of Natural History. That previous record, reported in 2022, was set by the 267-million-year-old ancestor of small crustaceans called sea fireflies.

Chemical reactions within some organisms generate light, which can help the organisms hunt prey, attract mates or hide from predators (SN: 6/9/16, p. 12). The ability to produce light has evolved at least 100 times across the tree of life, from fishes to corals to fungi. DeLeo and colleagues wanted to understand how the trait developed in octocorals, a coral subgroup. These species, including soft corals and sea pens, have eightfold symmetry and many are luminous.

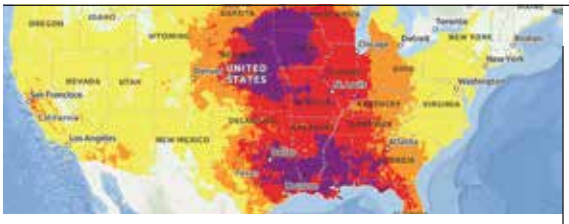
Analyzing the DNA of 270 octocoral species revealed genetic similarities that the team used to create an evolutionary tree. The scientists used octocoral fossils to estimate when lineages split. Based on when glowing species evolved and where in the tree they reside, the team calculated the probability of coral ancestors being bioluminescent.

"It turns out the ancestor to all octocorals was bioluminescent," DeLeo says. That ancestral species lived roughly half a billion years ago, the team calculates.

Bioluminescence may have originated as a by-product of other, more ancient chemical reactions within cells, DeLeo says. Perhaps bioluminescent reactions persisted because they benefited animal communication and survival.

Octocoral bioluminescence is surprisingly old given the trait's volatility, says Todd Oakley, an evolutionary biologist at the University of California, Santa Barbara who led the 2022 study on sea fireflies.

It's possible that organisms such as algae and comb jellies could have evolved their glow even earlier. But limitations in the fossil record make dating when bioluminescence first arose in those groups a challenge, DeLeo says. —*Jake Buehler*



FOR DAILY USE

This map could help you stay safe during heat waves

Above-average temperatures will likely roast much of the United States this summer. Now, a new online tool can help people assess the risk heat may pose to their health. "You can put in your zip code and see current heat risk and air quality levels and a seven-day heat risk forecast for your area," Mandy Cohen, director of the Centers for Disease Control and Prevention, said April 22 at a news conference. "You can plan your day [or] your week with your health in mind." The tool, called HeatRisk, maps risk using a color gradient, from pale green for little to no risk to deep magenta for extreme risk. Forecasts (example shown above), based on National Weather Service and CDC data, consider how unusual temperatures are for the time of year, heat duration and whether nights will offer cool reprieve. —*Nikk Ogasa*

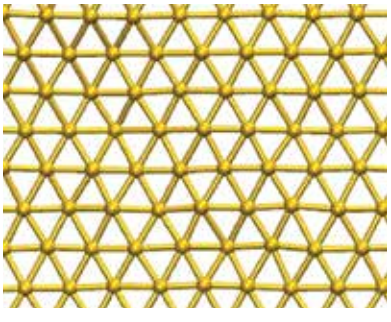
INTRODUCING

Meet goldene, graphene's newest cousin

For the first time, scientists have created a free-standing sheet of gold that's just one atom thick.

The development, reported April 16 in *Nature Synthesis*, could someday allow researchers to use less gold in electronics and chemical reactions, says materials physicist Lars Hultman of Linköping University in Sweden. Goldene may also exhibit exotic properties like other two-dimensional materials do (SN: 10/12/19 & 10/26/19, p. 29).

Gold joins a rarefied group consisting of several elements, including iron, carbon and phosphorus, that have been formulated into 2-D sheets. To make goldene, Hultman and colleagues first made titanium gold carbide, whose 3-D structure contains 2-D sheets of gold. Then the team chemically etched off the surrounding material. "The good news was that we were freeing goldene," Hultman says. To keep the sheets from curling up, the team added a surfactant to the solution that they floated in. Hultman hopes to next make 2-D sheets of iridium and platinum. —*Skyler Ware*



Each gold atom in goldene (illustrated) is bonded to six other gold atoms in a layer just one atom thick.

FROM TOP: SÖNKE JOHNSEN; NOAA; S. KASHIWAYA *ET AL*/*NATURE SYNTHESIS* 2024

Explore a U.S. map of heat and health risk at **bit.ly/HeatRisk**

CLIMATE

Grim results of the ocean's hot streak

Off-the-charts temperatures impact corals, sea ice and more

BY NIKK OGASA

Earth's largest ecosystem is broiling. Every day for more than a year, the average temperature of most of the ocean's surface has been the highest ever recorded on that calendar date, National Oceanic and Atmospheric Administration data show.

"We're currently outpacing last year," says Robert West, a NOAA meteorologist in Miami. "We're continuing to set records, even now over last year's records."

That's partly due to El Niño, a natural climate phenomenon that spreads warm surface waters across the tropical Pacific Ocean. But natural climate cycles can't explain what's happening deeper down.

The amount of heat stored in the ocean's top two kilometers has been increasing for decades, says Miami-based NOAA oceanographer Hosmay Lopez. Since 1971, the ocean has absorbed about 90 percent of the excess heat trapped in the atmosphere by greenhouse gas emissions (SN: 3/12/22, p. 16). What's more, the absorption rate is accelerating.

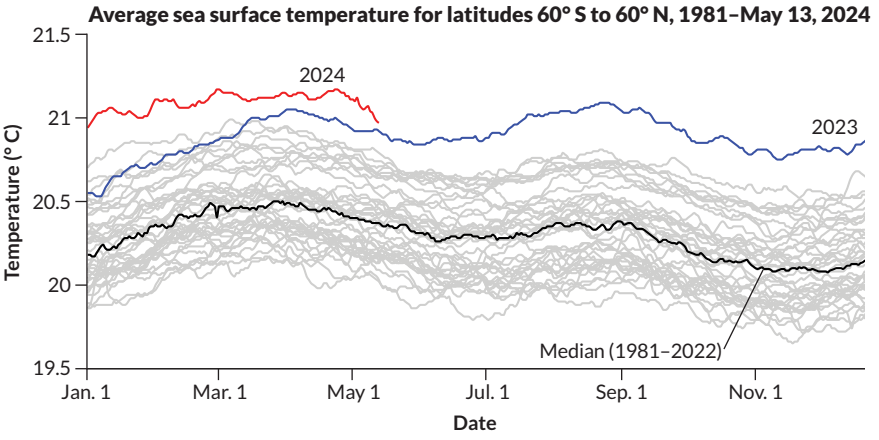
So, what are the impacts of all this heat?

Atlantic hurricanes may ramp up

Hurricanes feed on water vapor and heat, so the hot Atlantic Ocean could make for an extremely active storm season, which runs June 1 through November 30.

Two outlook reports, released in April by Colorado State University in Fort Collins and the University of Pennsylvania, forecast 23 to 33 named storms. The CSU report estimates that five will be major hurricanes, classified as Category 3 or greater. When storms that powerful make landfall, they can be destructive and deadly. There's a 62 percent chance of a major hurricane hitting the United States this year.

Most hurricanes form in the Atlantic Ocean between the Caribbean Sea and the western coast of Africa. Surface temperatures in this region have been abnormally high. In April, they were more than 1.5 degrees Celsius above the long-term average for the time of year (about 25° C).



Soaring sea temps Since March 2023, the average sea surface temperature of the extra-polar ocean, at latitudes from 60° S to 60° N, has broken the daily record every single day, NOAA data show. And recent daily temperatures have shattered records that were set last spring.
SOURCE: CLIMATE REANALYZER/UNIV. OF MAINE; NOAA

There have been 11 months since 1981 for which surface temperatures have been that unusually warm. Nearly all have occurred in the last year, West says.

The possible emergence of La Niña, El Niño's counterpart that brings cooler surface waters to the tropical Pacific, may also contribute to the forecasted frenzy. During La Niña, Atlantic winds that tear apart brewing hurricanes weaken. As of May 5, NOAA reports a roughly 80 percent chance that La Niña will emerge by August to October, around peak hurricane season.

Coral bleaching spreads worldwide

When corals become stressed by rising temperatures, they expel the vibrant algae that live in their tissues and provide them with food. This evacuation is known as bleaching, and it can kill corals. Since February 2023, bleaching has become so widespread that NOAA has declared it a global event — the fourth ever recorded.

The coral death toll won't be clear until months or years after the event, says marine ecologist Carly Kenkel of the University of Southern California in Los Angeles. But, she says, "this is the worst bleaching that we've ever seen for the Caribbean, and it's certainly looking like that for the Great Barrier Reef as well."

Antarctic sea ice reaches new lows

Over the last year, Antarctic sea ice has fared terribly. In a typical February, sea ice dwindles to an annual minimum of roughly 3 million square kilometers, according to the National Snow and Ice Data Center in Boulder, Colo. This February, it retreated to 2 million square kilometers, tying for the second lowest annual minimum extent on record. And in September 2023, the ice reached a new record-low annual maximum extent: 17 million square kilometers.

Ocean warming and changes in atmospheric circulation were probably driving factors, says Monica Ionita, a climatologist at the Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research in Bremerhaven, Germany. "It was too warm above the ice, and too warm below."

Looking ahead

For now, it's unclear what trajectory sea surface temperatures will take. The departure of El Niño and the arrival of La Niña may help bring them down, Lopez says.

But record-high temperatures occurred during the 2020–2023 La Niña event. "Even if you have a relatively cooler area in the equatorial Pacific," West says, "it doesn't necessarily mean that you stop breaking records everywhere." ■

C. CROCKETT

ANIMALS

Lampreys have ‘fight or flight’ cells

The finding upends ideas about nervous system evolution

BY CLAUDIA LÓPEZ LLOREDA

With terrifyingly sharp teeth arranged around a circular mouth, lampreys look about as primitive a vertebrate as you could imagine. But a new study finds that these jawless fish have a surprising similarity to people: nerve cells responsible for the “fight or flight” stress response.

Finding these nerve cells in lampreys challenges the idea that this part of the nervous system emerged only in jawed vertebrates, after they split from their jawless counterparts millions of years ago. And it puts lampreys closer to complex vertebrates — like humans.

“The conclusions are textbook-changing level,” says Daniel Meulemans Medeiros, an evolutionary biologist at the University of Colorado Boulder who was not involved with the new study but has worked with the research group before.

Scientists had thought that jawless fish such as sea lampreys (*Petromyzon marinus*) lack certain nervous system characteristics found in jawed vertebrates, such as the sympathetic nervous system. This system, which is part of the peripheral nervous system that branches out from the brain and spinal cord, releases hormones that prime the body to fight or flee when faced with some external threat or stressor.

In past work, Caltech neuroscientist Marianne Bronner and colleagues had examined lampreys’ peripheral nervous system in detail. While studying peripheral nerve cells, study coauthor Brittany Edens, a researcher in Bronner’s lab, found some in an unusual spot — outside the intestine. The team decided to investigate.

Using a technique that tags and lights up specific RNA molecules in individual cells of lamprey embryos, the scientists found clusters of cells aligned with the heart and the trunk that had several active genes associated with the sympathetic nerve cells found in jawed vertebrates.

Tracking where the cells in these clusters originated involved injecting lamprey embryos with a fluorescent dye to label the neural crest, a patch of stem cells that migrate and give rise to the peripheral nervous system. As the embryos continued developing, nerve cells around the heart and trunk lit up, indicating that they came from the neural crest — just like the sympathetic nerve cells in jawed vertebrates do.

Taken together, the findings suggest the heart and trunk cells were sympathetic nerve cells, Bronner and colleagues report in the May 2 *Nature*.

Compared with jawed vertebrates, the lampreys’ sympathetic nervous system formed much later in development, and the cell clusters were smaller. Previous studies may have missed these cells by looking for them at the wrong time during embryonic development, the researchers say.

Even though lampreys have a sympathetic nervous system, it’s rudimentary, Bronner says. “It’s very simplified compared to what it would be in mammals.”

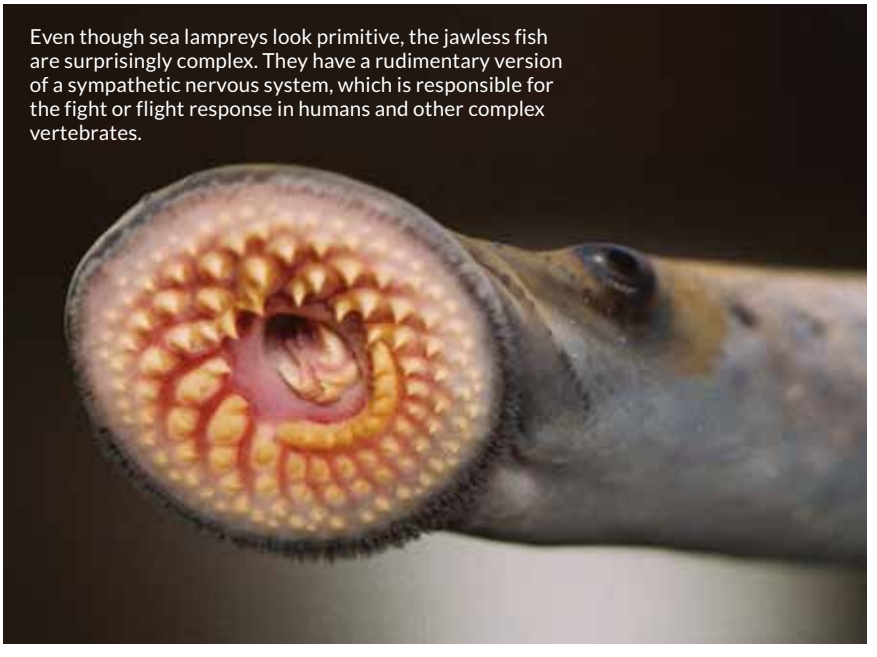
Still, the findings suggest that the sympathetic nervous system was not an innovation of jawed vertebrates. Rather, the blueprint has been around since even before lampreys diverged from the main vertebrate line about half a billion years ago, says neuroscientist Shreyas Suryanarayana of Duke University.

“As you look deeper [in evolutionary history], it becomes clear that the basic building blocks of these complex systems present in humans are, in fact, very old,” Suryanarayana says. This system diversified, expanded and grew larger in jawed vertebrates, he says.

Previous studies had already begun to dismantle the idea of a simple nervous system in lampreys. Researchers had found that proteins and connections in specific brain areas of the lamprey resembled those seen in other vertebrates. More recently, scientists found that the way that brain areas in lampreys organize also applies to all vertebrates.

Medeiros suggests that researchers should now look even further back in evolutionary time at invertebrates to see if they also have sympathetic nerve cells, which could explain how the vertebrate nervous system evolved.

Bronner agrees. “That’s really one of the questions that has fascinated me for years: How did you go from invertebrates to vertebrates?” she says. “I don’t have the answer, but I will keep trying to figure it out.” ■



Even though sea lampreys look primitive, the jawless fish are surprisingly complex. They have a rudimentary version of a sympathetic nervous system, which is responsible for the fight or flight response in humans and other complex vertebrates.

T. LAWRENCE, GREAT LAKES FISHERY COMMISSION (CC BY-SA 2.0 DEED)

PALEONTOLOGY

T. rex's smarts scrutinized

A new cell census stirs debate over the dinosaur's brainpower

Tyrannosaurus rex's brain, which occupied 30 to 40 percent of the braincase (blue in the reconstruction), could have packed millions or billions of neurons. Whether that number can shed light on intelligence is unclear.

BY FREDA KREIER

How brainy was *Tyrannosaurus rex*? It depends on who you ask.

Last year, the iconic Cretaceous dinosaur received the glow-up of a lifetime when Suzana Herculano-Houzel, a neuroscientist at Vanderbilt University in Nashville, calculated that the predator had 3.3 billion neurons in one part of the forebrain alone. The discovery put *T. rex*'s forebrain on par with modern baboons'.

The finding raised eyebrows — and doubts. Any suggestion that these dinosaurs were as smart as primates "seems like a large leap," says Cristián Gutiérrez-Ibáñez, a comparative neuroscientist at the University of Alberta in Edmonton, Canada. "Having the same number of neurons as a primate does not make you a primate."

Now, Gutiérrez-Ibáñez and colleagues have come up with a more conservative neuron count. The *T. rex* telencephalon, a part of the forebrain involved in sensory, cognitive and motor functions, had closer to 360 million neurons, the team reports April 26 in the *Anatomical Record*. The new estimate suggests that *T. rex*'s forebrain is more similar to that of modern crocodiles than of primates, the researchers say.

Calculating how many neurons an animal possesses requires knowing how densely packed the brain cells are. That can be tough not only because neuron density varies widely between animals, but also because neurons aren't well preserved in the fossil record. When scientists look at extinct animals, they must use the neuron densities of modern relatives as proxies.

Here lies the issue. *T. rex* is related to both reptiles and birds. But reptiles have fewer neurons per square centimeter of brain than birds. When calculating the number of neurons in extinct theropods, the dinosaur group that includes *T. rex*, scientists must decide whether to use neuron densities of birds, reptiles or some combination of the two.

In the 2023 study, Herculano-Houzel calculated the ratio between brain size and body mass of about 30 dinosaurs and then looked at how the species stacked up against modern birds and reptiles. Her calculations using ancient bird families hinted that theropod brains were more like bird brains than that of other dinosaurs. Thus, she used the neuron densities of modern birds that are most closely related to theropods to calculate how many neurons *T. rex* had.

Even if birds are living dinosaurs, that assumption is flawed, Gutiérrez-Ibáñez says. Adding a broader range of living birds to the comparison of brain-to-body ratios brought *T. rex*'s more in line with that of scaled reptiles, he and colleagues argue.

Herculano-Houzel's study also inflated the number of *T. rex*'s neurons by assuming that dinosaur brains occupied the whole braincase, like modern bird brains do, Gutiérrez-Ibáñez says. The brain of *T. rex* and many other dinosaurs floated in fluid — a trait found in modern crocodiles.

Gutiérrez-Ibáñez's team recalculated *T. rex*'s brain size using a smaller brain volume, which cut down the amount of neurons in the telencephalon from 3.3 billion to 1.2 billion. Using reptile neuron density reduced the amount even further, to between 245 million and 360 million cells.

Herculano-Houzel says that her study did account for dinosaur brains not completely filling the braincase. She is also not convinced by the new findings.

Gutiérrez-Ibáñez and colleagues made a "fatal mistake" in their assumptions about the brain-to-body ratio that led to the lower cell count, Herculano-Houzel says. By throwing in distantly related birds like pelicans and penguins — which have fundamentally different brain-to-body ratios — the team arrived at the incorrect conclusion, she says.

Whether *T. rex* had a lot of neurons to spare might not be a good indicator of the dinosaur's brainpower anyway, says Amy Balanoff, an evolutionary biologist at Johns Hopkins School of Medicine who was not involved in either study. Even if *T. rex* had a neuron density on par with primates, many of the cells in the telencephalon were probably devoted to helping the dinosaur gather olfactory information. The smell centers of the *T. rex* forebrain were huge, Balanoff notes.

Still, "I do really appreciate the original study for starting the conversation," Balanoff says. "You can't move science forward if you're unwilling to put the data out there." ■

ANIMALS

Traffic noise harms bird eggs

The raucous din of modern life can seriously mess with animals. Traffic noise can drown out mating calls, spike stress hormones and even increase mortality. Now, research suggests this noise can harm some critters even before they can hear it.

Zebra finch eggs and nestlings exposed to everyday traffic noise experience lifelong reductions in health and reproduction, behavioral ecologist Mylene Mariette and colleagues report in the April 26 *Science*. These harms stemmed from direct exposure to the sound itself, the researchers say, suggesting noise pollution poses a more pervasive threat than previously thought.

"We were really surprised," says Mariette, of Deakin University in Geelong, Australia. "Not just because the effects were strong, but they lasted a long time."

Earlier research had linked noise exposure during development to health problems later in life, but scientists couldn't rule out whether it was because noise messed with parenting. In the new work, the team exposed zebra finches (*Taeniopygia guttata castanotis*) to traffic noise or birdsong overnight as either eggs, chicks or during both life stages. Nestlings were separated from their parents for the sound treatments.

Compared with birds raised in a natural sound environment, birds exposed to traffic noise hatched less often and hatchlings were about 15 percent lighter on average. The effects were most pronounced in birds exposed to the noise both while in the egg and as hatchlings. In an enclosure where zebra finches could breed freely, birds exposed to traffic noise produced about 60 percent fewer offspring — roughly four fewer birds — than those raised amid natural sounds. *—Jonathan Lambert*

PAUL SOUDERS/CORBIS/GETTY IMAGES

Beluga whales like this one at Connecticut's Mystic Aquarium sport a blob of forehead fat called a melon. The cetaceans contort the melon into shapes, possibly to communicate with each other.

ANIMALS

Belugas may communicate via 'melons'

Captive whales can mold forehead fat into five distinct shapes

BY ELIZABETH ANNE BROWN

The beluga whale wears its heart on its sleeve — or rather, its forehead.

Researchers have created a visual encyclopedia of the expressions that belugas (*Delphinapterus leucas*) in captivity seem to make with their highly mobile melon, a squishy deposit of fat on the forehead that helps direct sound waves for echolocation.

Using muscles and connective tissue, belugas can push the melon forward over their lips, press it down until it's flattened against their skull, lift it vertically to create an impressive fleshy top hat, and shake it with such force that it jiggles like Jell-O. "If that doesn't scream 'pay attention to me,' I don't know what does," says animal behaviorist Justin Richard of the University of Rhode Island in Kingston.

Before Richard became a scientist, he spent a decade working closely with belugas at the Mystic Aquarium in Connecticut. "Even as a trainer, I knew the shapes meant something," Richard says. "But nobody had been able to put together enough observations to make sense of it."

Over the course of a year, from 2013 to 2014, Richard and colleagues recorded interactions between four belugas at the Mystic Aquarium. Analyzing the footage revealed that the belugas make five distinct melon shapes the scientists dubbed push, press, flat, lift and shake. The belugas sported an average of nearly two shapes per minute during social interaction, the team reports March 2 in *Animal Cognition*.

It's not clear whether the shapes are intentional gestures or unconscious reflections of the beluga's emotional state. But nearly 94 percent of the shapes made during social interactions occurred in another beluga's sight line, so Richard suspects they're purposeful signals. Shake and press are linked with courtship behavior, while the other shapes have proved more difficult to parse, he says. "There are probably some gradations that are meaningful to them that are difficult for us to pick out."

The team has validated the findings in a larger captive population — 51 belugas at MarineLand Canada in Niagara Falls exhibit the same melon shapes that the Mystic whales do. It's unclear whether wild belugas also make these shapes and whether the shapes aid echolocation.

The study establishes a shared vocabulary that scientists can build on, says comparative psychologist Malin Lilley of Texas A&M University–Central Texas in Killeen. This labeling is key for decoding beluga communication, Lilley says, and it's just plain cool to have words to describe the squishy expressions she's seen in her years of beluga research. ■

Watch a video of belugas shaking their melons at **bit.ly/SN_Beluga**

HEALTH & MEDICINE

Malaria parasites evade rapid tests

Mutations may be spreading across at least three continents

BY JONATHAN LAMBERT

Rapid diagnostic tests have emerged as a vital tool in the fight to control malaria, a mosquito-borne disease that kills around half a million people globally each year. The inexpensive test strips, which work in just minutes, have diagnosed millions of cases, hastening access to lifesaving treatment. But this progress could be undermined by the malaria-causing parasite itself.

Gene mutations that render *Plasmodium falciparum* invisible to the gold-standard rapid test are spreading across many countries, contributing to false-negative test rates as high as 80 percent at some hospitals. That suggests the mutations could be spreading unnoticed, causing hundreds of thousands of malaria cases to go undetected, scientists worry. Without new tests, the mutations could hinder eradication efforts.

Most malaria rapid tests work by detecting two specific *P. falciparum* proteins. In some parasites, portions of genes that code for these proteins have been deleted, making the parasites undetectable, researchers reported in 2010.

While there are alternative rapid tests that rely on other proteins, these tests aren't widely used. They are "not quite as sensitive and a little more expensive," says infectious disease modeler Oliver Watson of Imperial College London. As a result, the global supply is limited.

Test-evading mutations have popped up in at least 40 countries across South America, Africa and Asia. Many of the countries have reported barely a trace, but there's evidence of rapid spread in certain regions, especially the Horn of Africa.

Startling numbers of false-negative rapid tests began popping up in Eritrea in 2014. Subsequent studies found test-evading parasites were to blame. At one hospital, these parasites infected 21 out of 26 malaria patients. At another, the parasites infected 10 out of 24 patients. The high prevalence led Eritrea to switch to alternative rapid tests. Ethiopia and Djibouti followed suit.

These countries' efforts have largely worked. "There are no indications that [the spread of mutations had] a major impact in malaria control efforts, especially because of the prompt detection and subsequent test policy changes," says microbiologist Michael Aidoo of the U.S. Centers for Disease Control and Prevention.

In 2019, the World Health Organization advised malaria-endemic countries to switch testing strategies when mutation prevalence reaches 5 percent. Since monitoring requires expensive, time-consuming methods, the global picture is still fuzzy in some areas.

"There's a vital need for more surveys," Watson says, to track where the mutations are spreading and how fast they're increasing. Within 20 years, 29 of 49 malaria-endemic countries in Africa could have some areas that reach the WHO threshold, he and colleagues estimate in a paper posted in January at medRxiv.org. East Africa, Senegal and Mali are among the regions at highest risk.

The findings underscore the need for widely available and sensitive rapid tests. Without them, malaria will become much harder to control, Watson says. "It's just an incredibly worrying problem." ■

NEUROSCIENCE

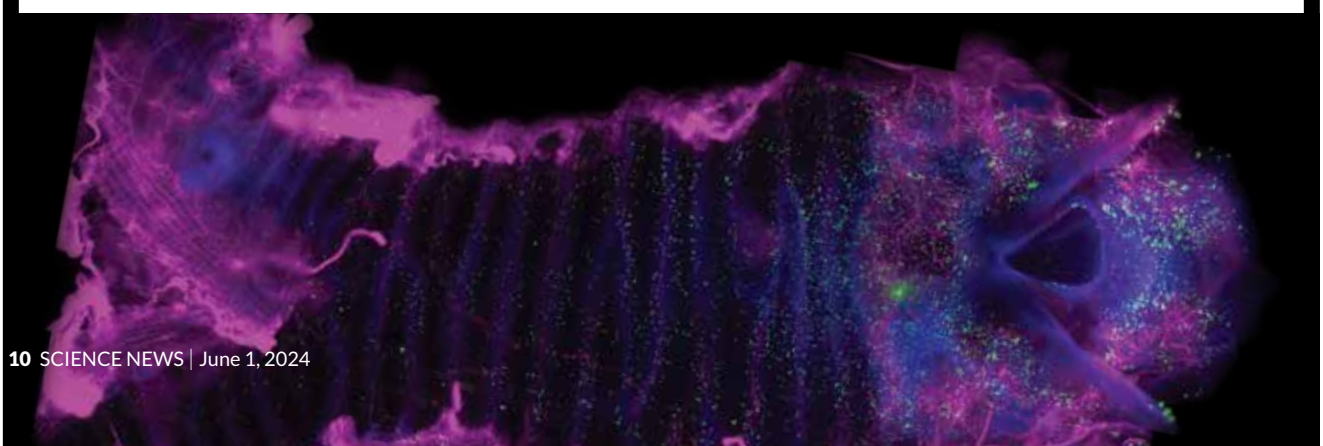
These windpipe cells trigger coughs to keep water out of the lungs

Have you ever taken a gulp of water that goes down the wrong way? It feels like your windpipe seizes up and you quickly cough, maybe even several times. Researchers now know which cells are responsible for that quick reaction.

Hormone-producing cells in the larynx and trachea, parts of the upper airway, can sense water and acid passing through, scientists at the University of California, San Francisco report in the April 19 *Science*. These neuroendocrine cells then communicate with the nervous system to trigger reflexes, like coughing.

Physiologists Laura Seeholzer and David Julius subjected mouse cells in dishes to stimuli and tracked the cells' calcium levels, which indicates chattiness with their neighbors. Unlike the lungs' neuroendocrine cells, which respond to pressure changes, those in the larynx and trachea responded to water and acid. In mice, activating these cells (green in the microscope image of a mouse windpipe, below) triggered coughing, presumably to expel substances in the airway.

Many types of sensory cells communicate with the nervous system to drive behavior, Seeholzer says. Like taste buds or skin cells, airway neuroendocrine cells help protect against harmful substances. — *Nora Bradford*



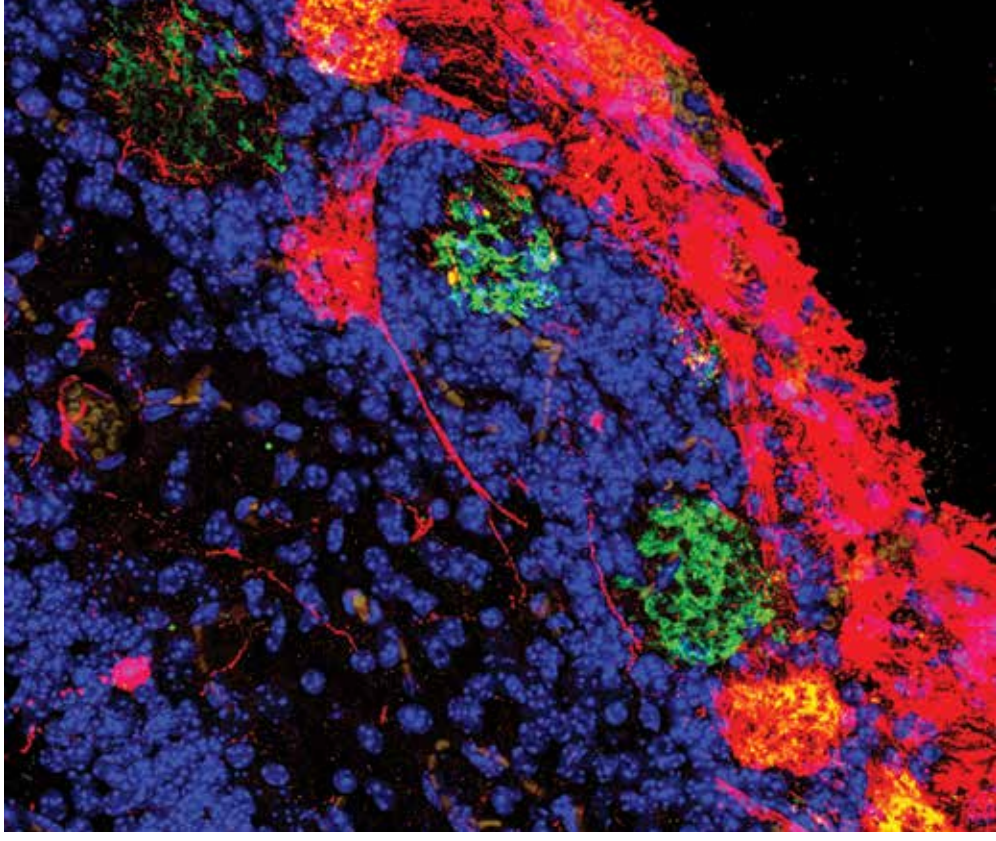
L. SEEHOLZER

NEUROSCIENCE

Hybrid brains pass a smell test

Mouse noggins filled in with rat cells shed light on development

BY LAURA SANDERS



Structures made of rat nerve fibers (red spheres in this micrograph) that help sense odors formed in the brains of mice, alongside structures made of rat and mouse fibers (orange) or just mouse fibers (green). This hybrid smell system can help scientists understand how flexible brains can be.

BEN THROESCH

What does it feel like to be a rat? We will never know, but some very unusual mice may now have an inkling.

In a series of new experiments, bits of rat brain grew inside the brains of mice. Donor stem cells from rats formed elaborate, functional neural structures in mice's brains, despite being from a completely different species, scientists report in two papers in the April 25 *Cell*.

The findings are "remarkable," says neuroscientist Afsaneh Gaillard of INSERM and the University of Poitiers in France. "The ability to generate specific neuronal cells that can successfully integrate into the brain may provide a solution for treating a variety of brain diseases associated with neuronal loss."

These chimeric mice reveal just how flexible brain development can be (SN: 4/22/23, *p.* 8). And while no one is suggesting that human brains could be grown in another animal, the findings may help clarify biological details relevant to interspecies organ transplants, the researchers say.

The success of these rat-mouse hybrids depended on timing: Rat and mouse cells had to grow into brains together from a very early stage. Rat stem cells that had the potential to mature into several different cell types were injected into mouse embryos. From there, the rat cells developed alongside mouse cells in the growing brain, though researchers couldn't control exactly where rat cells ended up.

In one set of experiments, scientists cleared the way for rat cells to develop in the young mouse brains. Stem cell biologist Jun Wu of the University of Texas Southwestern Medical Center in Dallas and colleagues used a form of the genetic tool CRISPR. The team inactivated a mouse gene that instructs cells to build a forebrain, a region involved in learning, remembering and sensing the world. This left the mice without forebrains — normally, a lethal problem.

But rat stem cells filled the void. "The chimeras can live a normal life, up to two years that we analyzed," Wu says. These mice seemed to behave normally, and their forebrains were the right size and shape. Gaillard points out, however, that more detailed studies are needed to say how similar these rat cells are to the mouse cells they replaced.

In other experiments, mice put rat cells to good use by sniffing out buried treats. Neuroscientist Kristin Baldwin of Columbia University and colleagues focused on brain areas that handle smells. Rat stem cells transplanted into the embryos of mice engineered to have damaged smell systems knitted themselves into neural circuits. Those circuits allowed the mice to sniff out and dig up a buried Oreo cookie.

Some clusters of nerve cell endings that help animals sense odors were built solely from rat cells, the researchers found. And in some mice, random chance had made it so half the brain was made strictly of mouse cells while the other half had rat cells. In these cases, "the rat [cells were] really driving the brain to respond," Baldwin says. "That was pretty cool that half of its brain was smelling, and half of it wasn't."

In both studies, a close look at the rat donor cells showed that they adopted many of the traits of surrounding mouse cells. Rat cell size, growth timing and cellular targets looked less like rat cells and more like mouse cells. That suggests that the environment the cell grows up in can strongly influence the cell, regardless of its species identity.

By figuring out the details of interspecies cell transfers, researchers hope to learn more about how brains evolve and develop. Wu is keen to study the brains of wild rodents, including the African pygmy mouse. It has a tiny brain, commensurate with a body that's 6 to 8 centimeters long. Wu wonders if stem cells from this minuscule mouse would grow larger forebrains inside the head of a regular house mouse.

The new results could lead to insights on the biological limits on brain cell flexibility, Baldwin says. These unusual hybrid brains might also offer hints about how human brains grow, knowledge that could one day lead to treatments for when brain development goes awry. ■

Altermagnets are made of atoms that alternate their orientation as well as the orientation of their spins, represented by purple and blue in this illustration.

L. ŠMEJKAL AND ANNA BIRK HELLENES

PHYSICS

Altermagnets shatter the status quo

A newfound type of magentic material could speed up computers

BY EMILY CONOVER

For the first time in nearly a century, physicists have identified a brand-new type of magnetic material.

Crack open a physics textbook and you may read that scientists classify magnetic materials into two main types: ferromagnets and antiferromagnets. Ferromagnets are what most people think of when magnets come to mind. These materials possess an external magnetic field that lets them hold up photos on a refrigerator or cause a magnetic compass to point north. Antiferromagnets have no external magnetic field but have other magnetic quirks.

Now, that classic pair has become a trio. In a variety of studies, physicists have reported a new class of magnetic materials called altermagnets, which could lead to new technologies such as faster, more efficient computer hard drives.

Even though the idea behind altermagnets is extremely simple, "nobody thought about this possibility" until recently, says theoretical physicist Igor Mazin of George Mason University in Fairfax, Va. The fact that a third magnetic category could have remained unnoticed this long is "very surprising," Mazin says.

That's because the study of magnetic materials is an ancient science. Ferromagnets have been known for thousands of years. Lodestone, a magnetized form of magnetite, fascinated the ancient Greeks. The ancient Chinese forged the mineral into the first compasses. Antiferromagnets were discovered in the 1930s.

Then, a few years ago, theoretical predictions suggested altermagnets could exist. When searches began, researchers quickly discovered that the magnetic materials are real and plentiful.

What makes an altermagnet?

On a microscopic level, materials get their magnetism from their atoms. The atoms have spin, a quantum mechanical property bestowed by the atoms' electrons. That spin gives each atom a minuscule magnetic field. The spins can point in different directions, normally called spin up and spin down. Any material with spins arranged in an orderly way—even when not subjected to any outside magnetic field from another source—is considered a magnetic material by physicists.

In ferromagnets, atoms' spins align, which combines the atoms' magnetic fields to create a magnetic field around the material. Antiferromagnets do the opposite: The atoms' spins point in alternating directions, which cancels out the magnetic fields and produces no net field.

In altermagnets, the atoms' spins alternate, but with an added twist. Not only are the spins of neighboring atoms opposite, but the atoms are also rotated. If you think of antiferromagnets like a checkerboard, with alternating black and white squares standing in for spin up and spin down, then altermagnets are like an M.C. Escher drawing with tessellating shapes—birds, horses or another of Escher's motifs—that don't just alternate in color but are also rotated with respect to one another.

If you take an altermagnet, flip its spins around and rotate the material—by 90 degrees, for example—it will look identical to its original state. That's a special type of symmetry, different from other magnetic materials. And this symmetry puts altermagnets in their own class, physicist Jairo Sinova of Johannes Gutenberg University Mainz in Germany

and colleagues argued in 2022 in *Physical Review* X. That study is one of a smattering of theoretical papers since 2019 that helped put altermagnets on the map.

Experiments have now begun confirming the altermagnetic identities of certain materials.

Altermagnets get real

Scientists predicted that the electrons within altermagnets would have some unusual characteristics. To confirm the altermagnetic nature of a given material, scientists need to map out that electron behavior. Particularly important is plotting out how the energy of an electron in the material relates to its momentum.

In ferromagnets, electrons with a given energy on that map split up: The momentum depends on the spin. Spin up electrons will have a different momentum than spin down electrons of the same energy.

In antiferromagnets, however, spin up and spin down electrons are the same. For a given energy, both spins will have the same momentum.

Here's where altermagnets' weird dual nature comes into play. Scientists predicted that the materials' electrons would be split according to spin, but only for electrons moving in certain directions. That means in some orientations, the material will act like a ferromagnet, and in others like an antiferromagnet.

To confirm this effect, scientists used a technique called angle-resolved photoemission spectroscopy, which measures the electrons emitted when a material is hit with light. With that method, the team observed spin splitting in the material manganese telluride.

Manganese telluride, studied since the 1950s, was previously thought to be well understood as an antiferromagnet. But the results matched predicted altermagnetic behavior, the researchers reported in the Feb. 15 *Nature*.

Around the same time, two other teams also found evidence of spin splitting in manganese telluride, according to papers published in the Jan. 19 *Physical Review Letters* and the March 15 *Physical Review B*.

And more altermagnetic materials are cropping up. A paper in the Feb. 2 *Science Advances* found hallmarks of altermagnetism in ruthenium dioxide, and a March 8 paper in *Nature Communications* described altermagnetic behavior in thin films of a chromium-antimony compound.

"The bottom line is ... it's not only one rare system" that hosts an altermagnet, says Libor Šmejkal, a physicist at Johannes Gutenberg University Mainz. The results confirmed that altermagnets aren't just theoretical. They are a new, third class of magnetic material.

Not only are altermagnets found in multiple materials, but there are more altermagnet candidates (232) than there are known ferromagnets (193). And confirmed altermagnetic materials aren't obscure or toxic, says experimental physicist Helena Reichlová of the Institute of Physics of the Czech Academy of Sciences in Prague. Researchers already know how to produce and work with these materials. "They are already here with us, they were just hidden to us," Reichlová says.

New magnets find their niche

Altermagnets' nature could make them particularly suited to certain technological applications. Currently, ferromagnets are used for magnetic computer hard drives, which encode 0s and 1s in tiny magnetic bits. But the technology is limited by the ferromagnets' magnetic fields.

"This magnetization in ferromagnets, it's the source of all these exciting effects which we, for instance, use in hard drives," Šmejkal says. "But at the same time, it's [an] enemy."

> "They are already here with us, they were just hidden to us."
>
> HELENA REICHLOVÁ

Magnetic bits are difficult to pack tightly in a small space. Ferromagnets placed in close proximity can interfere with one another via their magnetic fields. And the magnetic bits have a speed limit—they can be switched from 0 to 1 only so fast.

Scientists had considered replacing ferromagnets in hard drives with antiferromagnets, which have no magnetic field. But there's a problem with that plan. To read out data, hard drives take advantage of the spin-splitting behavior of ferromagnets. In antiferromagnets, electrons don't split up according to spin.

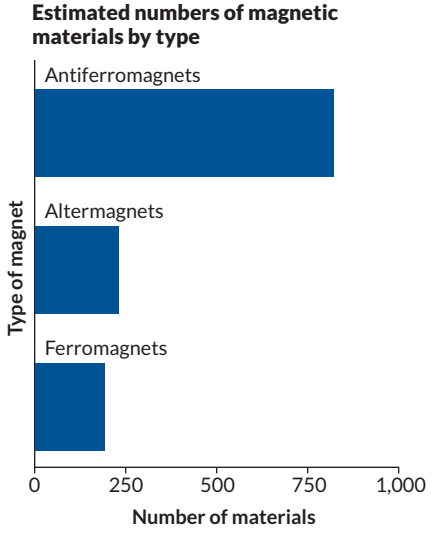
Altermagnets, which have no net magnetic field but do split electrons by spin, could provide the best of both worlds. Altermagnetism "seems to remedy some of the key limitations of ferromagnets," says Tomáš Jungwirth, a physicist at the Institute of Physics of the Czech Academy of Sciences.

What's more, whereas ferromagnets tend to be metals, altermagnets can be made of a variety of material types (SN: 1/14/23, *p.* 14). Manganese telluride, for example, is a semiconductor. Because semiconductors are used to make computer chips, scientists hoped that a magnetic material that is also a semiconductor might allow for the possibility of combining a memory and processor in one material (SN: 10/19/13, *p.* 28).

With "the best of antiferromagnets, the best of ferromagnets and a few things that are unique qualities to themselves," Sinova says, altermagnets are demolishing the limitations of the magnetic status quo.

"These materials break all those barriers," Sinova says. "They just really plow right through them." ■

Counting magnets Based on a database of known materials, scientists estimated the number of altermagnet candidates. The materials may be more common than well-known ferromagnets.



B. PRICE

ARCHAEOLOGY

A Stone Age diet was wildly green

Curiously, the hunter-gatherers never grew the plants they ate

BY JUDE COLEMAN

The plant-heavy diet of a late Stone Age hunter-gatherer group is challenging a common theory about how agriculture arose. Despite dining for over a millennia on wild plants such as acorns, pistachios and oats, the Iberomaurusians in what is now Morocco never cultivated them.

Before humans figured out farming, they relied on hunting and gathering, with most protein coming from animals. Over time, some groups shifted to cultivating plants, which led to the plants' domestication — so goes the typical story of agriculture's emergence.

Scientists once assumed that the Iberomaurusians relied mostly on animals. But data from human remains in a cave in northeastern Morocco point to a largely plant-based diet, archaeologist Zineb Moubtahij of Géosciences Environnement Toulouse in France and colleagues report April 29 in *Nature Ecology & Evolution*.

The Iberomaurusians lived in the area starting roughly 23,000 years ago and buried the dead in part of the cave. Moubtahij's team analyzed human remains dating from about 15,000 to 14,000 years ago, looking at certain types of zinc, carbon and nitrogen deposited in teeth and bones from food. Comparing the levels with those in sheep, fox and other animal remains at the site suggests that the group's diet was similar to an herbivore's. Meat was on the menu, Moubtahij says, but Iberomaurusians leaned toward gatherer.

The group never domesticated the plants it ate — the archaeological record doesn't show changes to the plants' features over time. Why remains a mystery, Moubtahij says. Agriculture eventually arrived in Morocco from other lands about 7,600 years ago.

Studies like this one show "there were alternative pathways and food production systems," says archaeologist Michael Westaway of the University of Queensland in Australia. "Not all roads lead to agriculture." ■

NEWS IN BRIEF

ASTRONOMY

How the sun might build campfires

Scientists are starting to figure out what causes campfire flares on the sun.

These tiny eruptions, discovered in 2020, resemble more massive explosions such as solar flares and coronal mass ejections but are only a millionth or a billionth the size. Using observations of 52 campfires, solar physicist Navdeep Panesar of Lockheed Martin Solar and Astrophysics Laboratory in Palo Alto, Calif., and colleagues tracked these bursts from their beginnings.

Nearly 80 percent of the campfires were preceded by a dark structure made from cool plasma, Panesar reported April 9 in Dallas at the Triennial Earth-Sun Summit. "When this cool plasma rises, a brightening appears underneath it. That brightening turns into a campfire."

The findings suggest campfires arise in a similar fashion to solar flares and mass ejections, which form when magnetic fields of opposite polarities get tangled and cancel one another out, leading to a powerful release of energy. — *Adam Mann*

PHYSICS

New growing method takes the pressure off synthetic diamonds

Diamonds in nature famously form under immense pressure in Earth's mantle. But a new laboratory technique allows diamonds to skip the squeeze.

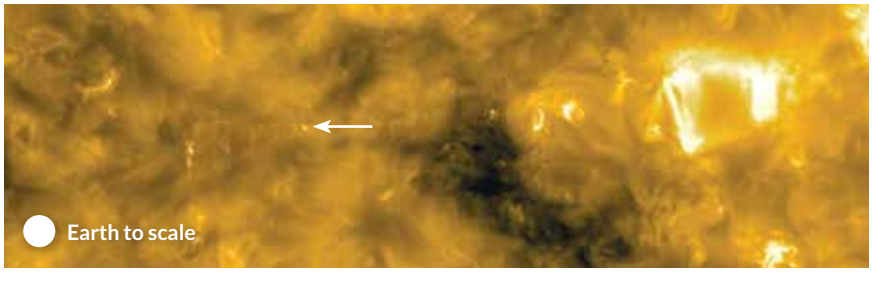
The most common method for growing synthetic diamonds, known as HPHT for high pressure and high temperature, requires around 5 gigapascals of pressure, similar to the pressure in the upper mantle. With this technique, carbon dissolved in liquid metal forms diamonds at temperatures of around 1400° Celsius.

But diamonds can also be grown at atmospheric pressure in a liquid of gallium, iron, nickel and silicon exposed to hydrogen and carbon-rich methane gas, scientists report April 24 in *Nature*. The technique also requires a lower temperature than HPHT: 1025° C. The addition of silicon seems to kick off the initial stages of growth, allowing a tiny bit of diamond to nucleate.

Scientists use diamonds for sensing magnetic fields, searching for new subatomic particles and more. The new method could make generating such materials easier, says coauthor Rodney Ruoff, a physical chemist at the Institute for Basic Science Center for Multidimensional Carbon Materials in Ulsan, South Korea.

Another technique to produce diamonds in the lab, called chemical vapor deposition, or CVD, takes place at low pressures, with a vapor of carbon-rich gas being deposited on a surface. Unlike CVD and HPHT, the new technique doesn't make use of a diamond "seed," an initial bit of diamond to kick off the growth. CVD and HPHT are widely used in the jewelry industry.

Whether the new technique will make diamonds destined for bling remains to be seen. — *Emily Conover*



A tiny campfire flare (white arrow) appears in this ultraviolet image of the sun taken by the European Space Agency's Solar Orbiter. A scaled Earth-sized dot is shown for comparison.

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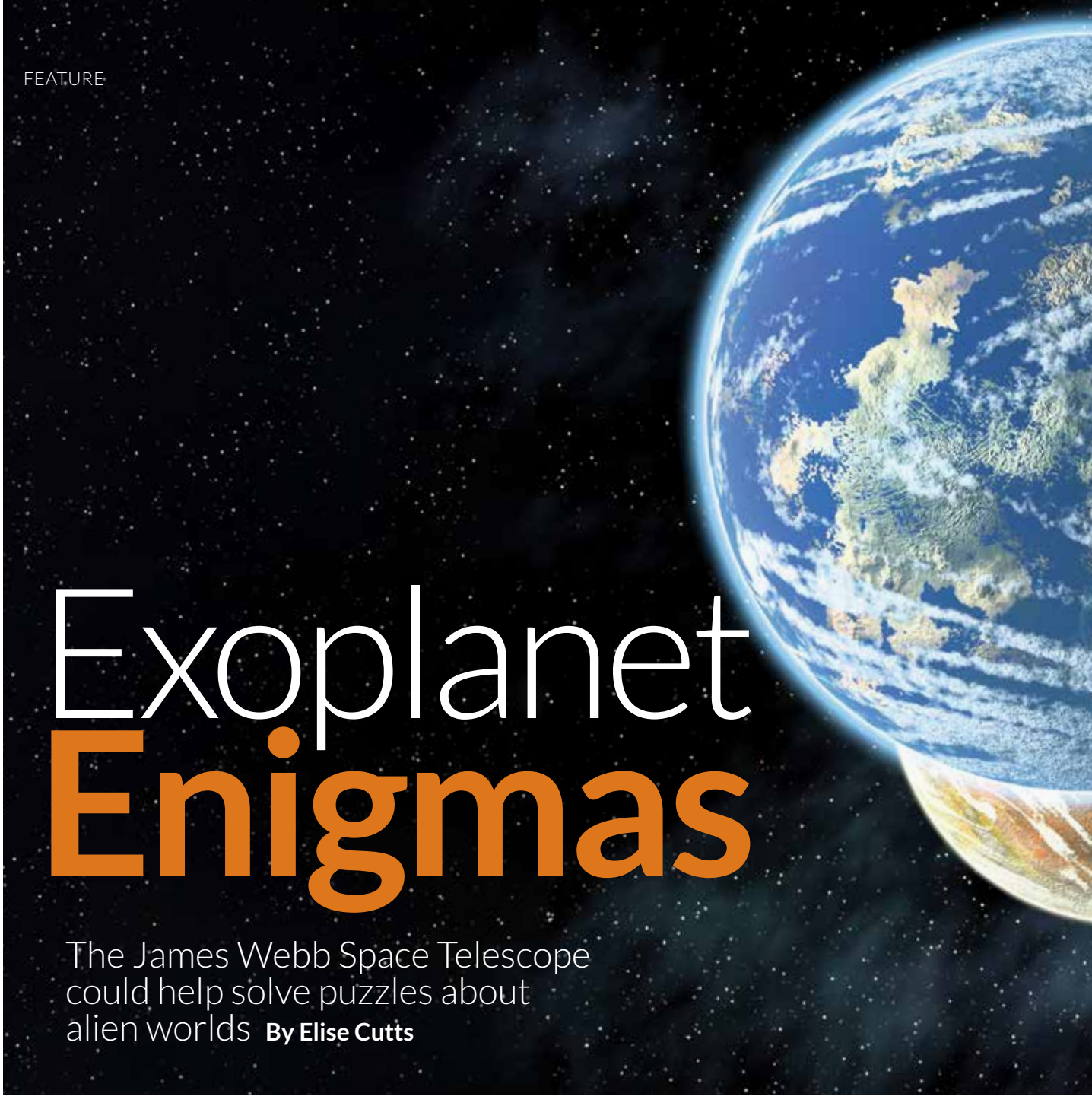


Exoplanet Enigmas

The James Webb Space Telescope could help solve puzzles about alien worlds

By Elise Cutts

Detecting exoplanets used to be so difficult that scientists spotted the first black hole, detected the leftover radiation from the Big Bang and took snapshots of countless distant galaxies before discovering the first planet beyond our solar system in 1992. Plenty of exoplanet astronomers began their careers before the field of exoplanet astronomy even existed.

Now though, astronomers have identified well over 5,000—and continue to find more. Given the stream of discoveries, it can be easy to forget how little we still know about these distant worlds. The colorful volcanoes, oceans and cloud-streaked atmospheres that appear in artists' renditions are speculative fantasies often inspired by the only information scientists have about most worlds: their mass, radius and distance from their star.

But the James Webb Space Telescope is revealing exoplanets in dazzling new detail. Scientists are using the telescope, launched at the end of 2021, to study the atmospheres of hundreds of worlds, from gas giants to rocky worlds about the size of Earth.

As an exoplanet orbits its star, starlight passes through the planet's atmosphere, and light at specific wavelengths is absorbed depending on the gases present. This leaves traces in the spectrum

JPL-CALTECH/NASA, R. HURT/SSC-CALTECH

The James Webb Space Telescope will help astronomers answer fundamental questions about planets beyond our solar system (illustrated above), including what these planets are made of and how they form.

of starlight, which scientists can use to figure out which chemicals the light passed by. JWST is sensitive to infrared wavelengths where these traces are strongest and has already detected water, carbon dioxide, methane and more on other worlds.

Given these detections, Laura Kreidberg of the Max Planck Institute for Astronomy in Heidelberg, Germany, says she often gets asked one question in particular about what JWST might reveal.

"There's a lot of excitement about finding signatures of alien life," she says. "And I'm excited about that also." But, she adds, scientists have a lot to learn about planets before they'll be able to detect life on other worlds with confidence. And due to technical limitations, the telescope's gaze will be mostly restricted to exoplanets that are very hot, very big or both — not conditions thought to be suitable for life.

Most of what we know about exoplanets today comes from the eight planets in our solar system. JWST's planned 10-year lifetime could reveal a lot, perhaps answering fundamental questions including what exoplanets are made of, how they form and whether our solar system is an oddball within our galactic neighborhood.

Here are five big planetary puzzles that scientists hope to solve with JWST.

Why do some rocky planets have atmospheres and others don't?

If a rocky planet is going to host life, it needs an atmosphere. But scientists still aren't sure what determines whether a rocky body can hold onto a gaseous outer shell.

Astronomers are searching for what they call the "cosmic shoreline," a conceptual dividing line that separates worlds with and without atmospheres. In 2017, scientists identified such a shoreline within our solar system, set by the balance between the amount of radiation a planet or moon receives from the sun and the strength of the world's surface gravity. Sunlight provides gas particles with the energy needed to escape from the upper atmosphere, while gravity holds atmospheric gases to the planet.

To test whether this type of cosmic shoreline exists throughout the galaxy, scientists need to figure out which exoplanets have atmospheres and which don't. This question may sound incredibly basic, but it's only just now becoming possible to answer thanks to JWST.

Renyu Hu, an astronomer at NASA's Jet Propulsion Laboratory in Pasadena, Calif., says he and colleagues have settled the atmosphere question for 55 Cancri e, a planet that orbits a sunlike star some 40 light-years from Earth (SN: 11/24/07, *p.* 334). 55 Cancri e is a super-Earth, a bit bigger than Earth but much smaller than Neptune (SN: 6/13/15, *p.* 4). In a paper published May 8 in *Nature*, Hu and colleagues present JWST data suggesting that 55 Cancri e has an atmosphere of either carbon monoxide, carbon dioxide or a mix of the two with nitrogen. It's the first detection of an atmosphere shrouding a terrestrial, or rocky, exoplanet.

> "If we learned that a planet doesn't have an atmosphere, we learned a lot about it already."
>
> LAURA KREIDBERG

But scientists are pessimistic about the existence of atmospheres on the other rocky worlds JWST is observing — specifically those orbiting M-dwarf stars. These small, dim stars are easiest for JWST to see. They also tend to spew bursts of atmosphere-stripping radiation more often than stars like our sun. So some scientists doubt that rocky planets around these stars can hold onto atmospheres.

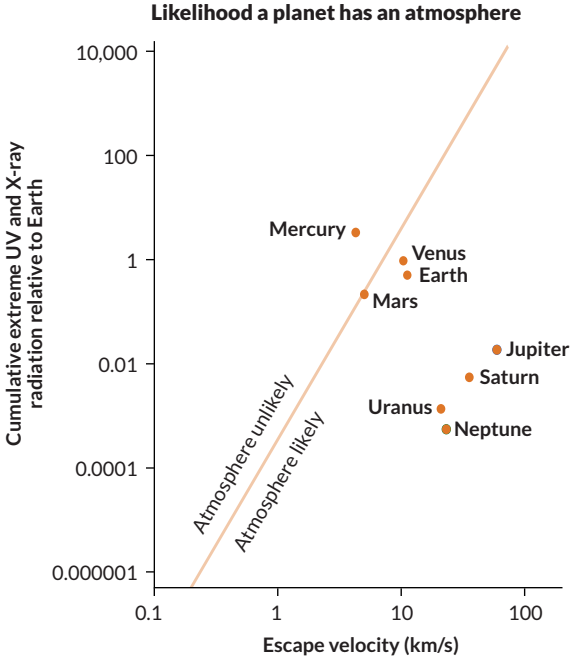
According to JWST observations of LHS 3844b, a super-Earth orbiting such a star, the planet is almost certainly a bare rock. JWST observations of the planets TRAPPIST-1b and TRAPPIST-1c, which orbit the M-dwarf TRAPPIST-1, suggest that these planets are bare too (SN: 4/22/23, *p.* 11). But it's also possible that they could have very thin atmospheres, says astronomer Elsa Ducrot of the Paris Observatory. Follow-up work with JWST will help settle the question.

As scientists use JWST to identify more examples of rocky planets with and without atmospheres, our understanding of the cosmic shoreline can be put to the test.

"There are some colleagues of mine who just want an atmosphere to be there so badly. They're just heartbroken if it isn't there," Kreidberg says. "But for me, if we learned that a planet doesn't have an atmosphere, we learned a lot about it already."

Air or no air The cosmic shoreline is a theoretical dividing line between planets with and without atmospheres based on the relationship between how much gas-stripping radiation a planet gets from its star and the strength of its gravity. Solar system planets are shown.

SOURCE: K.J. ZAHNLE AND D.C. CATLING/*ASTROPHYSICAL JOURNAL* 2017



What is exoplanet geology like?

Discovering exoplanets without atmospheres also will allow astronomers to study something impossible to probe directly before JWST: exoplanet geology.

"I'm really excited about this," Kreidberg says. "Of course, I want to see the atmospheres. But I think there's a lot you can learn from the surface also."

Kreidberg and her team plan to use JWST to look for the chemical fingerprints of specific rocks in the infrared light cast by the rocky, airless super-Earth LHS 3844b. Learning what the planet's surface is

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made of would be a powerful clue about the planet's geologic history and ongoing processes.

Finding signs of granite would be especially intriguing. Granite is a common rock on Earth that forms from recycled and remelted rock. On Earth, this process depends in part on plate tectonics. But beyond Earth, granite appears to be vanishingly rare — probably because plate tectonics is too. Right now, there's no more evidence for plate tectonics on other worlds than there is for alien life (*SN: 1/16/21, p. 16*). Finding granitelike rock on an exoplanet would be a major discovery.

Astronomers are also seeking signs of rocks that are more common in our solar system. For example, a surface covered in the black rock basalt would hint at volcanic processes. And rocks more like those in Earth's mantle, such as peridotite, could point to a recently frozen magma ocean or exotic, high-temperature volcanism.

JWST might even reveal the textures of rocks on exoplanet surfaces.

In our solar system, radiation from the sun wears down rocks on worlds without atmospheres. The result is a crumbly material called regolith that creates a ragged, rough planetary surface. Kreidberg and colleagues plan to look for regolith on LHS 3844b by measuring how the planet's brightness changes as it orbits its star. Compared with a rough surface, a smooth one should appear to reflect less of the sunlight that comes in at shallow angles. Smoothness could hint at a process like volcanism that refreshes the surface with new rock. Or astronomers might find that radiation from the planet's M-dwarf star doesn't weather planets the same way our sun's radiation does.

What are rocky exoplanets made of?

While JWST will help astronomers learn about the surfaces of exoplanets, it also might offer a glimpse at their geologic guts thanks to a particularly extreme type of terrestrial world.

Hotter than scorched Mercury, lava worlds orbit so close to their stars that their years are best measured in hours, not days or months. This proximity causes the planets to become tidally locked, meaning the same side of the planet always faces its sun. As a result, one hemisphere freezes in endless night while the other's rocky surface melts into lava.

The magma oceans on the daysides of lava planets offer about as close to a window into the interior of a planet as astronomers could hope to find. Gases escaping from the magma might give clues to the composition of the planet's deep interior. And learning what planets are made of can tell astronomers a lot about how these bodies form, and whether their compositions and histories are similar to or different from the way rocky planets form in our solar system.

"You might be probing really deep — which is something that I think is hard to do even on Earth," says Lisa Đặng, an exoplanet scientist at the University of Montreal who studies these blazing hot planets using JWST.

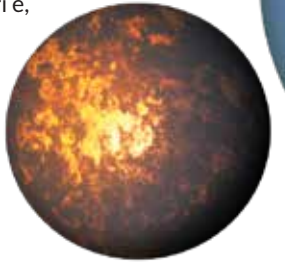
Because they should have magma oceans, lava planets are expected to have atmospheres; even if part of the atmosphere is lost over time, it would be constantly replenished by gas released from magma. Scientists haven't yet detected whiffs of such gases. But Đặng is trying. She's observing the lava world K2-141b, a super-Earth 200 light-years away that orbits a

Super discoveries

Astronomers are hungry to learn more about a type of planet not found in our solar system: super-Earths, which are bigger than Earth but smaller than Neptune (planets are shown to scale). The James Webb telescope has already snooped on at least two. The searingly hot LHS 3844b lacks an atmosphere, JWST data suggest. That should allow JWST to gather intel on surface geology. 55 Cancri e, another sizzler, has an atmosphere — the first detected around a rocky exoplanet.

Earth

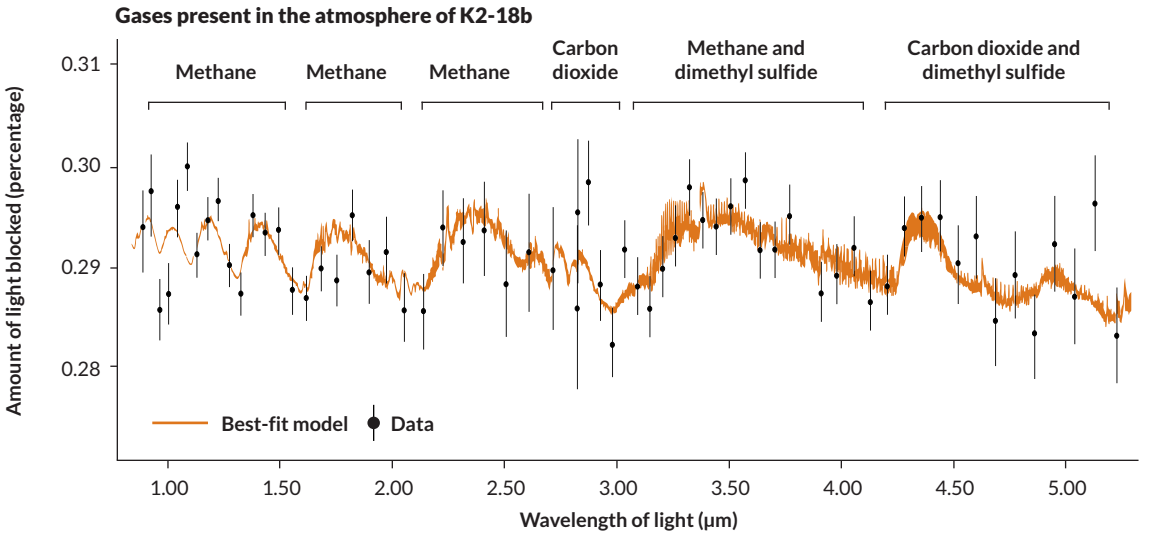
LHS 3844b



55 Cancri e

Neptune

NASA, ESA, CSA, DANI PLAYER/STSCI



Alien atmosphere Using the James Webb Space Telescope, astronomers discovered methane, carbon dioxide and dimethyl sulfide in the atmosphere of exoplanet K2-18b. The team studied starlight that passed through the planet's atmosphere and looked at the patterns of wavelengths of light that had been absorbed to indicate the presence of different gases. SOURCE: NASA, ESA, CSA, RALF CRAWFORD/STSCI, JOSEPH OLMSTED/STSCI

K-type star, also called an orange dwarf.

A "lava planet is a special case of planetary formation. And oftentimes, some of the most extreme cases are the most revealing," Đặng says.

What are sub-Neptunes?

While what we know about Earth, Mercury and Mars can help astronomers imagine what alien rocky planets are like, the most common type of planet in our galaxy can't be found in our solar system. Sub-Neptunes, so named because the planets' radii are just a bit smaller than Neptune's, seem to be everywhere scientists look. But scientists still know very little about these worlds. For example, are they gas giants, rocky planets or something else entirely?

Sub-Neptunes seem to be everywhere scientists look. Are they gas giants, rocky planets or something else?

"They seem to be incredibly common, statistically," says exoplanet scientist Joshua Krissansen-Totton of the University of Washington in Seattle. "We also really have no idea what they're made of."

Based on their masses and radii alone, sub-Neptunes might be miniature ice giants rich in ammonia, methane and water, like Neptune and Uranus. But the same data could describe planets with very different structures, such as rocky cores wreathed in hydrogen and helium, or exotic water worlds made mostly of different forms of water, not necessarily liquid (*SN: 8/1/20, p. 16*).

Using JWST, scientists plan to study the atmospheres of sub-Neptunes to distinguish between these possibilities. JWST observations of the sub-Neptune K2-18b made headlines last year after researchers detected carbon dioxide and methane but no ammonia—an expected component of gas planets—in its atmosphere. The team interpreted this gas mix as evidence for a water world since ammonia dissolves easily in water and would get trapped in an ocean if it were there. But other researchers, including Krissansen-Totton, think the same data could fit a Neptune-like composition with a thick gas envelope over a rocky core. A definitive answer will require follow-up observations.

If sub-Neptunes turn out to be gas-wreathed rocks, that conclusion could explain another mystery about the variety of planet types in our galaxy.

When astronomers look across the range of planet sizes, there's a dip in the number of planets with radii somewhere between those of Earth and Neptune. There are many sub-Neptunes just smaller than Neptune and many super-Earths just bigger than Earth, but very few planets right in between.

One possible explanation for this radius valley is that super-Earths and sub-Neptunes are actually the same types of planets, just spotted at different points in their lifetimes, says astrophysicist Collin Cherubim of Harvard University.

Super-Earths might simply be the leftover rocky cores of sub-Neptunes that lost their hydrogen-rich atmospheres. That process would dramatically

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shrink the planets' radii. If true, scientists may have made the planetary equivalent of mistaking a juvenile animal for a new species.

To explore this possibility, Kreidberg and colleagues are using JWST to study the atmosphere of a planet called WASP-47e, which sits smack-dab in the middle of the radius valley. They want to determine what the planet is made of, and if it might be in the process of losing its atmosphere.

How do gas planets form?

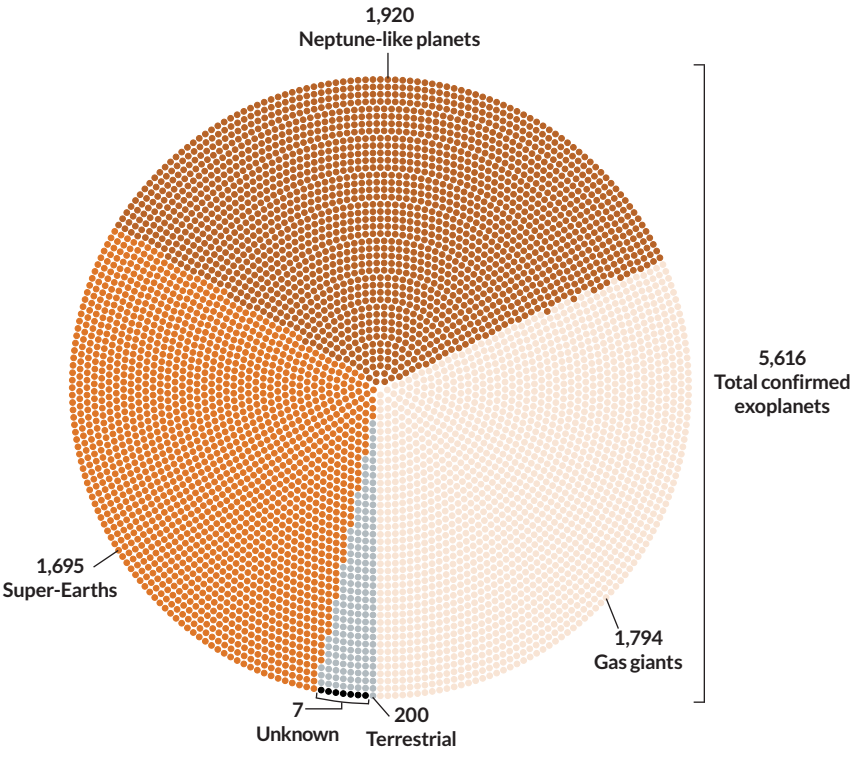
Despite having four gas giants in our solar system, scientists still aren't sure how these enormous worlds form and evolve — and whether our four are oddballs or not.

"Essentially, it's three questions: How do gaseous planets form? How do they evolve? And what are they made of?" says planetary scientist Ravit Helled of the University of Zurich, who studies gas giants. These are "fundamental questions in planetary science that we still haven't answered."

In particular, scientists want to know whether gas giants form where we find them or whether they tend to wander over time, as they seem to have done in our solar system. Planets can wander due to gravitational interactions with other objects, including the disks of gas and dust that orbit young stars and provide the raw materials for planets. Gas planet migration can wreak gravitational havoc, knocking other planets out of their orbits and flinging around small bodies like comets and asteroids. The resulting chaos can have serious implications for the stability and potential habitability of smaller worlds.

JWST could provide astronomers with a vital clue to this mystery — the composition of gas giant atmospheres. The abundance of elements heavier than hydrogen and helium in gas giant atmospheres should depend on where the planet formed relative to its star. In general, the heavier the elements found in an atmosphere, the farther out the planet formed. Observing enough gas giant planets to start identifying trends — and planets that buck them — could reveal the general rules governing how these planets form and migrate.

Scientists also want to find out whether warm gas giants form in the same way as cool ones do. JWST is mostly restricted to observing planets close to their stars, so the gas planets it can observe are much toastier than Jupiter, Saturn, Uranus and Neptune. It's not yet clear whether these toastier planets are just hotter versions of the gas giants in our solar system, or if they're a different class.



Inventory of other worlds As of May 9 astronomers have discovered 5,616 confirmed exoplanets. The majority are Neptune-like (including the slightly smaller sub-Neptunes), gas giants or super-Earths (larger than Earth but smaller than Neptune). Far fewer small terrestrial planets like Earth have been found. SOURCE: NASA

There's reason to be hopeful that some of these questions might be settled soon. Since gas giants are so big, they're much easier to study than small, rocky planets. Helled says that with JWST, astronomers will soon characterize the atmospheres of enough gas giants to have the statistical power to test hypotheses about their formation, compositions and evolution.

"The key is that we are going to have a large number of planets," Helled says. "Until JWST, it was a handful of objects. But once we have more and the measurements are accurate, we can start to understand trends in the statistics. And this is the power of JWST." ■

Explore more

- Nicholas F. Wogan *et al.* "JWST observations of K2-18b can be explained by a gas-rich mini-Neptune with no habitable surface." *The Astrophysical Journal Letters.* March 1, 2024.
- Nikku Madhusudhan *et al.* "Carbon-bearing molecules in a possible Hycean atmosphere." *The Astrophysical Journal Letters.* October 10, 2023.

Elise Cutts is a freelance science writer based in Graz, Austria.

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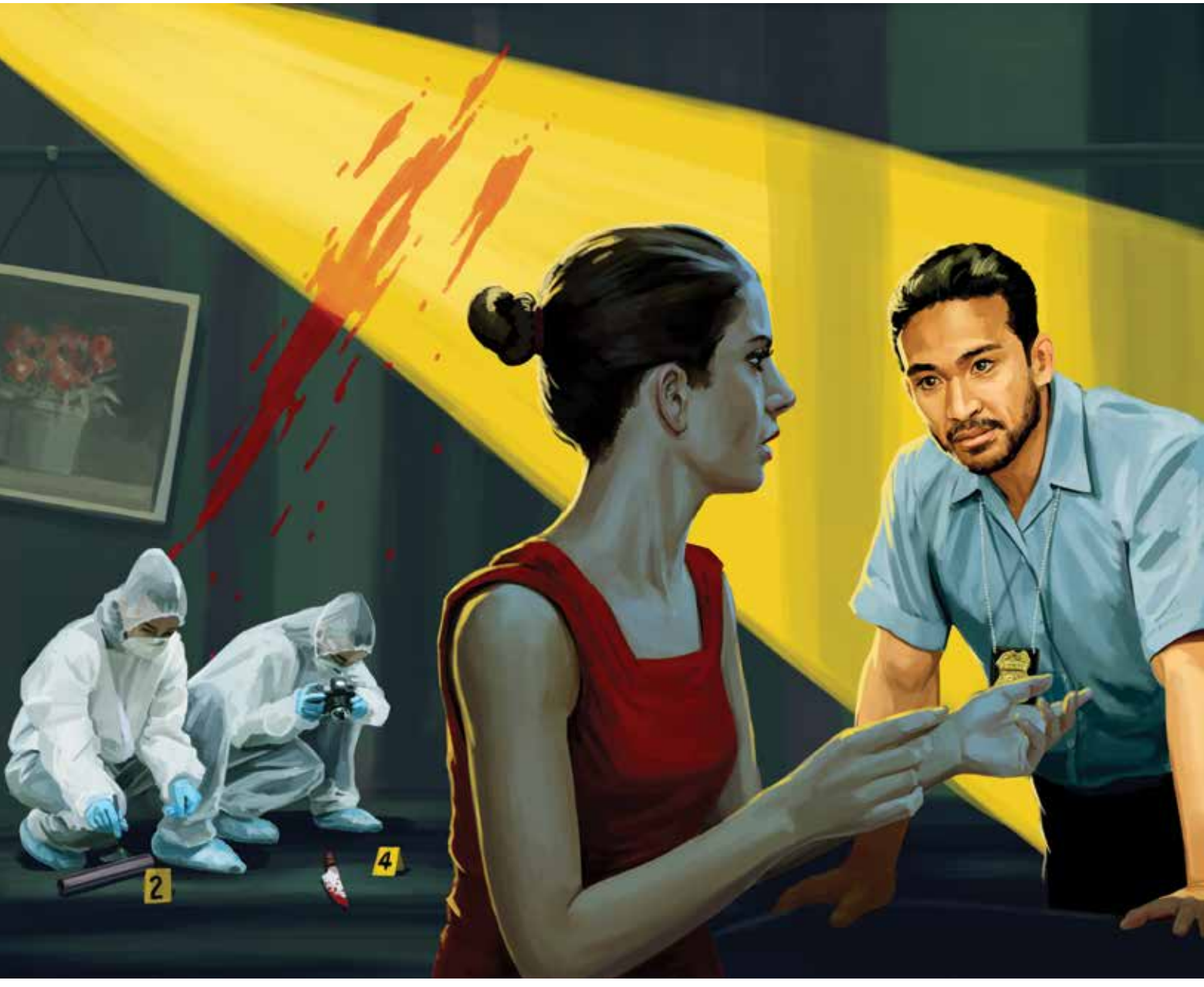


THE RED DRESS

Investigating crime science

People have been wrongly jailed for forensic failures. Scientists are pushing for reform **By Amber Dance**

Charles Don Flores has been facing death for 25 years. Flores has been on death row in Texas since a murder conviction in 1999. But John Wixted, a psychologist at the University of California, San Diego, says the latest memory science suggests Flores is innocent.

The murder Flores was convicted of happened during a botched attempt to locate drug money. An eyewitness, a woman who looked out her window while getting her kids ready for school, told the police that two white males with long hair got out of a Volkswagen Beetle and went into the house where the killing took place. The police quickly picked up the owner of the car, a long-haired white guy.

The police also suspected Flores, who had a history of drug dealing. He was also a known associate of the car owner, but there was a glaring mismatch with the witness description: Flores is Hispanic, with very short hair.

Still, the police put a "very conspicuous" photo of him in a lineup, says Gretchen Sween, Flores' lawyer. "His [photo] is front and center, and he's the only one wearing this bright-colored shirt, screaming 'pick me!'"

But the eyewitness did not pick him. It was only after some time passed, during which the witness saw Flores' picture on the news, that she came to think he was the one who entered the house. Thirteen months after she described two white men with long hair, she testified in court that it was Flores she saw.

Memory scientists have long been mistrustful of eyewitness reports because memory is malleable. But in recent years, Wixted says, research has shown that the initial lineup—the very first memory test—can be reliable. He argues that the witness's initial rejection of Flores' photo is evidence of innocence.

In 2013, Texas became the first state to introduce a "junk science" law allowing the courts to reexamine cases when new science warranted it. Sween has submitted hundreds of pages of arguments to get a judge to consider this new slant on memory science. So far, the Texas authorities have remained unconvinced.

"Our criminal justice system is generally slow to respond to any kind of science-based innovation," laments Tom Albright, a neuroscientist at the Salk Institute for Biological Studies in La Jolla, Calif.

But researchers are pushing ahead to improve the science that enters the courtroom. The fundamental question for all forms of evidence is simple, Albright says. "How do you know what is right?" Science can't provide 100 percent certainty that, say, a witness's memory is correct or one fingerprint matches another. But it can help improve the likelihood that evidence is tested fairly or evaluate the likelihood that it's correct.

Some progress has been made. Several once-popular forms of forensics have been scientifically debunked, says Linda Starr, a clinical professor of law at Santa Clara University in California and cofounder of the Northern California Innocence Project, a nonprofit that challenges wrongful convictions. One infamous example is bite marks. Since the 1970s, a few dentists have contended that a mold of a suspect's teeth can be matched to bite marks in skin, though this has never been proved scientifically. A 2009 report from the National Academy of Sciences noted how bite marks may be distorted by time and healing and that different experts often produce different findings.

More than two dozen convictions based on bite mark evidence have since been overturned, many due to new DNA evidence.

Now researchers are taking on even well-accepted forms of evidence, like fingerprints and DNA, that can be misinterpreted or misleading.

"There are a lot of cases where the prosecution contends they have forensic 'science,'" Starr says. "A lot of what they're claiming to be forensic science isn't science at all; it is mythology."

Do the eyes have it?

Though research has been clear about the shortcomings of eyewitness memory for decades, law enforcement has been slow to adopt best practices to reduce the risk of memory contamination, as appears likely to have happened in Flores' case.

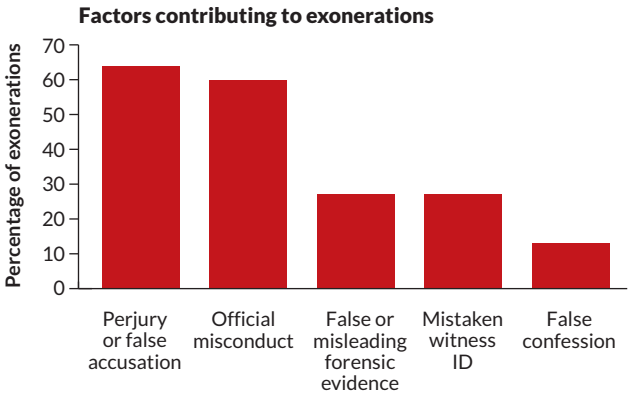
The justice system largely caught on to the problem of memory in the 1990s, when the introduction of DNA evidence overturned many convictions. In more than 3,500 exonerations tracked since 1989, there was some version of false identification in 27 percent of cases, according to the National Registry of Exonerations. What's become clear is that an eyewitness's memory can be contaminated, as surely as if someone spit into a tube full of DNA.

Over the last decade, expert groups, including the National Academy of Sciences and the American Psychological Association, have recommended that police investigators treat a lineup—usually done with photographs these days—like a controlled experiment. For example, the officer conducting the lineup should be "blind" as to which of the people is the suspect and which are "fillers" with no known link to the crime. That way, the officer cannot subconsciously influence the results.

Those best-practice recommendations are catching on, but slowly, says Gary Wells, a psychologist at Iowa State University in Ames who coauthored the American Psychological Association recommendations. "We continue to have cases popping up, sort of right and left, in which they're doing it wrong."

Charles Don Flores (shown in a photo used in a police lineup, left) was convicted of murder in 1999, even though the eyewitness described the suspect as a white man with long hair (police composite sketch, right).

FROM LEFT: FAMILY OF C.D. FLORES; COURTESY OF G. SWEEN



Exonerating circumstances Of over 3,500 exonerations in the United States tracked since 1989, problems with forensic evidence and eyewitness testimony each played a role in about a quarter of the cases (exonerations can have multiple contributing factors, so the bars total more than 100 percent). SOURCE: THE NATIONAL REGISTRY OF EXONERATIONS

One problem arises when the filler photos don't match the witness's description of a suspect, or the suspect stands out in some way—as Sween contends happened with Flores. Fillers should all have the same features as the eyewitness described, and not be too similar or too different from the suspect. For now, it's on police officers to engineer the perfect lineup, with no external check on how appropriate the fillers are.

As a solution, Albright and colleagues are working on a computer system to select the best possible filler photographs. The catch is that computer algorithms tend to focus on different facial features than humans do. So the researchers asked human subjects to rank similarity between different artificially generated faces and then used machine learning to train the computer to judge facial similarity the way people do. Using that information, the system can generate lineups—from real or AI-generated faces—in which all the fillers are more or less similar to the suspect. Next up, the scientists plan to figure out just how similar the filler faces should be to the suspect for the best possible lineup results.

Proper filler selection would help, but it doesn't solve a key problem Wixted sees in the criminal justice system: He wants police and courts to appreciate a newer, twofold understanding of eyewitness testing. First, eyewitnesses who are confident in their identification tend to be more accurate, according to an analysis Wixted and Wells penned in 2017. For example, the pair analyzed 15 studies in which witnesses who viewed mock crimes were asked to report their confidence on a 100-point scale. Across those studies, the higher witnesses rated their own confidence, the more likely they were to identify the proper suspect. Accurate eyewitnesses also tend to make decisions quickly, because facial memory happens fast: "seconds, not minutes," Wixted says.

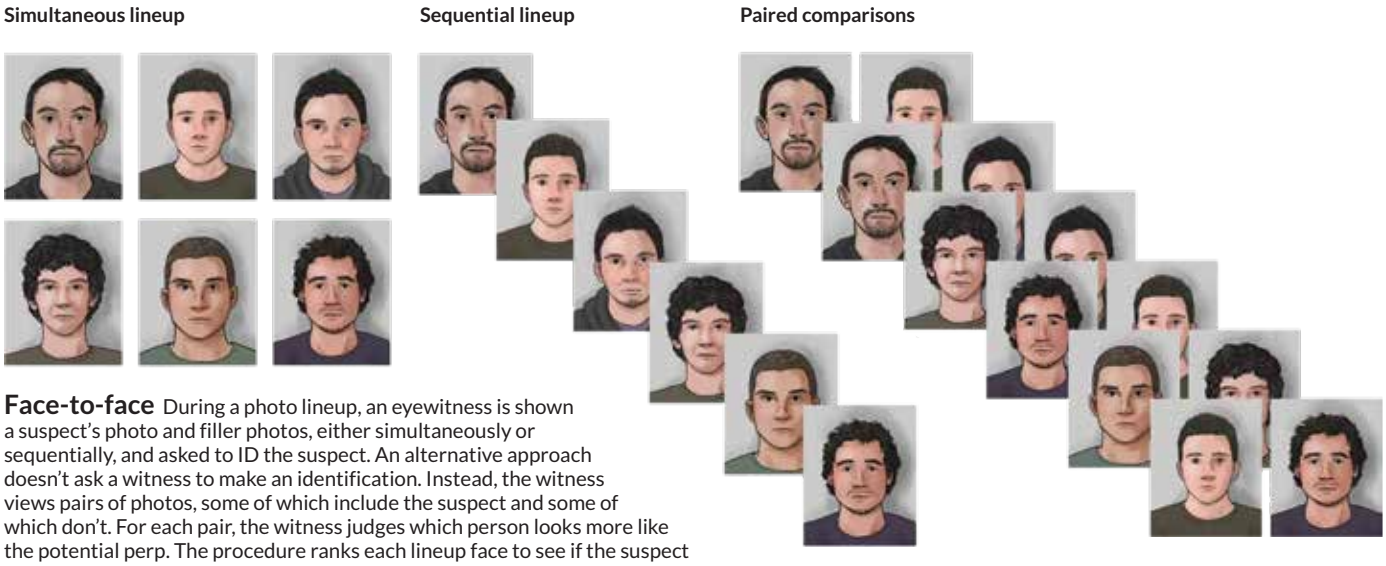
Conversely, low confidence indicates the identification isn't too reliable. In trial transcripts from 92 cases later overturned by DNA evidence, most witnesses who thought back to the first lineup recalled low confidence or outright rejection of all options, according to research by Brandon Garrett, a law professor at Duke University.

The confidence correlation is appropriate only when the lineup is conducted according to all best practices, which remains a rare occurrence, warns Elizabeth Loftus, a psychologist at the University of California, Irvine. But Wixted argues it's still relevant, if less so, even in imperfect lineups.

The second recent realization is that the very first lineup a witness sees, assuming police follow best practices to avoid biasing the witness, has the lowest chance of contamination. So a witness's memory should be tested just once. "There's no do-overs," Wixted says.

Together, these factors suggest that a confident witness on the first, proper lineup can be credible, but that low confidence or subsequent lineups should be discounted.

FROM TOP: C. CHANG, S. GEPSHTEIN *ET AL/NAT. COMMUN.* 2020 (CC BY 4.0 DEED)



Face-to-face During a photo lineup, an eyewitness is shown a suspect's photo and filler photos, either simultaneously or sequentially, and asked to ID the suspect. An alternative approach doesn't ask a witness to make an identification. Instead, the witness views pairs of photos, some of which include the suspect and some of which don't. For each pair, the witness judges which person looks more like the potential perp. The procedure ranks each lineup face to see if the suspect was overall judged as most similar to who the witness saw.

Those recommendations come mainly from lab experiments. How does witness confidence play out in the real world? Wells tested this in a 2023 study with his graduate student Adele Quigley-McBride, an experimental psychologist now on the faculty at Simon Fraser University in Burnaby, Canada. They obtained 75 audio recordings of witness statements during real, properly conducted lineups. While the researchers couldn't be sure that the suspects were truly the criminals, they knew that any filler identification must be incorrect because those people were not connected to the crime in any way.

Volunteers listened to those lineup recordings and rated witness confidence. Witnesses who quickly and confidently picked a face — within about half a minute or less — were more likely to pick the suspect than a filler image. In one experiment, for example, the identifications that ended on a suspect had been rated, on average, as 69 percent confident, as opposed to about 56 percent for those that ended up on a filler. Quigley-McBride proposes that timing witness decisions and recording confidence assessments could be valuable information for investigators.

Witnesses also bring their own biases. They may assume that since the police have generated a lineup, the criminal must be in it. "It's very difficult to recognize the absence of the perpetrator," Wells says.

In a 2020 study, Albright used the science of memory and perception to design an approach that might sidestep witness bias, by not asking witnesses to pick out a suspect from a lineup at all. Instead, the eyewitness views pairs of faces one at a time. Some pairs contain the suspect and a filler; some contain two fillers. For each pair, the witness judges which person looks more like the remembered perpetrator. Based on those pairwise "votes," the procedure can rank each lineup face and determine if the suspect comes out as most similar. "It's just as good as existing methods and less susceptible to bias," Albright says.

Wixted says the approach is "a great idea, but too far ahead of its time." Defense attorneys would likely attack any evidence that lacks a direct witness identification.

Putting fingerprints to the test

Fingerprints have been police tools for a long time, more than a century. They were considered infallible for much of that history.

Limitations to fingerprint analysis came to light in spectacular fashion in 2004, with the bombing of four commuter trains in Madrid. Spanish police found a blue plastic bag full of detonators and traces of explosives. Forensic experts used a standard technique to raise prints off the bag: fumigating it with vaporized superglue, which stuck to the finger marks, and staining the bag with fluorescent dye to reveal a blurry fingerprint.

Running that print against the FBI's fingerprint database highlighted a possible match to Brandon Mayfield, an Oregon lawyer. One FBI expert, then another, then another confirmed Mayfield's print matched the one from the bag.

Mayfield was arrested. But he hadn't been anywhere near

Fixing faulty forensics

Some forensic techniques that seem scientific have been criticized as subjective and had their certainty questioned. That doesn't necessarily mean they are never brought into court or that they're meritless. For some techniques, researchers are studying how to make them more accurate.

Hair analysis Experts judge traits such as color, texture and microscopic features to see if it's possible a hair came from a suspect, but not to make a direct match. Analysis of DNA from hair has largely supplanted physical examination. But if no root is present, authorities won't be able to extract a complete DNA profile. Scientists at the National Institute of Standards and Technology are analyzing whether certain hair proteins, which vary from person to person, can be correlated with a suspect's own hair protein or DNA profile.

Fire scene investigation Fire investigators once thought certain features, such as burn "pour patterns," indicated an arsonist used fuel to spur a fast-spreading fire. In fact, these and other signs once linked to arson can appear in accidental fires, too, for example due to high temperatures or water from a firefighter's hose. A 2017 report from the American Association for the Advancement of Science said identifying a fire's origin and cause "can be very challenging and is based on subjective judgments and interpretations."

Firearms analysis A gun's internal parts leave "toolmarks" on the bullet. Examiners study these microscopic marks to decide whether two bullets probably came from the same gun. A 2016 President's Council of Advisors on Science and Technology report said the practice "falls short of the scientific criteria for foundational validity." In 2023, a judge ruled for the first time that this kind of evidence was inadmissible. Researchers at NIST and the Center for Statistics and Applications in Forensic Evidence, or CSAFE, are developing automated, quantifiable methods to improve objectivity.

Bloodstain pattern analysis Experts examine blood pooled or spattered at a crime scene to determine the cause, such as stabbing, and the point of origin, such as the height the blood came from. While some of this is scientifically valid, the analysis can be complex, with overlapping blood patterns. In 2009, the National Academy of Sciences warned that "some experts extrapolate far beyond what can be supported." CSAFE has compiled a blood spatter database and is working on more objective approaches.

— Amber Dance

ICONS: C. CHANG

Madrid during the bombing. He didn't even possess a current passport. Spanish authorities later arrested someone else, and the FBI apologized to Mayfield and let him go.

The case highlights an unfortunate "paradox" resulting from fingerprint databases, in that "the larger the databases get…the larger the probability that you find a spurious match," says Alicia Carriquiry. She directs the Center for Statistics and Applications in Forensic Evidence, or CSAFE, at Iowa State University.

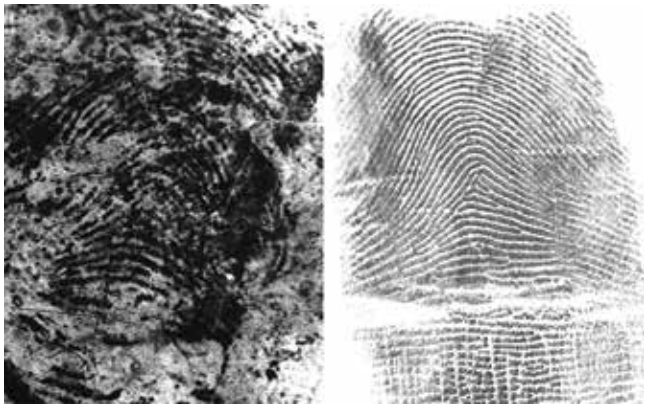
In fingerprint analyses, the question at hand is whether two prints, one from a crime scene and one from a suspect or a fingerprint database, came from the same digit. The problem is that prints lifted from a crime scene are often partial, distorted, overlapping or otherwise hard to make out. The expert's challenge is to identify features called minutiae, such as the place a ridge ends or splits in two, and then decide if they correspond between two prints.

> "Our criminal justice system is generally slow to respond to any kind of science-based innovation."
>
> **TOM ALBRIGHT**

Studies since the Madrid bombing illustrate the potential for mistakes. In a 2011 report, FBI researchers tested 169 experienced print examiners on 744 fingerprint pairs, of which 520 pairs contained true matches. Eighty-five percent of the examiners missed at least one of the true matches in a subset of 100 or so pairs each examined. Examiners can also be inconsistent: In a subsequent study, the researchers brought back 72 of those examiners seven months later and gave them 25 of the same fingerprint pairs they saw before. The examiners changed their conclusions on about 10 percent of the pairings.

Forensic examiners can also be biased when they think they see a very rare feature in a fingerprint and mentally assign that feature a higher significance than others, Quigley-McBride says. No one has checked exactly how rare individual features are, but she is part of a CSAFE team quantifying these features in a database of more than 2,000 fingerprints.

Computer software can assist fingerprint experts with a "sanity check," says forensic scientist Glenn Langenburg, owner of the consulting firm Elite Forensic Services in St. Paul, Minn. One option is a program known rather informally as Xena (yes, for the television warrior princess) developed by Langenburg's former colleagues at the University of Lausanne in Switzerland.



In the 2004 Madrid train bombings, authorities lifted a fingerprint (left) from a bag full of detonators and trace explosives and made a spurious match to a fingerprint in an FBI database (right).

Xena's goal is to calculate a likelihood ratio, a number that compares the probability of a fingerprint looking like it does if it came from the suspect (the numerator) versus the probability of the fingerprint looking as it does if it's from some random, unidentified individual (the denominator). The same type of statistic is used to support DNA evidence.

To compute the numerator probability, the program starts with the suspect's pristine print and simulates various ways it might be distorted, creating 700 possible "pseudomarks." Then Xena asks, if the suspect is the person behind the print from the crime scene, what's the probability any of those 700 could be a good match?

To calculate the denominator probability, the program compares the crime scene print to 1 million fingerprints from random people and asks, what are the chances that this crime scene print would be a good match for any of these?

If the likelihood ratio is high, that suggests the similarities between the two prints are more likely if the suspect is indeed the source of the crime scene print than if not. If it's low, then the statistics suggest it's quite possible the print didn't come from the suspect. Xena wasn't available at the time of the Mayfield case, but when researchers ran those prints later, it returned a very low score for Mayfield, Langenburg says.

Another option, called FRStat, was developed by the U.S. Army Criminal Investigation Laboratory. It crunches the numbers a bit differently to calculate the degree of similarity between fingerprints after an expert has marked five to 15 minutiae.

While U.S. Army courts have admitted FRStat numbers, and some Swiss agencies have adopted Xena, few fingerprint examiners in the United States have taken up either. But Carriquiry thinks U.S. civilian courts will begin to use FRStat soon.

Trace DNA makes for thin evidence

When DNA evidence was first introduced in the late 20th century, courts debated its merits in what came to be known as the "DNA wars." The molecules won, and DNA's current top status in forensic evidence is well-deserved—at least when it's used in the most traditional sense.

Forensic scientists traditionally isolate DNA from a sample chock-full of DNA, like bloodstains or semen from a rape kit, and then focus in on about 20 specific places in the genomic sequence. These are spots where the genetic letters repeat like a stutter, such as GATA GATA GATA. People can have different numbers of repeats in each spot. If the profiles are the same between the suspect and the crime scene evidence, that doesn't confirm the two people are one and the same. But because scientists have examined the stutter spots in enough human genomes, they can calculate a likelihood ratio and testify based on that.

So far, so good. That procedure can help juries answer the

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question, "Whose DNA is this?" says Jarrah Kennedy, a forensic DNA scientist at the Kansas City Police Crime Laboratory.

But in recent years, the technology has gotten so sensitive that DNA can now be recovered from even scant amounts of biological material. Forensic scientists can pluck a DNA fingerprint out of just a handful of skin cells found on, say, the handle of a gun. Much of Kennedy's workload is now examining this kind of trace DNA, she says.

The analysis can be tricky because DNA profiles from trace evidence are less robust. Some stutter numbers might be missing; contamination by other DNA could make extra ones appear. It's even more complicated if the sample contains more than one person's DNA. This is where the examiner's expertise, and opinions, come into their assessments.

"Human people do this work, and human people make mistakes and errors," says Tiffany Roy, a forensic DNA expert and owner of the consulting firm ForensicAid in West Palm Beach, Fla.

And even if Roy or Kennedy can find a DNA profile on trace evidence, such small amounts of DNA mean they haven't necessarily identified the profile of the culprit of a crime. Did the suspect's DNA land on the gun because they pulled the trigger? Or because they handled the weapon weeks before it ever went off?

"It's not about the 'who?' anymore," Kennedy says. "It's about 'how?' or 'when?'"

Such DNA traces complicated the case of Amanda Knox, the American exchange student in Italy who was convicted in 2009, with two others, of sexually assaulting and killing her roommate. DNA profiles from Knox and her boyfriend were found on the victim's bra clasp and a knife handle. But experts later deemed the DNA evidence weak: There was a high risk the bra clasp had been contaminated over the weeks it sat at the crime scene, and the signal from the knife was so low, it may have been incorrect. The pair were acquitted, upon appeal, in 2015.

Here, again, statistical software can help forensic scientists decide how many DNA profiles contributed to a mixture or to calculate likelihood ratios. But Roy estimates that only about half of U.S. labs use the most up-to-date tools. "It keeps me awake at night."

And Roy suspects the courts may at some point have to consider whether science can inform how a person's DNA got on an item. Thus, she says, "I think there's a new DNA war coming." She doesn't think the science can go that far.

When science saves the day

Change happens slowly, Wixted says. And Flores and others remain incarcerated despite efforts by Sween and others questioning faulty evidence.

One reason U.S. courts often lag behind the science is that it's up to the judge to decide whether any specific bit of evidence is included in a trial. The federal standard on expert testimony, known as Rule 702 and first set out in 1975, is generally interpreted to mean that judges must assess whether the science in question is performed according to set standards, has a potential or known error rate, and has been through the wringer of scientific peer review. But in practice, many judges don't do much in the way of gatekeeping. Last December, Rule 702 was updated to reemphasize the role of judges in blocking inappropriate science or experts.

COURTESY OF SILVIA SOLORIO

Miguel Solorio, convicted of murder in 2000, was exonerated and released from prison in 2023 after it was determined that witnesses' memories had been contaminated by repeated police lineups.

In Texas, Sween says she's not done fighting for Flores, who's still living in a six-by-nine-foot cell on death row but has graduated from a faith-based rehabilitation program and started a book club with the help of someone on the outside. "He's a pretty remarkable guy," Sween says.

But in another case Wixted was involved with, the new memory science led to a happier ending.

Miguel Solorio was arrested in 1998, suspected of a drive-by shooting in Whittier, Calif. His girlfriend — now wife — provided an alibi. Four eyewitnesses, the first time they saw a lineup, didn't identify him. But the police kept offering additional lineups, with Solorio in every one. Eventually, two witnesses identified him in court. He was convicted and sentenced to life in prison without parole.

When the Northern California Innocence Project and the Los Angeles County District Attorney's Office took a fresh look at the case, they realized that the eyewitnesses' memories had been contaminated by the repeated lineups. The initial tests were "powerful evidence of Mr. Solorio's innocence," the district attorney wrote in an official concession letter.

Last November, Solorio walked out of prison, a free man. ■

Explore more

- Thomas D. Albright *et al*. "Science, evidence, law and justice." *Proceedings of the National Academy of Sciences*. October 2, 2023.

Amber Dance is a freelance science journalist based in Los Angeles.

BLAZING THE TRAIL FOR YOUNG ENGINEERS

The Texas Alliance for Minorities in Engineering (TAME) is dedicated to supporting students from underrepresented groups in the field of engineering, helping them to build confidence and community. Through programming inspired by the United Nations' Sustainable Development Goals, TAME enables students to explore engineering through the lens of current events and culturally relevant curricula.

As a part of the Society for Science's STEM Action Grant program, TAME received a $2,500 grant in 2023 to support its important work of building new STEM pipelines in the Lone Star State. In 2024, TAME will serve nearly 3,000 middle and high school students across Texas through more than 100 engineering clubs and 12 engineering competitions.

Last year, the Society's STEM Action Grant program invested $245,000 in grant funding to 53 community-based organizations across 24 states and Washington, D.C. These groups are all committed to shaping the next generation of STEM leaders.

Learn more about the STEM Action Grant program:
www.societyforscience.org/stemactiongrants

The Catalyst
Thomas R. Cech
W.W. NORTON & CO., $28.99

BOOKSHELF

RNA's superpowers just might amaze you

Make no mistake, RNA is the main character of Nobel Prize–winning scientist Thomas Cech's new book.

The Catalyst is part ode to the oft-overlooked molecule and part detailed history of the scientists who've studied it. RNA has clearly ensorcelled Cech. And after reading his book, the molecule may ensorcell you, too.

RNA was once considered the "biochemical backup singer" to the diva DNA, Cech writes. But this molecule, a largely single-stranded cousin of DNA, seems to be pretty wondrous all on its own. It can slice, it can splice, it can perform a rollicking array of genetic gymnastics that scientists may still not fully comprehend. Cech, a biochemist at the University of Colorado Boulder, catalogs these abilities in an informative story that offers readers a no-stone-unturned tour of the biochemical basics.

> RNA can slice, it can splice, it can perform a rollicking array of genetic gymnastics that scientists may still not fully comprehend.

Researchers harnessing RNA's skills have now aimed the molecule at some of medicine's most pressing problems. Messenger RNA, or mRNA, for example, is the hero of two widely used COVID-19 vaccines and may help scientists rapidly conjure vaccines for other viruses and even cancer (SN: 12/18/21 & 1/1/22, p. 20). Double-stranded snippets of the molecule, called small interfering RNA, or siRNA, can combat certain rare genetic diseases by shutting down the production of problematic proteins.

But RNA's superpowers aside—and in Cech's view, they are legion—*The Catalyst* makes a strong case for the value of basic research. This is research that peeks under nature's hood and attempts to uncover fundamental truths that govern our world. It's work driven by a scientist's curiosity, rather than yoked to a specific disease. And the payoffs can defy expectations.

That might sound counterintuitive. If the goal is to cure breast cancer or Alzheimer's disease, for instance, why shouldn't researchers laser-focus on those illnesses? Cech argues convincingly that taking such a narrow view of medicine means scientists might miss something important.

Take sickle cell disease. Last year, the U.S. Food and Drug Administration approved the first CRISPR/Cas9 gene-editing therapy to treat the genetic disorder (SN: 1/13/24, p. 6). CRISPR/Cas9 is a kind of molecular scissors that relies on RNA to make targeted changes to the genome. But that technology didn't get its start in research on blood diseases. Scientists developed CRISPR after investigating a quirk of bacterial genomes (SN: 4/15/17, p. 22).

Cech's own RNA breakthrough came from studying another unlikely source: pond scum. He zeroed in on *Tetrahymena thermophila*, a single-celled organism with an unusual genome. Each *Tetrahymena* carries thousands of copies of the gene for ribosomal RNA, a molecule that builds proteins. While studying that RNA, Cech's team discovered something "whose existence violated what had been considered to be a bedrock rule of nature." They had discovered ribozymes, RNAs that act like enzymes.

Until then, scientists had assumed that all enzymes were proteins. An RNA that could perform the same catalytic feats bordered on blasphemy. The discovery was momentous and earned Cech the 1989 Nobel Prize in chemistry, which he shared with molecular biologist Sidney Altman (SN: 10/21/89, p. 262). Cech ably captures the excitement, sending readers back in time to peer over the shoulders of lab members doing the historic experiments.

But the untold value of unexpected discoveries from unlikely sources seems to be lost on funders, Cech writes. The National Institutes of Health, for instance, has cut funding for studies on the basic biology of organisms like *Tetrahymena* in favor of more disease-oriented research.

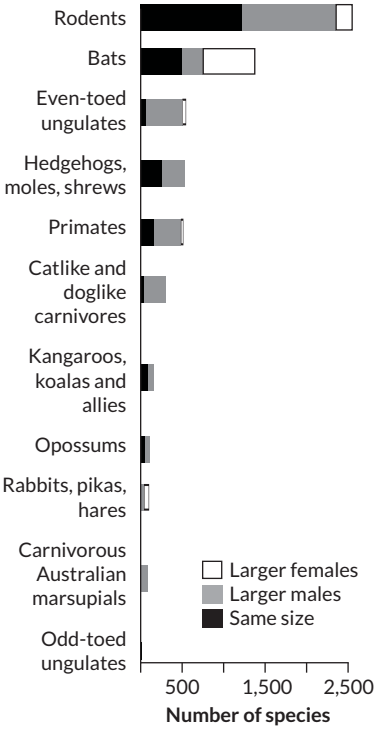
That could be a monumental blow to medicine. Because, as Cech writes, "the story of RNA illustrates that many of our most promising new drugs and therapies have come out of research that was driven by scientific curiosity alone."

—*Meghan Rosen*

TETIANA LAZUNOVA/GETTY IMAGES PLUS

APRIL 6, 2024

Rates of sexual size dimorphism in select mammalian orders
(see "Accessible images," right)



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A recent study calls into question the long-standing assumption that male mammals tend to be larger than females, ***Jonathan Lambert*** *reported in "Mammal size rule needs rethinking"* (SN: 4/6/24, p. 12).

Reader **Bernard Larner** pointed out that the chart in the story showing rates of sexual size dimorphism in different mammalian orders was not accessible to people who have red-green color blindness.

A gray-scale version of that chart, which is interpretable to those who have red-green color blindness, is shown in the sidebar at left.

Science News is committed to making our stories accessible to all readers. We typically run charts through a color-blind checker before publication, but we missed this one.

We appreciate our readers for keeping us accountable.

Potassium's climate potential

Several methods aim to strip excess carbon dioxide from the atmosphere and stash it in the ocean to help slow climate change. But more research is needed on how these methods could impact ecosystems, ***Carolyn Gramling*** *reported in "Ocean to the rescue"* (SN: 4/6/24, p. 22).

One potential way to enhance the ocean's uptake of carbon dioxide is to increase the water's acid-buffering ability by adding finely ground alkaline minerals, **Gramling** reported.

Reader **Brian Graham** wondered whether potassium hydroxide, sourced from used alkaline batteries, could do the trick. Repurposing used batteries in this way would also reduce the waste that ends up in landfills, he noted.

Graham's out-of-the-box idea is interesting, but it's unclear whether it would be economically attractive, **Gramling** says.

Used alkaline batteries contain various ingredients, including potassium hydroxide, zinc oxide, steel and plastic. None of these materials are particularly valuable, **Gramling** says. They can also be expensive to process, creating barriers to recycling to recover the raw materials.

"There isn't really a market out there right now for specifically recovering the potassium hydroxide from the waste," **Gramling** says.

What's more, researchers would still need to study the environmental impact of dumping excess potassium into the ocean, **Gramling** says.

K.J. TOMBAK *ET AL/NATURE COMMUNICATIONS* 2024, ADAPTED BY B. PRICE

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Eisenhower Dollar: The last circulating U.S. dollar coin, the Eisenhower Dollar, aka the "Ike Dollar," was prized by Americans, with its design featuring war hero President Dwight D. Eisenhower, backed by an image symbolizing the Apollo II moon landing. First struck with silver 1971-1976, the Eisenhower Dollar in this set was struck in 40% silver for collectors, and you will receive a coin in Brilliant Uncirculated (BU) condition.

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Silver Eagle Type 2: In honor of the popular 99.9% silver coin's 35th anniversary in 2021, the Silver Eagle received a new, esteemed Type 2 "Eagle Landing" reverse design. This is the current issued coin by the U.S. Mint. Brilliant Uncirculated (BU) condition coin included in set.

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This newfound longhorn beetle species is surprisingly fluffy

Meet *Excastra albopilosa*, a newly identified longhorn beetle species that rocks a fluffy white coat.

Discovered in Australia, the fuzzy-looking arthropod also has distinct, separated eye lobes, short antennal segments and unique variations in the shapes of its legs. All these factors suggest the beetle (shown above and below) warrants being classified as its own genus, researchers report March 19 in the *Australian Journal of Taxonomy*.

Thousands of species of all kinds are discovered each year, at least half of which are insects. "I'm actually surprised that this species had not been discovered before," says Menno Schilthuizen, an evolutionary biologist at Taxon Expeditions in Leiden, Netherlands, who was not involved in the study. The visually striking beetle, nearly a centimeter long, was found in an area of Queensland that's popular among entomology enthusiasts.

While staying near Lamington National Park, entomologist James Tweed of the University of Queensland in Brisbane had stepped out to brush his teeth when he stumbled across "some white thing" hanging on a long and narrow leaf of basket grass.

Upon closer inspection, Tweed suspected the thing might be a type of longhorn beetle. He snapped a photo and uploaded it to iNaturalist, an app that helps people identify organisms. Other app users couldn't identify it. Neither could a senior beetle expert at the Australian National Insect Collection in Canberra.

Together, the researchers scanned through the collection of all longhorn beetle databases of Australia. Given the newfound beetle's distinct physical appearance, "we were pretty confident that this was a distinct genus and species," Tweed says. Its proposed name is derived from the Latin words *Excastra*, meaning "from a camp," and *albopilosa*, meaning "white and hairy."

Tweed and colleagues remain uncertain about the exact function of the white hairs. If the fluff gives predators the impression that the beetle has a fungal infection, then that might reduce the insect's chances of getting eaten. Or perhaps the hairs help the beetle regulate its body temperature.

Discovering species that are new to science is a "very satisfying feeling," Schilthuizen says. Of the estimated 5 million insect species globally, researchers have named only about a million.

The new work, Schilthuizen says, is a way to "at least safeguard yet another species, add it to the scientific literature and make sure that somebody else recognizes it when they find it." —*Saugat Bolakhe*

FROM TOP: LINGZI ZHOU/AUSTRALIAN NATIONAL INSECT COLLECTION; J. TWEED

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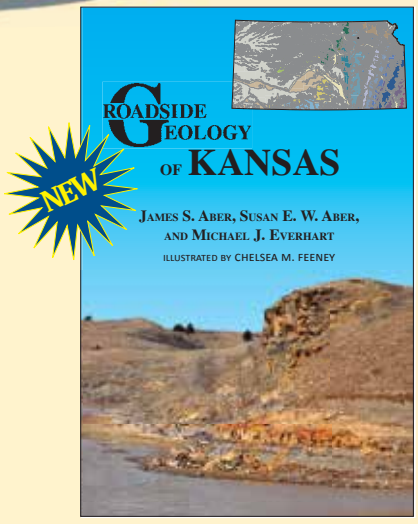

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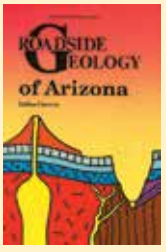

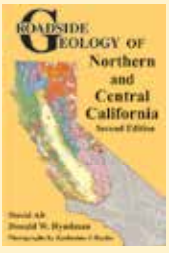

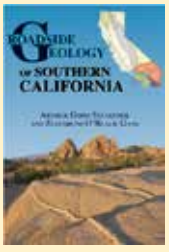

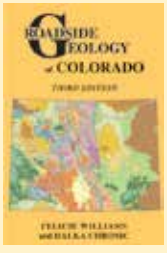

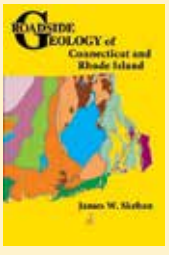

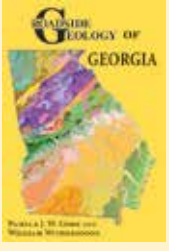

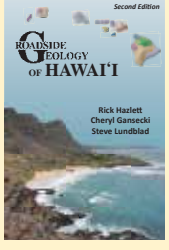

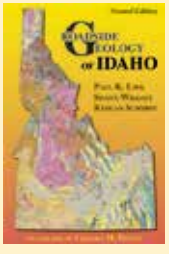

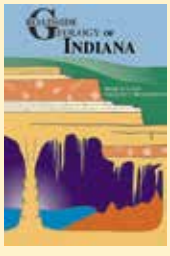

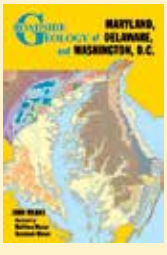

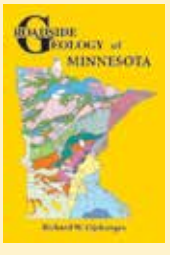

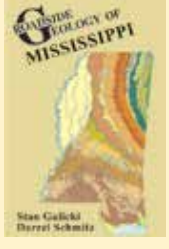

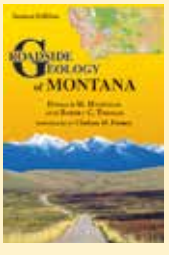

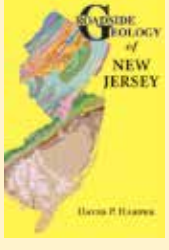

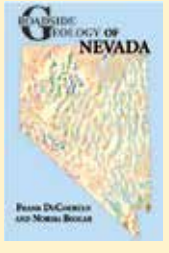

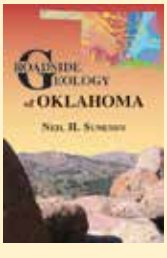

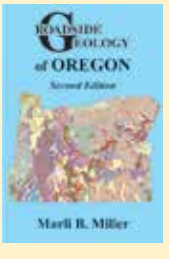

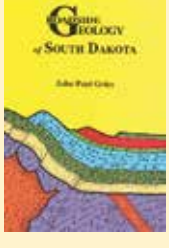

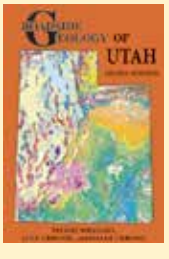

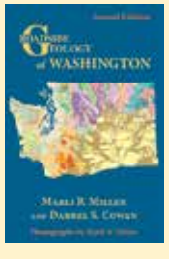

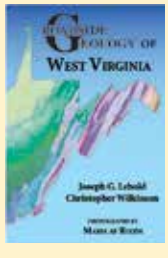

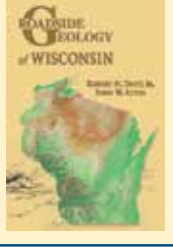

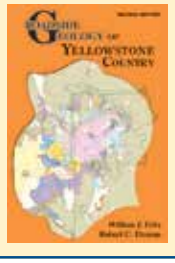

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