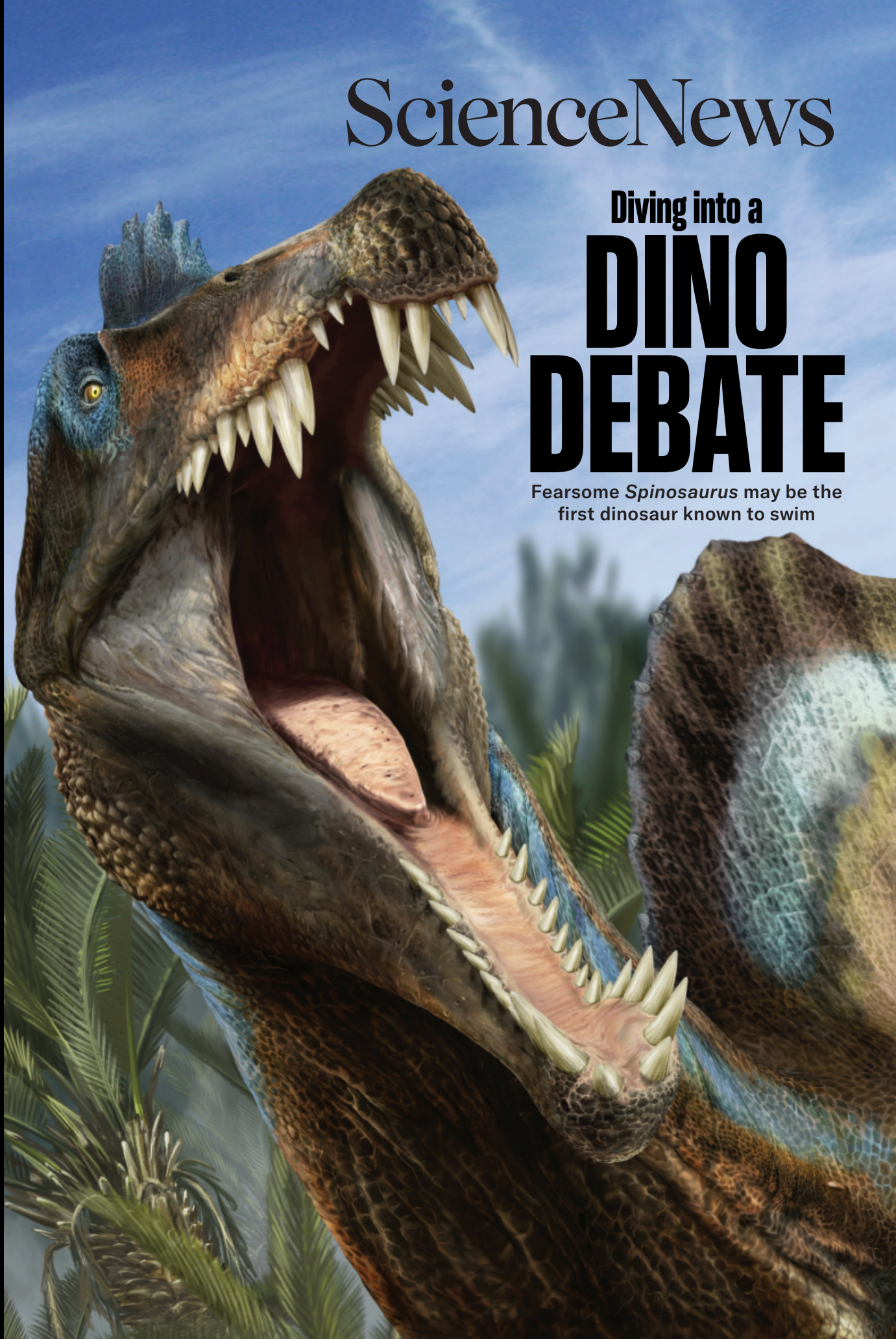
ScienceNews

Diving into a DINO DEBATE

Fearsome *Spinosaurus* may be the first dinosaur known to swim



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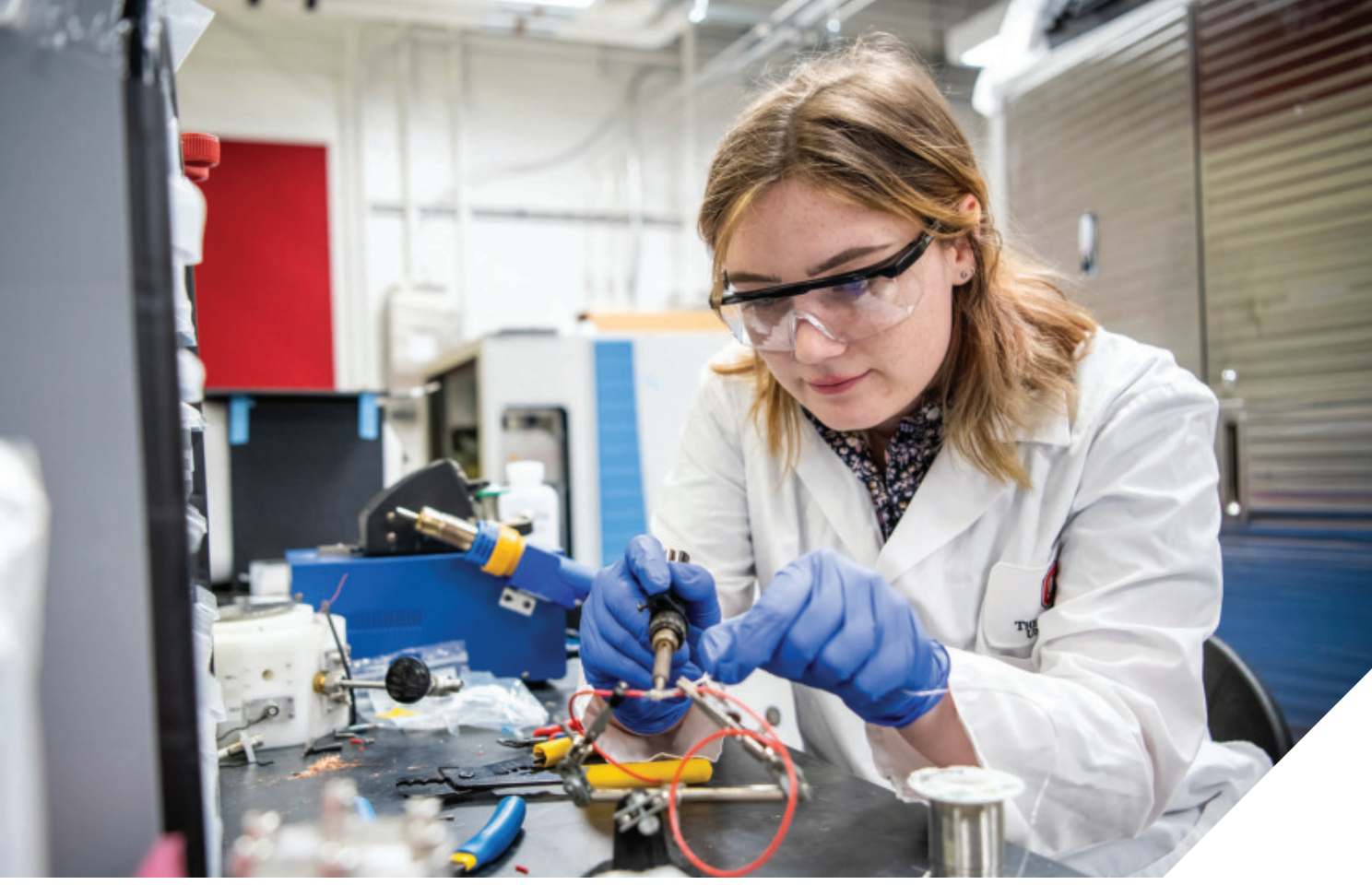

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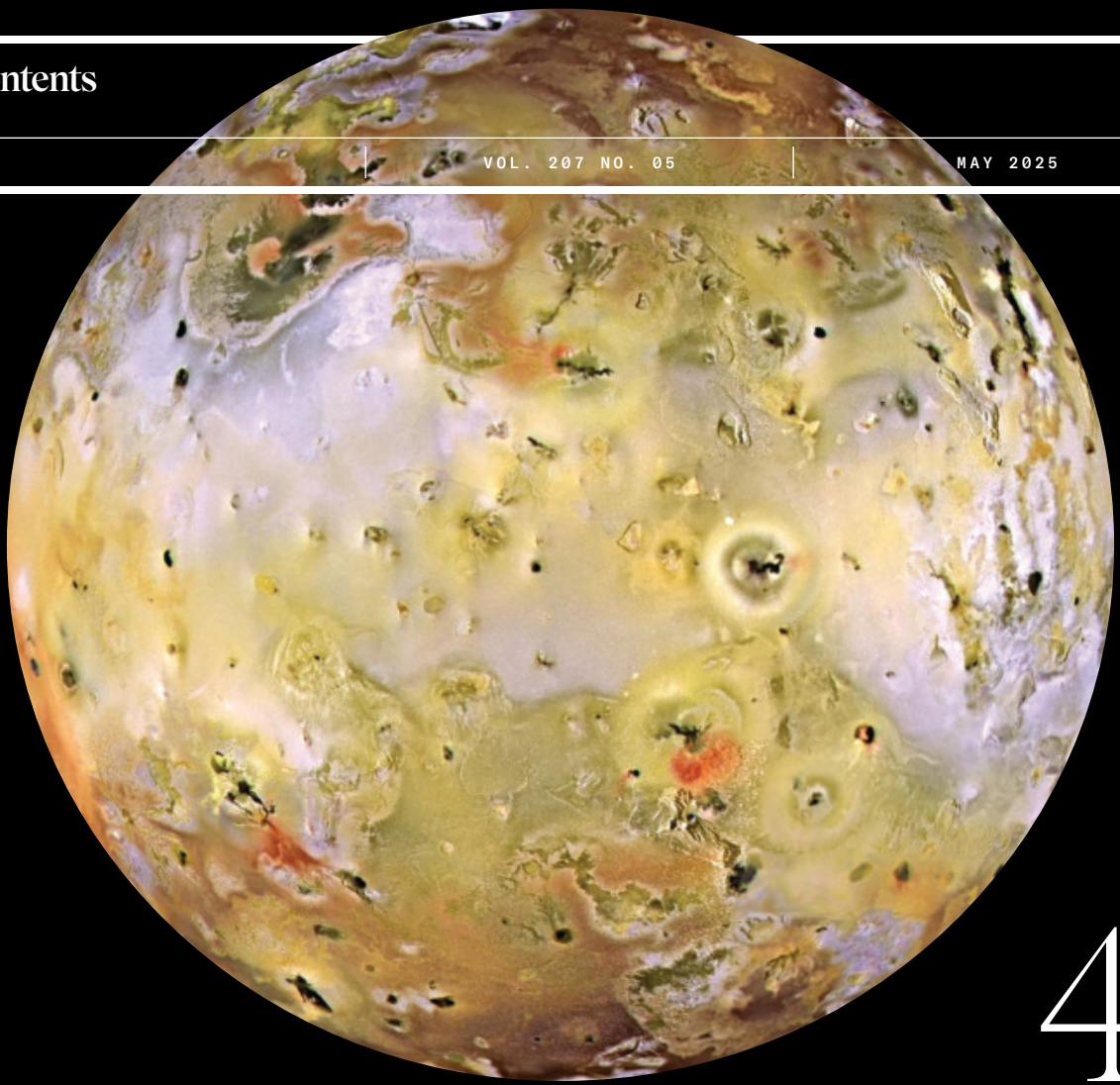

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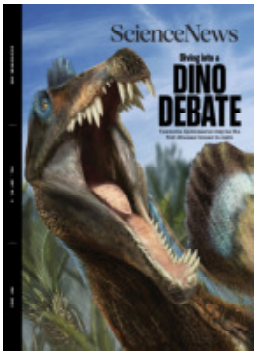

On the Cover

Illustration by Davide Bonadonna

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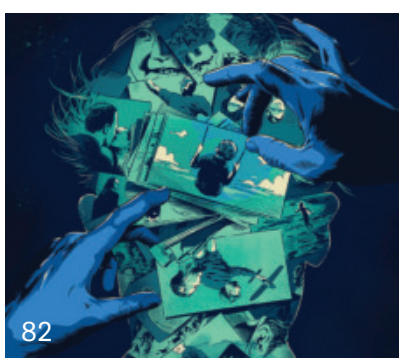
Features

Curiosities



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FROM TOP: DAVID PALUMBO; TIM MCDONAGH

Seeking the anomalies that lead to discoveries

Science is, at its heart, a system for asking questions and seeking answers. Researchers must detect clues amid a cacophony of information. Pharmacist Joseph Lambson is one person with a gift for identifying signals in the noise. When he got a call from a poison control specialist saying that people were overdosing on the drug semaglutide, used to treat obesity and diabetes, he knew what this meant.

Pharmaceutical companies were unable to keep up with demand for the drug, which comes in a prefilled injector pen, and people were buying alternative versions that are not as error-proof. Even with the drug no longer in shortage, the dangers persist. Senior writer Meghan Rosen talked with Lambson as part of her investigation into a proliferating online market where patients say they're willing to take risks to get what they see as a life-altering drug (Page 48).

Patterns were also key to a discovery that could transform our understanding of the evolution of human thought. Archaeologists have long believed that "modern" human cognitive skills like planning and collaboration emerged only about 50,000 years ago. But archaeologists now propose that human ancestors were deploying such sophisticated skills as early as 300,000 years ago, behavioral sciences writer Bruce Bower reports (Page 64). It took decades of digging at a German site discovered during mining operations and sifting through disparate evidence, including weapons, tools, animal bones and ecological data, to uncover what transpired. The results suggest that these early hunters used advanced thinking to herd wild horses into an ambush.

And then there's the splashiest topic in dinosaur land: Did *Spinosaurus* swim? Over the last decade, the swimming skills (or the lack thereof) of this huge, toothy predator have become hotly contested based on differing interpretations of the evidence, earth and climate writer Carolyn Gramling reports (Page 56). The fossil record is skimpy, but paleontologists on both sides of the debate are piecing together fresh clues to support their claims. Depending on how it plays out, *Spinosaurus* could be crowned the first known swimming dino.

Hollywood has already picked a side. In this summer's *Jurassic World Rebirth*, the next movie in the *Jurassic Park* franchise, three swimming *Spinosaurus* dinosaurs attack a patrol boat in the Caribbean. Spoiler alert: Things do not go well for the humans, but the movie is a win for all of us who love dinosaurs and the enduring puzzles they represent.

Nancy Shute
Editor in Chief
nshute@sciencenews.org

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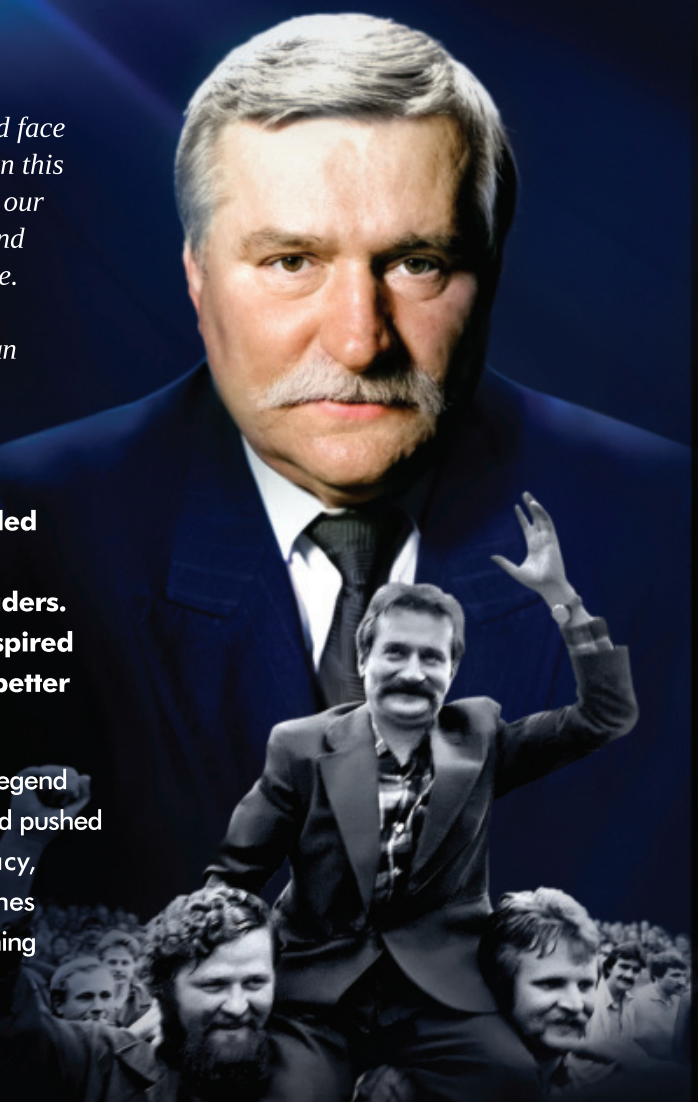

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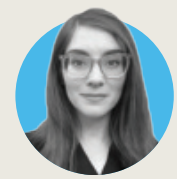
CAROLYN GRAMLING

EARTH & CLIMATE WRITER

● FIVE YEARS AGO, a group of scientists discovered a nearly complete *Spinosaurus* tail. Based on the tail's length and shape, the group argued that this dinosaur of the late Cretaceous Period had been a swimmer, and not a landlubber as once thought. The claim rocked the field of paleontology, fueling an intense, ongoing debate that Carolyn Gramling unravels in this issue's cover story (Page 56). "Spinosaurids — *Spinosaurus* and its various cousins — are an oddball branch of the dinosaur family tree," Gramling says. "There's so much we don't really know about them, and so many of their fossils that were found later met unlucky fates: bombed by the Allies or burned up in a museum fire." Gramling's story provides readers with the scientific context before the controversy gets the Hollywood treatment this July in *Jurassic World Rebirth*.

Bruce Bower
Behavioral sciences writer Bruce Bower has been at *Science News* for 40 years. And he's been studying human behavior for just as long. In this issue, Bower's expertise shines in describing how our ancestors 300,000 years ago hunted in groups, yet more evidence of sophisticated behavior at that time (Page 64). "*Science News* has given me an opportunity to pursue self-directed learning," Bower says, which he turns into stories. "It's not always easy or frustration-free, but it's never boring. That has kept me going from the last century to this one."



Meghan Rosen
When Ozempic and Wegovy were in shortage, flashy ads for compounded GLP-1 drugs were all over social media feeds. Spotting these ads led senior writer Meghan Rosen to investigate the many ways people are accessing various forms of GLP-1 drugs. Some people are even seeking out chemicals marketed for use in research and not as medication. There's a real potential for misuse, Rosen reports (Page 48). "GLP-1 drugs can be helpful for many people, but it's important to know what you're getting and any potential risks," she says.

Siddhant Pusdekar
Trees in India's Western Ghats are surprisingly good at withstanding extreme heat, freelance journalist Siddhant Pusdekar reports (Page 26). Pusdekar grew up just east of the mountains and is familiar with their peaks. He was surprised to learn how much there is to be discovered about the region's flora. "I look forward to following the progress in this area," Pusdekar says.

Sid Sivakumar
Puzzle maker Sid Sivakumar has been working for *Science News* behind the scenes, editing crossword puzzles — and is now stepping into the limelight with a debut crossword for the magazine (Page 84). Sivakumar, an M.D./Ph.D. student at Washington University in St. Louis who studies the brain's response to stroke, started making puzzles at age 6. "I love crossword puzzles because they feel like engineering problems that are designed for solvers to reliably reverse engineer," Sivakumar says.

CLOCKWISE FROM TOP LEFT: SOCIETY FOR SCIENCE (FIRST THREE); COURTESY OF S. PUSDEKAR; S. SIVAKUMAR

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ARCHAEOLOGY

MAYA-ERA PUPPETS WITH PECULIAR EXPRESSIONS

By Tom Metcalfe

● **Five expressive clay** figurines unearthed near the top of a ruined pyramid in western El Salvador were probably used as puppets in Maya-era rituals, researchers report in *Antiquity*. The puppets date to around 400 B.C., though similar ones may have been used from about 1000 B.C. to A.D. 600. The most striking features of the largest puppets, about 30 centimeters tall, are their movable heads and strange facial expressions: angry when viewed at eye level, grinning from above and scared from below. Although the puppets had no clothes, they may have been dressed up for their ritual roles. What messages or stories they conveyed are not known.

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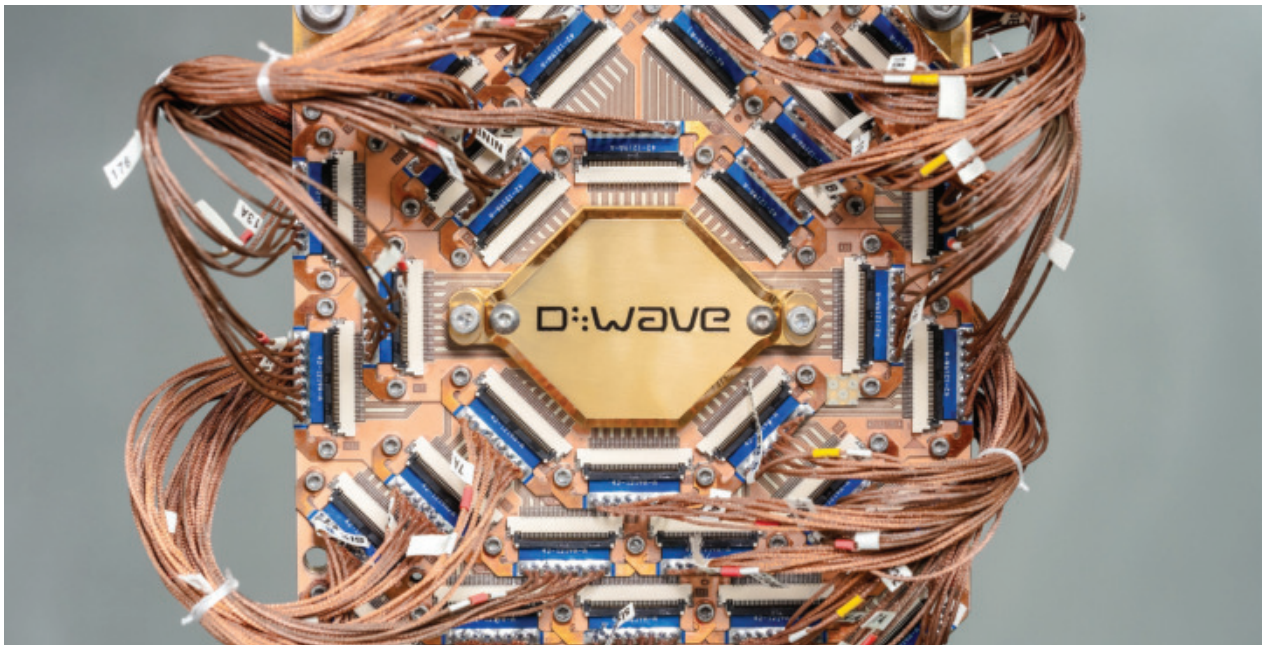
News

The Blue Ghost lander took this photo of its shadow on the moon. It's the first privately owned spacecraft to successfully alight on the lunar surface, but it won't be the last (see Page 33).

FIREFLY AEROSPACE



QUANTUM PHYSICS

QUANTUM COMPUTING REACHES A MILESTONE (MAYBE)

BY MARA JOHNSON-GROH

The tug-of-war between quantum and classical computers is intensifying. In just minutes, a special quantum processor solved a complex real-world problem that a classical supercomputer would take millions of years to complete, researchers claim in *Science*. And that supercomputer, the team reports, would consume more electricity to run the whole computation than the entire globe uses in a year. However, another group of researchers claims to have already found a way for a classical supercomputer to solve a subset of the same problem in just over two hours.

Quantum computers leverage principles of quantum mechanics to potentially offer huge advantages in processing power and speed compared with the classical computers we're familiar with in our daily lives. This capability theoretically allows quantum computers to tackle problems much faster than classical computers can.

The new, conflicting results follow similar claims made in recent years. The nascent field of quantum computing has been advancing at the same time that supercomputers are being made more efficient, resulting in a closely matched rivalry. While quantum computers have demonstrated the ability to solve systems with completely randomized numbers faster than classical computers, they have yet to excel in solving physical problems relevant to real-world systems.

In the latest matchup, scientists at D-Wave Quantum Inc. in Canada used a quantum computer equipped with a quantum annealing processor. Such processors differ from more typical quantum processors and have shown promise for doing specific tasks. Annealing processors

↖ A D-Wave quantum computer with an annealing processor (shown) tackled a problem that would stymie a classical supercomputer.

D-WAVE QUANTUM INC.

are well-equipped to tackle large problems because their quantum bits, or qubits, are coupled to many other qubits instead of just one, as in other types of quantum processors. But they are useful mainly for specific types of problems, and D-Wave's computers have previously attracted skepticism.

For the new result, D-Wave researchers used a quantum annealing processor to simulate quantum dynamics by using arrays of magnetized disordered pieces known as spin glasses. This setup is relevant to materials science, where understanding the evolution of such systems can help design new metals for hard drives, medical sensors and other devices.

The researchers simulated that evolution in two, three and infinite dimensions. After trying to solve the problem with approximations on a supercomputer, they concluded that it couldn't be done within a reasonable time frame.

"It's a milestone result," says Andrew King, a quantum computer scientist at D-Wave. "We've demonstrated quantum supremacy for the first time on an actual problem of real interest."

Physicist Daniel Lidar, codirector of the Quantum Computing Center at the University of Southern California in Los Angeles, agrees that the work is impressive. "They really managed to perform quantum simulations on their hardware that are beyond the reach of current classical methods."

But the claim isn't without controversy. King and colleagues posted a preliminary draft of the paper about a year ago on arXiv.org, providing other researchers the opportunity to scrutinize the findings.

Quantum computer scientist Joseph Tindall of the Flatiron Institute in New York City and colleagues simulated part of the same problem using a classical computer. They developed a method that repurposed an algorithm called belief propagation, commonly used in AI. The team's results, posted to arXiv.org but not yet peer-reviewed, claim to be more accurate than D-Wave's for certain cases of the 2-D and 3-D systems.

The classical simulations focused on only a subset of the D-Wave results, and the two groups are at odds as to whether the classical simulations can reproduce all the abilities of the quantum computer simulations.

But the quantum computer indisputably excelled with the infinite-dimensional system, which is useful for improving AI. Simulating it classically would require an entirely different approach compared with the methods used for the 2-D and 3-D systems, Lidar says. It's unclear whether that can be done. ✖

HEALTH & MEDICINE

CAR-T cells put cancer in long-term remission

By Andrea Tamayo

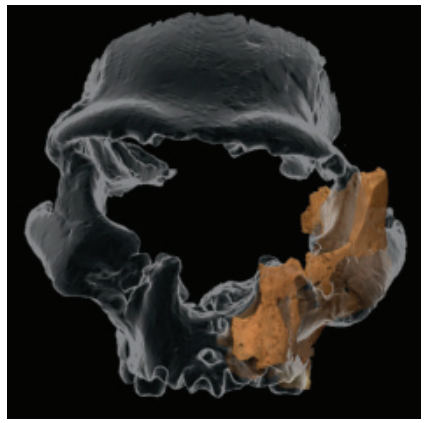
● **About 18 years ago,** a 4-year-old girl with a rare nerve cell cancer received an infusion of immune cells that were genetically engineered to fight the disease. Since then, she has remained cancer-free, possibly making her the longest-surviving patient with cancer who received this type of tailored treatment, researchers report in *Nature Medicine*.

In a clinical trial, the girl received CAR-T cell therapy, which reprograms some of a patient's own immune cells to kill cancer cells. Since 2017, seven CAR-T cell therapies for blood cancers have been approved by the U.S. Food and Drug Administration. But solid tumors, like the girl's neuroblastoma, have been harder to treat with the technology. Such tumors, which account for about 90 percent of all cancers, are tough to penetrate and contain molecules that can hinder CAR-T cells, says physician-scientist Helen Heslop of Texas Children's Hospital in Houston.

Heslop's team recruited 19 children with neuroblastoma. Eleven had active cancer and eight were at high risk of relapsing. From 2004 to 2009, all patients were infused with CAR-T cells. After seven years, 12 patients had died from their cancer. Of the survivors, one was in remission eight years after, five were disease-free 10 to 15 years after and one is the 18-year survivor.

It's unclear why the therapy didn't work long-term for some patients. Perhaps the CAR-T cells didn't stick around or the tumor lost the target protein, says cancer immunotherapist Carl June of the University of Pennsylvania Perelman School of Medicine. Heslop and others have since added molecules to make CAR-T cells last longer and track down tumors better.

In 2023, an Italian team reported five neuroblastoma patients were cancer-free two years after getting next-gen CAR-T cells. Hopefully, those patients will survive long-term too, Heslop says. ✖



ANTHROPOLOGY

Western Europe's oldest face wrinkles human evolution

By Bruce Bower

● **A Spanish cave** has divulged the oldest known fossil remains of human ancestors in Western Europe.

Excavations at a site known as Sima del Elefante produced fossil fragments that, when pieced together, form a partial left upper jaw and cheek bone dating to between 1.4 million and 1.1 million years ago, say zooarchaeologist Rosa Huguet and colleagues. That ancient midface comes from a previously unknown European *Homo* population, the team reports in *Nature*.

"This discovery introduces a new actor in the story of human evolution in Europe," Huguet, of the Catalan Institute of Human Paleoecology and Social Evolution in Tarragona, Spain, said at a news briefing.

Some features of the jaw and cheek resemble those of *H. erectus* individuals who reached a site called Dmanisi in Georgia around 1.8 million years ago. But not enough evidence exists to determine whether the new find qualifies as *H. erectus* or as a separate species, the investigators say.

Huguet's team digitally scanned each fossil fragment to create a virtual, 3-D version of the entire midface. A mirror image of the reassembled left-side fossils was used to portray the right side of the virtual midface.

A lower-jaw fossil previously unearthed at Sima del Elefante dates to roughly 1.2 million to 1.1 million years ago and may have belonged to the same *Homo* species as the facial fossil, they suggest.

Hominid fossils excavated over the last 30 years at Gran Dolina, a cave near Sima del Elefante, come from a species Huguet's group calls *H. antecessor*, which lived between 900,000 and 800,000 years ago. Vertically oriented, flat cheek bones of *H. antecessor* resemble those of people today, unlike the older Sima del Elefante fossils.

Evolutionary ties between those two ancient European *Homo* species remain unclear. Members of the Sima del Elefante species — who also left behind simple stone cutting or chopping tools — might have survived until shortly after the arrival of *H. antecessor*, the scientists say. In support of that scenario, animal and plant remains excavated in the same sediment as the ancient midface fossils suggest mild temperatures enabled long-term occupation of the Sima del Elefante region.

If recent evidence holds up of extreme cold temporarily driving hominid populations out of Europe shortly before 1.1 million years ago, then the Sima del Elefante *Homo* species may have died out before *H. antecessor* arrived, the team says.

Biological anthropologist G. Philip Rightmire of Harvard University suspects that the Sima del Elefante crowd belonged to *H. erectus*. The midface traits of an *H. erectus* individual at Dmanisi align with the Spanish discovery, he says. After *H. erectus* left Africa, "I would put my money on a long-lasting population occupying Dmanisi around 1.8 million years ago, with later populations moving into Europe." ✖

↖ **Jaw and cheek fossils found in Spain come from the oldest known human ancestors in Western Europe. Traits of the partial face seem to align closely with those of *Homo erectus*, as shown in this comparison.**

R. HUGUET *ET AL*/*NATURE* 2025

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THE HEALTH CHECKUP

YOU MAY BE SLEEPING AT THE WRONG TIMES

BY SUJATA GUPTA

On the eve of Daylight Saving Time, I flew home to Vermont from California. Crossing several time zones, I arrived near midnight. At 2 a.m., the clock jumped ahead an hour, leaving me discombobulated. "How messed up am I?" I asked sleep researcher and evolutionary anthropologist David Samson days later. Jet lag can make people feel moody and hungry at weird times, but my extreme state probably masked chronic sleep dysregulation, he told me.

For most of human history, people woke with the sun and slept with the stars. Environmental cues like light and temperature synchronized the body's clock, or circadian rhythm, to the day-night cycle. Nowadays, many of us spend more time indoors than out, where we bathe in artificial light and temperatures set for optimal comfort.

It's a "circadian jail cell," says Samson, of the University of Toronto. The body, he says, "is a receptacle of data. If we're blocking the data, our physiology's got nothing to work on."

And a misaligned body clock could be cause for concern, as it disrupts hormone release and other bodily processes, Samson says. Circadian disruption has been linked to depression, cancers, heart disease and inflammation.

In fact, when we sleep may be a bigger problem than the amount we sleep. Samson and a colleague recently reviewed 54 sleep studies conducted between 1967 and 2022 that analyzed over 5,100 people from 21 countries. People in the industrialized world averaged 7.1 hours of sleep per night, the pair reports in *Proceedings of the Royal Society B*. People in the nonindustrialized world, most without electricity access and living more like humans of the past, got on average 42 minutes less sleep per night, or 6.4 hours total.

Though people in the industrialized world get enough sleep on average, they tend to sleep out of sync with their body clocks, Samson says. In studies measuring individuals' activity levels throughout the day — a proxy for circadian rhythm — people in the nonindustrialized world lived more in tune with the sun than people in the industrialized world.

Other researchers question this line of reasoning. Neuroscientist Horacio de la Iglesia argues that the "traditional" foraging societies in Samson's work might be outliers. His data suggest that people in traditional communities with few outside stressors, such as predators, but without electricity sleep as much as nine hours a night.

It's hard to separate sleep deprivation from circadian disruptions, says de la Iglesia, of the University of Washington in Seattle. When communities get electricity, people start sleeping less and later than before, his research shows. A person who goes to sleep late may still have to get up early for work. "When your circadian clock is misaligned, you also sleep less," he says.

For de la Iglesia, one path forward is for society to be more flexible with the start of the work or school day. Imagine a world in which someone with a 1 a.m. bedtime can wake up eight hours later without issue.

Samson argues that getting your body's clock on track is still important, especially if you feel out of sorts after a full night's sleep. Practicing good "chronohygiene," he says, can mean making indoor spaces more like the outdoors. Set the thermostat so that your home is cooler at night and warmer during the day. Or install lights that blaze blue come morning and dim and redden alongside sundown.

Don't fret about blue light from smartphones and other screens, says time-use expert Juana Lamote de Grignon Perez of University College London. Despite warnings about the impact on sleep, "the amount of light that these devices emit is negligible," she says. A five-minute morning walk "has a much stronger impact on your body than checking your phone for 30 minutes."

Of course, doomscrolling while in bed may be keeping you up for other reasons. So maybe it is best to put the phone down. ✖

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PLANETARY SCIENCE

BARNARD'S STAR REVEALS ITS PLANETS

By Lisa Grossman

● The nearest single star to the sun, Barnard's star, has a brood of planets all its own. The red dwarf star, about six light-years from Earth, hosts four planets each about two to three times the mass of Mars, astronomers report in the *Astrophysical Journal Letters*.

"Barnard's star has a long history of claimed detections, but none of them could be confirmed for a long time," says astronomer Ritvik Basant of the University of Chicago. "It's pretty exciting to know what's orbiting the nearest stars."

From 2021 to 2023, Basant and colleagues observed Barnard's star 112 times using the Gemini North telescope in Hawaii. "I was starting to see these signals in the dataset," Basant says. But because he was still calibrating the instrument, "we ignored it for that time."

Then last October, a team using a telescope in Chile reported evidence of one planet orbiting Barnard's star and hints of three others. With these hints in mind, Basant's team reexamined its data, confirming three planets. Combining the two teams' data confirmed the fourth. A view of Barnard's star from one of the planets is illustrated above.

The planets are so close to Barnard's star that they orbit it in less than a week, which means they're too hot to be habitable, Basant says. In fact, the new observations probably rule out the presence of any habitable-zone planets. ✖

PLANETARY SCIENCE

URANUS RADIATES HEAT FROM ITS INSIDES AFTER ALL

BY KEN CROSWELL

Uranus emits more energy than it gets from the sun, two new studies report — a discovery that contradicts findings from the venerable Voyager spacecraft.

When Voyager 2 sped past Uranus on January 24, 1986, the spacecraft detected no significant excess heat from the planet, making it seemingly unique among the solar system's giant worlds. However, new observations from space- and ground-based telescopes reveal that Uranus does in fact radiate more energy than sunlight provides, two teams of researchers report in papers posted to arXiv.org.

"Uranus is not as odd as we thought it was," says planetary scientist Patrick Irwin of the University of Oxford, a coauthor of one study.

Both teams say that Uranus, which takes 84 years to orbit the sun, reflects a bit more sunlight into space than Voyager had found. This means that the sun heats the planet less than previously thought, suggesting that Uranus must generate some heat to explain its temperature.

The upshot: "Uranus does indeed have internal heat," says Liming Li, a planetary scientist at the University of Houston and coauthor of the other study. This heat is presumably left over from the planet's birth.

Li's team estimates that Uranus emits 12.5 percent more energy than it receives from the sun. Irwin's team pegs the excess at 15 percent, which is consistent with the other team's result.

"Uranus is still an outlier," Irwin says, because the other giant planets — Jupiter, Saturn and Neptune — radiate more than twice as much energy as they get from the sun.

No one knows why Uranus is so subdued. But the planet has another oddity: It rotates on its side, with an axial tilt of 98 degrees — compared with 3 degrees for Jupiter, 27 degrees for Saturn and 28 degrees for Neptune.

Planetary scientists have long suspected that a giant object knocked Uranus over. If so, the impact may have dredged up hot material from the interior, Irwin says, causing Uranus to lose much of its heat during its youth. ✖

INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA, R. PROCTOR AND J. POLLARD

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GENETICS

FIVE GENES MAY RAISE OBESITY RISK IN LABS

By Alex Viveros

● Labrador retrievers are among the most overweight dog breeds. Scientists have now identified multiple genes associated with obesity in the canines.

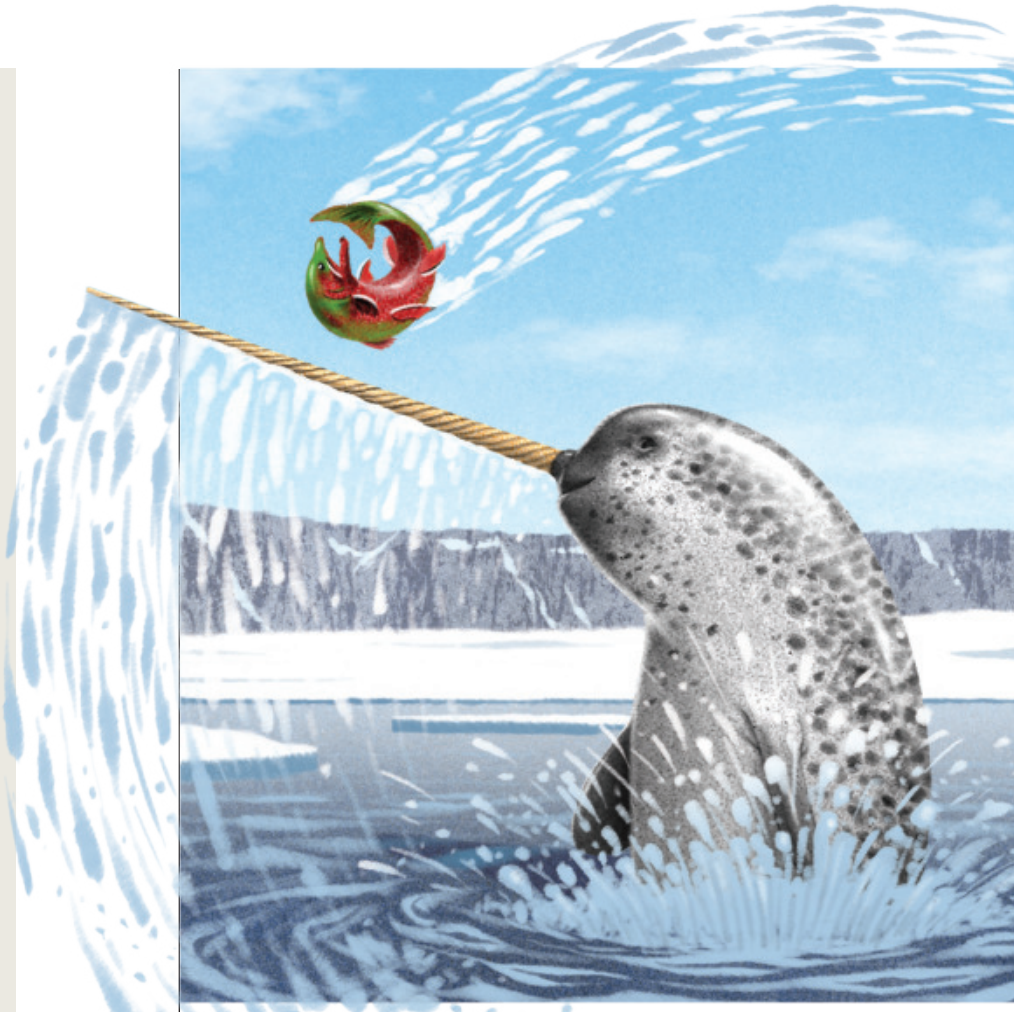
Veterinary surgeon Eleanor Raffan of the University of Cambridge and colleagues examined DNA from 241 labs in the United Kingdom and collected data on body fat, food begging and how strictly owners regulated the dogs' diets.

Five genes were associated with obesity in the dogs. The strongest effect came from *Dennd1b*, a gene that affects how the brain responds to food. Labs with a certain variant of *Dennd1b* had about 8 percent more body fat than labs without it, the team reports in *Science*.

Raffan and colleagues developed a scoring system to calculate whether a dog's genetic profile put them at a high or low risk for obesity. The team then compared high-risk and low-risk labs' relationships with food.

High-risk labs were more likely to beg and be highly food motivated. But a strictly regulated diet tended to help them stay at a healthy weight. Low-risk dogs tended to stay at a healthy weight regardless of how they were fed.

Owners don't need a genetic test to gauge their lab's obesity risk, Raffan says. If a dog seems like it would tip the scales if given the power to eat what it wants, that's a hint that the dog's genes may be behind the drive for food. ✖



ANIMALS

Narwhals seem to use their tusks to play

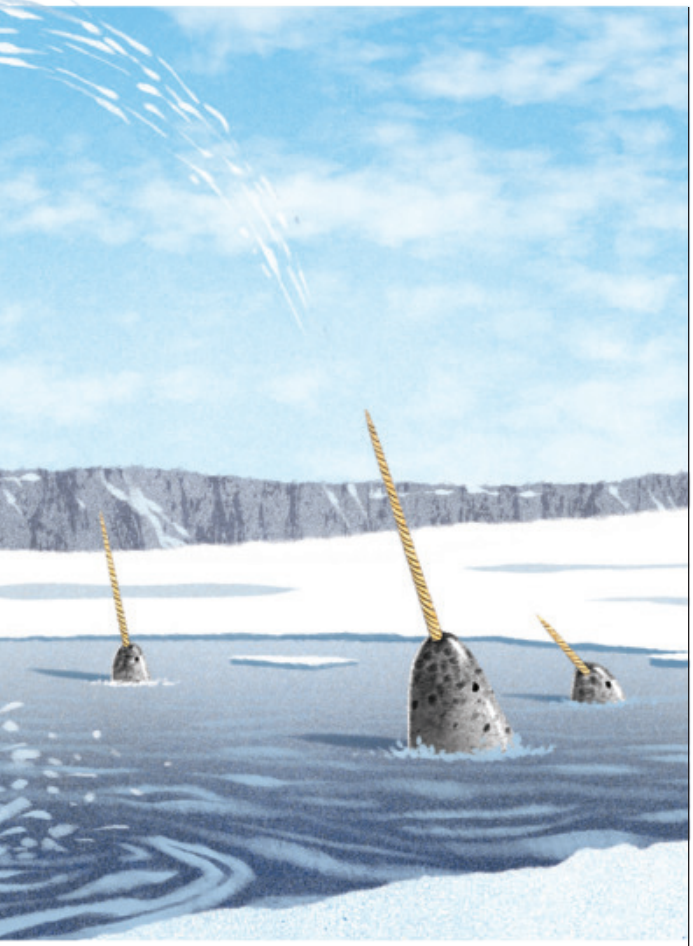
By McKenzie Prillaman

● **Narwhals wield their iconic tusks** in surprising ways — possibly even to play with newfound toys.

Aerial videos show the Arctic whales swinging their "horns" to thwack fish before eating them, and in one case, gingerly prodding and flipping a fish. The gentler movements may have been part of a narwhal play session,

↑ Narwhals summering in the Canadian High Arctic have been recorded while appearing to play.

FROM LEFT: MIKE KEATING/NEWSPIX/GETTY IMAGES; JASON RAISH



G. O'CORRY-CROWE ET AL./FRONTIERS IN MARINE SCIENCE 2025

researchers report in *Frontiers in Marine Science*. It's the first documented evidence of narwhals (*Monodon monoceros*) seemingly amusing themselves for fun.

Few scientists have seen these "sea unicorns" brandishing their tusks in the wild. The elongated, spiraled tooth protrudes from the top lip of males and some females, and can grow to about 3 meters, nearly the length of the roughly 4.5-meter-long whales. Researchers suspect the tusk evolved in males to show off to or compete for mates. But past studies have found it has additional benefits, like sensing changes in water temperature and salinity.

Although recent technologies involving genetics, satellite tagging, and aerial counts and mapping have led to breakthroughs in whale research, they provide only snapshots of what the animals do, says Greg O'Corry-Crowe, a behavioral ecologist and geneticist at Florida Atlantic University in Fort Pierce. He wanted to try what he calls an "old-style natural history and behavioral observation" of narwhals.

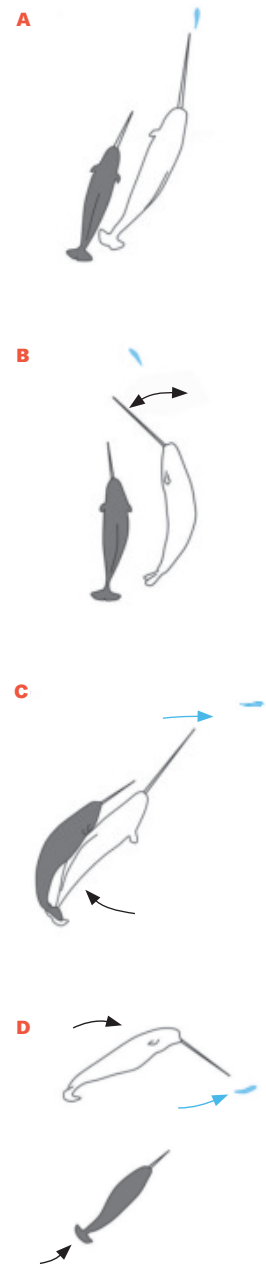
Using a remotely operated flying drone, O'Corry-Crowe and colleagues filmed narwhals swimming in the Canadian High Arctic in the summer of 2022.

One recording captured three narwhals among Arctic char (*Salvelinus alpinus*), chasing several fish and occasionally swinging their tusks like baseball bats to stun their prey before chowing down. Another video showed three narwhals following a large char, with one whale taking the lead in lightly nudging and flipping the fish with the tip or side of its tusk, altering the fish's path.

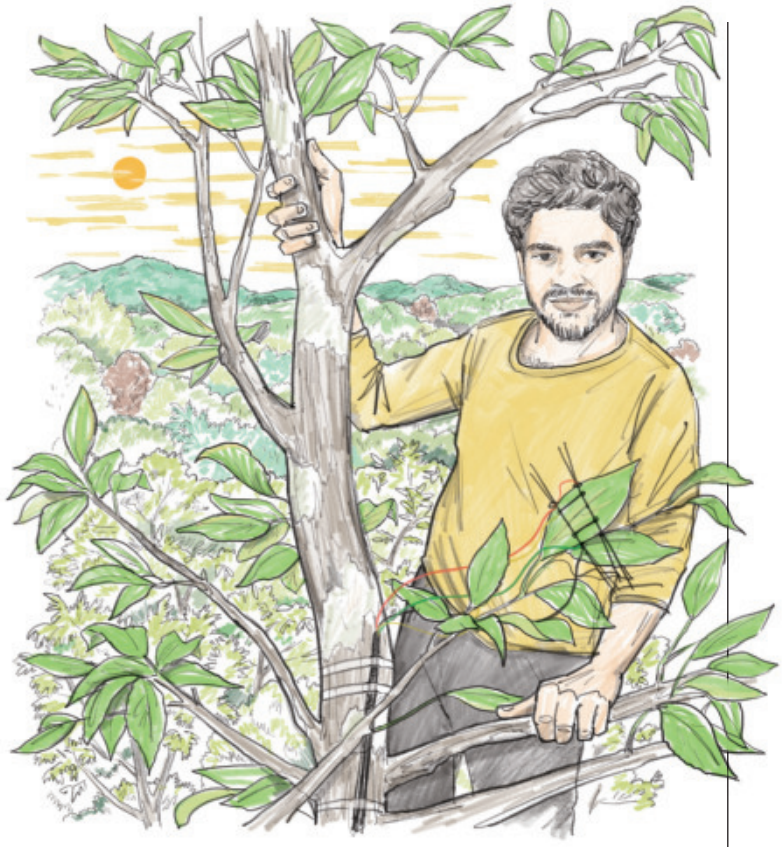
The second recording appears to show the two species investigating one another, as little evidence implies that narwhals normally eat char, and they do most of the year's hunting and dining in the winter, O'Corry-Crowe says. "There's this tentativeness," he explains. "The fish makes a dramatic movement, and even the big animal just recoils and goes *whoa*!" Aspects of the scene, such as the narwhals' low-stress environment, their repeated actions with their tusks and the fact that they didn't try to eat the fish, suggested the whales were playing.

Because of the Arctic's harsh environment, people often think creatures residing there are constantly fighting to survive, O'Corry-Crowe says. But the findings hint that sometimes these animals have time to explore — and possibly play — during their "summer vacation." ✖

A WHALE OF A TIME



Researchers recorded narwhals pursuing Arctic char. In one observation, a whale tracked a char with the tip of its tusk (A), swung the tusk back and forth (B) and blocked another narwhal's path (C) before getting back to tracking (D).



BRETT AFFRUNTI

↑ Ecologist Akhil Javad found that tropical trees' ability to photosynthesize may be resilient to global warming.

CLIMATE

Some trees cope surprisingly well with rising temperatures

By Siddhant Pusdekar

The new work is the first to study cumulative heat exposure in tropical trees.

● **Ecologist Akhil Javad felt the thrill** of fieldwork quickly fade when he was faced with the prospect of scaling trees over five times his height. But for some of the trees he was studying in India's Western Ghats, that was the only way to take their temperature.

So, Javad got climbing. Sensors that he placed on leaves in the upper canopy are providing unprecedented insights into how tropical forests are weathering global warming. The findings suggest that the trees may be in better shape than scientists expected, he and colleagues report in *Global Change Biology*.

In the summer, which lasts from March through June in the region, daily high temperatures in the mountains can cross 37° Celsius and are projected to rise by about 4 degrees in the next 60 years. That could be a problem for trees, since leaves can get much hotter than the surrounding air.

As the temperature of a leaf rises, its ability to harness sunlight to make sugar and oxygen becomes less efficient. On average, when leaves surpass 46.7°, their photosynthetic machinery begins to shut down. When that happens, trees don't get the energy they need. Many trees in the tropics are already experiencing temperatures beyond that average limit.

But what matters most is length of exposure, says Deepak Barua, an ecologist at the Indian Institute of Science Education and Research Pune who coauthored the new study. The work is the first to investigate cumulative heat exposure in tropical trees, he says.

On a 6-hectare plantation, Javad placed 14 sensors on the leaves of 12 trees — a mix of rose sandalwood, ironwood, Ceylon boxwood and kindal. It wasn't smooth sailing, though. Strong winds often dislodged sensors. Langur monkeys destroyed another. And a thunderstorm wiped out a week's worth of data.

Perpetually repositioning, replacing and checking sensors was "a pain," says Javad, of the University of Leeds in England. CONT. ON PAGE 29

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CONT. FROM PAGE 26 Constant troubleshooting is one reason why people avoid studying cumulative heat exposure, which makes the team's work even more valuable, says Andy Leigh, a plant ecologist at the University of Technology Sydney.

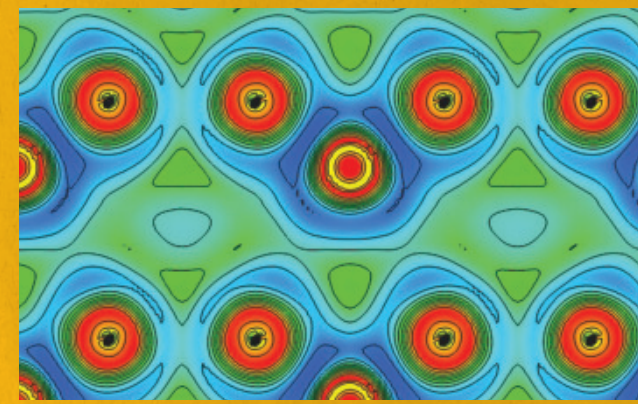
"It's really important for crazy scientists like us to get up trees and fight off monkeys, to put [sensors] on leaves," Leigh says. "Otherwise, we really aren't going to be able to understand how our natural systems ... are going to be looking after us in the future."

The sensors continuously recorded leaf and air temperatures throughout the four summer months in 2023. Meanwhile, in the lab, the team determined that critical thresholds for the area's trees ranged from about 47.8° to 50.8°. Thirty minutes of continuous exposure to these temperatures can permanently damage leaves.

But leaves crossed those temperature limits for less than 10 minutes a day, sensor data showed. What's more, just one of the monitored leaves averaged 30 minutes of exposure to temperatures at which photosynthesis begins to shut down over the four months. That isn't enough time to majorly hamper photosynthesis, Barua says.

For now, trees in these forests will continue efficiently photosynthesizing despite rising temperatures, the study suggests. But exposure to elevated temperatures even for a few minutes a day could affect reproduction and other aspects of tree health, Leigh says. Her team is gauging the extent of heat's indirect impacts on trees in Australia.

Barua is encouraged by the growing interest in heat exposure. He expects more researchers will put temperature sensors to work in ecosystems across the world. ✖



↗ Under high temperature and pressure, helium atoms (red circles with red centers) move into the spaces between iron atoms (red circles with black centers) in a piece of iron metal, as shown in this map.

HAN HSU/NATIONAL CENTRAL UNIV.

EARTH

Earth's core might hide primordial helium

By Skyler Ware

● **Helium from the early universe** could be stashed in Earth's core, according to scientists who coaxed the notoriously stubborn element into a new compound.

Formed under intense pressures, the compound packs helium atoms into crystalline iron, the researchers report in *Physical Review Letters*. It joins a short list of materials that incorporate the normally unreactive element.

Physicist Kei Hirose of the University of Tokyo and colleagues squeezed iron and helium in a diamond anvil cell at pressures greater than 50,000 atmospheres and temperatures above 1,000° Celsius. The resulting crystal's volume was larger than that of a pure iron crystal formed at the same pressure, due to helium ions packing into spaces between iron atoms.

The study could help explain why some volcanic eruptions on Earth spew an ancient form of helium, Hirose says. Most of the planet's helium atoms have two neutrons and form from the decay of elements like uranium. But some eruptions release helium atoms with one neutron, a version that formed just after the Big Bang. Taken together, the evidence suggests that Earth's iron-rich core could be a reservoir of this primordial helium. ✖

ANIMALS

These koalas are caught in a deadly catch-22

By Jake Buehler

● **Koalas in Sydney** face two existential threats.

The koalas in one corner of Australia's largest city are perilously inbred, scientists report in *Conservation Genetics*. But the solution, interbreeding with neighboring populations, risks exposing the marsupials to another threat: a deadly sexually transmitted disease.

Koalas in the southwestern Sydney metro area have the lowest genetic diversity anywhere in New South Wales. Conservation biologist Carolyn Hogg and colleagues analyzed DNA samples from 111 wild koalas across seven sites south of Sydney. Some neighborhoods — including Campbelltown, Heathcote and Liverpool — had koala populations with an average genetic similarity resembling that of half-siblings. Over time, inbred populations have more health problems and lower survival rates, which can make them vulnerable to extinction.

The heavy inbreeding may stem from isolation, says Hogg, of the University of Sydney. These koalas' forested habitat is bound by urban areas to the north, east and west.

That same isolation may be why these neighborhoods are among the few in New South Wales without reported chlamydia infections. The bacteria have devastated koala populations across Australia, causing infertility, blindness and death. In one Queensland population, chlamydia accounted for 18 percent of koala deaths from 2013 to 2017. Some populations have a nearly 100 percent prevalence.

Southwestern Sydney's isolation also means koalas there have less variation in their genetic toolkit for adapting to new threats, including diseases like chlamydia. And their resilience may soon be tested.

The analysis revealed crossbreeding between koalas farther south and southwest in Wollondilly and chlamydia-free Campbelltown. "The likelihood that the disease will eventually arrive in the disease-free area is quite high," Hogg says.

If the koalas are mating, they're swapping genes and also bacteria. Such crossbreeding might boost genetic diversity, but it could cause a catastrophic outbreak of chlamydia.

"The quickest way to inject new diversity is by bringing in individuals from another population or structuring environments in a way to ensure that different populations are connected and don't become geographically isolated — like building corridors," says evolutionary ecologist Chloé Schmidt of Dalhousie University in Halifax, Canada. "Here, corridors wouldn't be a great idea."

Neither would bringing in disease-free koalas from other areas, Hogg says. "The population is large, so introducing new genetic diversity and having it taken up into the population is complex and difficult to achieve."

The team plans to study the link between koala immune system genes and patterns of disease spread. The work won't fix the inbreeding problem, but it could shed light on individuals' genetic susceptibility to chlamydia, Hogg says. ✖

C. HOGG

Koalas have been devastated by chlamydia. Some in the Sydney area have avoided the sexually transmitted disease because they are isolated, but that isolation has also made them worryingly inbred. ↙

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PLANETARY SCIENCE

PRIVATE LANDERS MARK A NEW ERA OF LUNAR EXPLORATION

BY LISA GROSSMAN

This year's hot destination is the moon.

Two privately owned robotic landers from two Texas-based companies have touched down on the lunar surface, one right after the other. Blue Ghost, from Firefly Aerospace, landed safe and sound on the nearside — a first for any private spacecraft — in early March. Just days later, Intuitive Machines' Athena lander touched down near the south pole but met an untimely demise.

Athena attempted to alight on a flat-top mountain called Mons Mouton, but missed the site by 250 meters, possibly skidded across the ground and came to a stop on its side in a small crater. The lander's solar panels generated enough power to send a few shots of its surroundings to Earth, but Athena's orientation prevented it from recharging. It also prevented two rovers and a hopping robot named Grace, after the pioneering computer scientist Grace Hopper, from getting out of the lander. Those probes were supposed to take data from inside one of the south pole's permanently shadowed craters.

"I think we can all agree ... that landing on the moon is extremely hard," NASA Associate Administrator Nicola Fox said during a news briefing. Athena "was aiming to land in a place that humanity has not been to before."

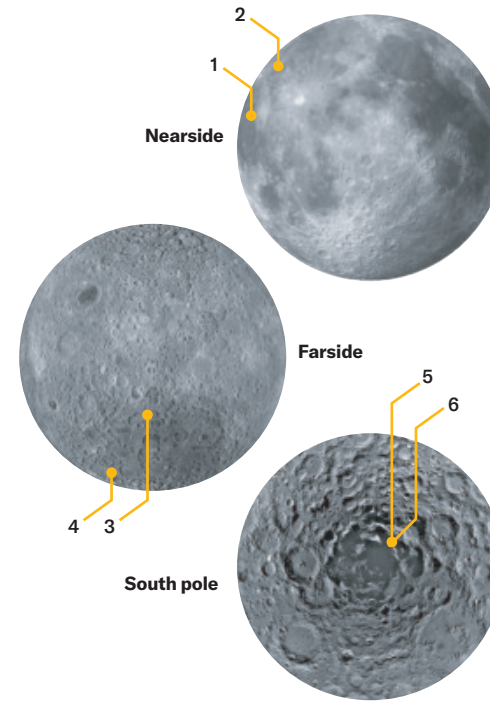
Intuitive Machines declared Athena dead on March 7, just a day after it landed, though "teams are continuing to assess the data collected throughout the mission," the company reported in a statement on its website.

Blue Ghost had better luck. During its 14-day mission exploring a volcanic plain called Mare Crisium, the lander put its 10 instruments to work. It tested a device that collects and sorts lunar soil with blasts of pressurized nitrogen gas, a drill to measure heat flow from the moon's interior and a dust shield that uses electrical forces to lift famously sticky moondust from glass surfaces. The lander also measured the stickiness of that dust and tested a form of lunar GPS. Meanwhile, cameras on the lander's underside took a video of the lander's engine plumes interacting with the lunar surface, which could provide insights for making future landings smoother and cleaner.

"The path to the stars is no longer limited to nations alone," said Jesus Charles, director of spacecraft operations at Firefly Aerospace, at a news briefing. "Blue Ghost's successful landing proves commercial industry has a critical role in humanity's journey beyond Earth."

It took many years of work and three failed attempts to get to this point. In February 2024, Intuitive Machines' first lander, Odysseus, broke a leg upon landing and fell on its side. A lander CONT. ON PAGE 34

FUTURE MISSIONS



NASA is collaborating with a handful of private companies to send more missions to the moon over the next several years. The current plans include:
1 Intuitive Machines IM-3 to Reiner Gamma, a bright spot on the crust known as a lunar swirl
2 Firefly Blue Ghost Mission 3 to Gruithuisen Domes, volcanic mounds
3 Firefly Blue Ghost Mission 2 to a site on the lunar farside
4 Team Draper to Schrödinger Basin, an impact crater
5 Astrobotic Griffin Mission-1 to Mons Mouton
6 Intuitive Machines IM-4 to Mons Mouton

ARIZONA STATE UNIV., GSFC/NASA

PHYSICS

PHYSICS EXPLAINS THE SOUND OF CLAPPING

By Emily Conover

● A round of applause, please. Scientists have finally figured out what's behind the sound of clapping.

The research pinpoints a mechanism called a Helmholtz resonator — the same acoustic concept that underlies the sound made when you blow across the top of an empty bottle. Experiments using baby powder to map the flow of air, alongside pressure measurements and high-speed video, confirm that explanation, researchers report in *Physical Review Research*.

A Helmholtz resonator consists of an enclosed cavity of air — like the inside of a glass bottle, or the space between clapping hands — with an opening connected to the cavity by a neck. Air vibrates back and forth within the neck, creating sound waves of a frequency that depends on the volume of the cavity and the dimensions of the neck and opening.

When a person claps their hands, a jet of air streams out of a gap where the hands meet, between the thumb and forefinger (shown in the photo series below). "This jet of air carries energy, and that's ... the initial start of the sound," says mechanical engineer Yicong Fu of Cornell University. The jet kicks off vibrations of the air. Fu and colleagues saw a similar effect using cup-shaped silicone models designed to mimic palms slapping together. ✖

↗ The Athena lander, built by Texas-based company Intuitive Machines, orbited the moon ahead of its attempt to land in March.

CONT. FROM PAGE 33 called Peregrine from the Pittsburgh-based company Astrobotic launched in January 2024 but never made it to the moon. And a lander called Beresheet from an Israeli nonprofit called SpaceIL crashed into the moon in 2019.

The success of Blue Ghost may be a harbinger of what's to come. Both that lander and Athena are part of NASA's Commercial Lunar Payload Services, or CLPS — a public-private program that started in 2018. As part of the program, NASA contracted 14 companies to send suites of science experiments and technology demonstrations to the moon through 2028. Many of these experiments are designed to pave the way for future human missions.

The CLPS companies regard each other as "competimates," a mashup of "competitor" and "teammate," says Firefly engineer Kevin Scholtes. "We're in this pool together, and there's a very real quality of, all ships rise with the tide," he says. "Ultimately, we want each other to be successful."

International companies and space agencies are also getting in on the action.

Resilience, a lander from Japanese company ispace, launched with Blue Ghost and is slated to touch down on the moon sometime this summer. And a commercial company in China called STAR.VISION plans to launch two small lunar exploration robots with the country's Chang'e-8 mission in 2028. It will be the first time China's national space agency will work with a private company. ✖

FROM TOP: INTUITIVE MACHINES; Y. FU/CORNELL UNIV.

SWARTHMORE COLLEGE

WHAT DO SWARTHMORE

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VOL. 207 NO. 05 | MAY 2025

GENETICS

What's the deal with woolly mice?

By Jason Bittel

● **Scientists working to crack the code** of de-extinction recently announced what they say is a turning point for the movement: the creation of transgenic mice with long, golden fur tufts inspired by the coats of woolly mammoths. They're called Colossal woolly mice. And yes, they are cute to boot.

Transgenic mice—those that have had their genomes altered through genetic engineering—are not new. But what's novel is the scale of the engineering. The team made eight edits across seven genes simultaneously in mice. Across three experiments, each of which used different combinations of edits, the method worked with high efficiency, resulting in living animals that presented the traits they were bred for.

In other words, the scientists have shown not only that they can make woolly mice, but also that they can do so reliably and repeatedly—a necessity for eventually bringing extinct woolly mammoths back to life.

"That's been overlooked as far as how actually big of a deal that is in genetic engineering," says Beth Shapiro, chief science officer at Colossal Biosciences in Dallas. She and colleagues described the findings in a paper posted at bioRxiv.org.

↑ This mouse was genetically engineered to have fur like a woolly mammoth's. But is the feat really a step toward bringing back the extinct pachyderm?

In all, the team created 32 woolly mice with traits the scientists had predicted. Shapiro says there were no misfires or surprises in the lot.

But what do a few extra-furry mice have to do with resurrecting mammoths? That part is more complicated and has led to misunderstandings since the findings were reported. For instance, the *New York Post* described the woolly mouse as a new species (it isn't) and one viral post on X stated that the scientists "spliced woolly mammoth genes into mice," which is also not true.

"We did not want to take elephant genes and shove them into a mouse," Shapiro says. "That wouldn't make any sense." Instead, scientists analyzed the genomes of 121 mammoths and elephants to identify genes that may have given woolly mammoths some of their characteristic traits. These include long, thick, golden hair as well as lipid metabolism and fatty acid absorption suitable for life in the bitter cold.

"We can do a lot with the mammoth genomes we have. We can line them up on a computer and compare them to elephant genomes and ask where all the mammoths are the same as each other but different from their elephant cousins," Shapiro says.

Using these hints about what makes a mammoth a mammoth, the scientists searched for similar traits in mice, either naturally occurring or that could be achieved through genetic engineering. Mice are much easier to work with than elephants, of course. The rodents require little space, breed quickly and have already been extensively studied with regards to their genetics. For instance, scientists have known since 1994 CONT. ON PAGE 38

COLOSSAL BIOSCIENCES

CONT. FROM PAGE 37 that if you turn off the *FGF5* gene, mice will grow much longer hair than usual. Similarly, a gene known as *Mc1r* makes mice blond, while *Frzd6* makes that hair whorly and frizzled.

The final step was transforming edited embryos into living, breathing, gloriously furred mice.

"Of course, mice are not elephants, which people have helpfully pointed out to us, as if we didn't know that," says Shapiro, referring to some common critiques her team has received. This is why the woolly mice are just one part of the de-extinction goal.

Colossal is also experimenting with Asian elephant cells, because that species is most closely related to woolly mammoths. Other research focuses on artificial reproductive techniques for implanting a genetically modified elephant embryo into a living elephant and then bringing that animal to term. The team is also working on bringing back the dodo and the thylacine, also known as the Tasmanian tiger.

Jacquelyn Gill, an ice age ecologist at the University of Maine in Orono, is excited about the idea of seeing a woolly mammoth in person. "I understand why someone would be compelled to see a mammoth," she says. "I've never seen my study system in person, right? It only exists in my mind's eye, because I study a past that is gone."

"A mammoth is not an elephant in a fur coat."

— Tori Herridge

But she is skeptical that Colossal's pursuit will qualify as resurrecting a woolly mammoth. For starters, thousands of years buried in permafrost have damaged every cell even in well-preserved mammoth remains. This degradation means cloning is off the table, Gill says.

While gene editing may result in a modified Asian elephant that superficially resembles a woolly mammoth, any attempt to do so will miss innumerable genetic flourishes that made woolly mammoths unique.

"A mammoth is not an elephant in a fur coat," says evolutionary biologist Tori Herridge of the University of Sheffield in England. The candidate genes for mammoth fur types and cold adaptation are interesting, but we still don't know "what makes a mammoth a mammoth," she says.

Genes are complicated. "One gene can affect many things, and many genes can act in concert," Herridge says. Researchers don't yet know if the genes for hair length, texture and color in woolly mice will produce the same effects in Asian elephants.

Some troubleshooting can be done in the lab, Shapiro says. The team is already growing elephant cells in dishes and testing how those cells respond to changes in gene activity. This allows the company to learn more about which genes to target without having to grow or experiment on an elephant.

The team has also already created elephant pluripotent stem cells, which could potentially be used to create any kind of cell — a crucial step toward assisted reproduction.

Complicating this step is the fact that Asian elephant gestation can last about 22 months, meaning the process to create just one transgenic elephant will take much longer than that of woolly mice, which are pregnant for just 18 to 21 days. Moreover, Asian elephants are an endangered species, which will probably restrict how this process unfolds.

Assuming that all of this will one day be possible, and in numbers sufficient to create a viable herd, other questions remain. For instance, scientists have shown that modern elephants are complex animals with established social and cultural knowledge that gets passed down through generations. "You can't teach a transgenic elephant how to be a woolly mammoth," Gill says.

And the habitat that mammoths once roamed has changed in the thousands of years since they died out. Tundra ecosystems are now less productive and diverse, Gill says. This may be because mammoths were keystone species that greatly shaped their environment. When mammoths disappeared, the ecosystem disappeared with them. But if mammoths made an ecosystem once, perhaps de-extincted ones could do it again.

Shapiro acknowledges the legitimate criticisms of Colossal's goals but remains optimistic about the future. In fact, the company's dodo project might succeed first. Bird genetics presents its own challenges, but there's a lot to be said for an animal that requires only an egg rather than a surrogate mother, she quips.

And while Colossal's founder, Ben Lamm, has stated that he wants to see woolly mammoth calves on the ground by 2028, Shapiro stresses that genetics is just one part of the equation. "We will have elephant cells that are edited and ready to go in early '27, which is what we would need to have something on the ground in 2028," Shapiro says. "But then there's a lot of hard biology that still ... needs to be solved." ✖

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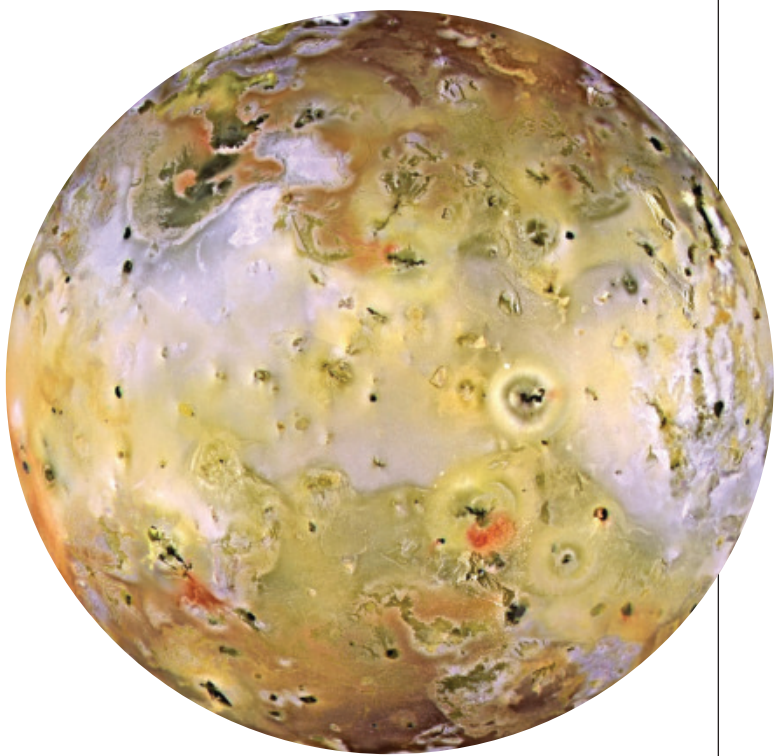

JPL/NASA, UNIV. OF ARIZONA

PLANETARY SCIENCE

Juno sizes up lava lakes on Jupiter's moon Io

By Katherine Kornei

● **Jupiter's moon Io,** the most volcanically active body in the solar system, is littered with hundreds of erupting volcanoes. High-resolution images now reveal several dozen lava lakes, researchers report in *JGR Planets*. These lakes are far larger than their analogs on Earth, and their structure sheds light on how magma moves beneath the surface of Io.

Io's volcanism — probably present over the moon's entire 4.6-billion-year existence — was discovered when the Voyager spacecraft flew by in 1979. The volcanic activity is caused by the intense gravitational pulls of Jupiter and nearby moons, which deform Io by tens of meters. "This squeezing is heating the body," says planetary scientist Alessandro Mura of Italy's National Institute for Astrophysics in Rome.

Using infrared images from NASA's Juno spacecraft, which has orbited Jupiter since 2016, Mura and colleagues pinpointed at least 40 lava lakes ranging from about 10 to 100 kilometers wide. That's much larger than lava lakes found on Earth, which tend to measure tens to hundreds of meters across.

Previous studies have reported lava lakes on Io but with only limited detail. Most of the newly analyzed lava lakes are hottest at their perimeters. This suggests that these lakes are largely capped by a cooler crust of solidified lava, the team says.

That idea makes sense given the conditions on Io, says planetary geologist Alfred McEwen of the University of Arizona in Tucson. "It's very, very cold. A crust starts forming immediately."

Molten lava remains exposed at the lake edges probably because of how the lakes interact with their surroundings, Mura's team says. The lakes sit within calderalike features that have steep walls, so as a lake fills or drains, its outer crust scrapes against the walls, breaking up the crust and exposing fresh lava.

The findings also shed light on how magma feeds these lakes. None of the analyzed lakes had a hot spot in the middle, Mura says, suggesting that magma doesn't simply upwell at a lake's center.

The team hopes to understand whether multiple lava lakes are fed by a common magma reservoir. In that case, different lakes' lava levels might go up and down in lockstep. Such observations could help reveal details about the plumbing that powers Io's volcanism, Mura says. "These can be a glimpse beneath the surface of Io." ✖

↖ Jupiter's moon Io, seen here in a photo from the Galileo spacecraft, is the most volcanically active body in the solar system.

TECHNOLOGY

THE FUTURE OF VIRTUAL FOOD LOOKS TASTY

BY SIMON MAKIN

Imagine tasting cake in a virtual world. Researchers have taken a step toward that reality with a device that delivers virtual tastes by squirting chemicals onto the tongue.

The system, called e-Taste, can detect chemicals in foodstuffs and wirelessly transmit this information to a device that delivers the same or equivalent chemicals to a user's tongue. By combining different chemicals, the device can mimic flavors ranging from cake to coffee, researchers report in *Science Advances*.

"This is a step towards the next generation of human-machine interfaces and virtual reality," says materials engineer Yizhen Jia of Ohio State University.

The system uses glucose for sweet, citric acid for sour, sodium chloride for salty, magnesium chloride for bitter and glutamate for savory umami. These edible chemicals are infused into gels inside the device, which get mixed in tiny channels. An electromagnetic pump delivers the mixture to the tongue via a flexible, ribbonlike conduit inserted into the mouth.

Jia and colleagues asked 10 people to distinguish between five intensities of sourness that the device produced. The team then created five complex tastes: lemonade, cake, fried egg, fish soup and coffee. Six volunteers who were trained to recognize the flavors achieved an overall accuracy of nearly 87 percent.

But, Jia says, "only putting chemicals on your tongue isn't going to be comparable" to tasting real food. Smell and feeling are also involved.

Jia's team plans to incorporate smell using gas sensors and machine learning. The team envisions applications in immersive gaming and even sensory rehabilitation. ✖

↑ Someday, virtual reality devices might re-create the tastes, smells and sensations of different kinds of food.

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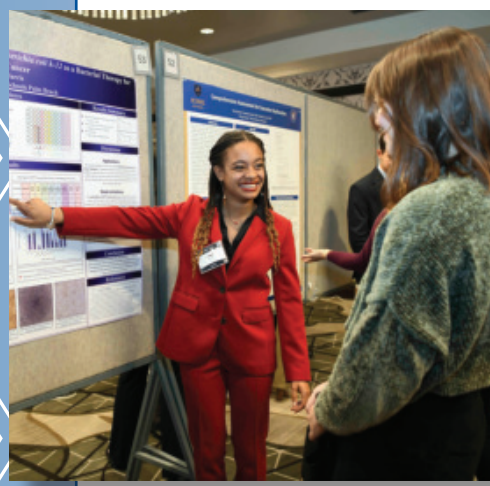

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CHEMISTRY

Meet the einstein tile's molecular cousin

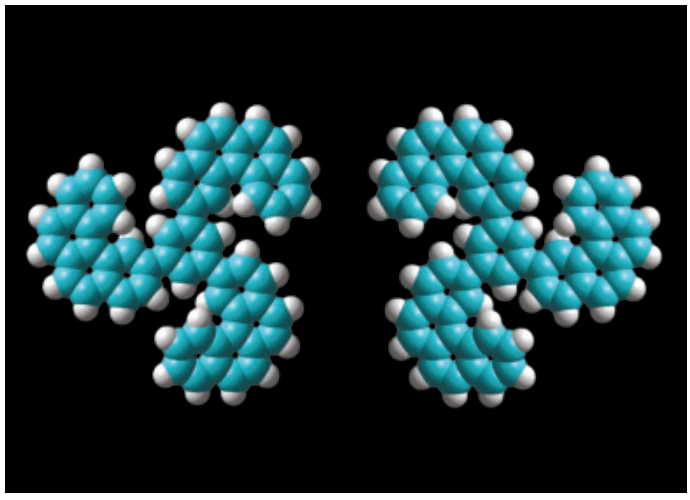
By Zack Savitsky

● **For centuries,** mathematicians have been fascinated by the shapes that can tile a plane without repetition. Now, a team of chemists has described a molecule that naturally assembles into these irregular patterns, laying the groundwork for engineering materials that behave differently from regular solids.

In 2018, chemist Karl-Heinz Ernst and colleagues sprayed a hydrocarbon molecule called tris(tetrahelicenebenzene) onto a silver substrate and watched it form patterns through a microscope. The molecules formed three-armed spirals that grouped together into triangles of different sizes. In each of 100 trials, new triangular sequences formed that never seemed to repeat. The team spent years trying to make sense of them.

Then, in 2023, computer scientist Craig Kaplan of the University of Waterloo in Canada and colleagues stunned the mathematics world when they found the elusive einstein tile: a single shape that can fill a plane only with a never-repeating pattern, meaning it's aperiodic. That discovery helped Ernst and colleagues realize that they had created sort of a molecular einstein, the team recently reported in *Nature Communications*.

"This is nature doing math," says Ernst, of the Swiss Federal Laboratories for Materials Science & Technology in Dübendorf.



EMPA

A simulation shows the two mirror versions of a hydrocarbon molecule that's reminiscent of an einstein tile (carbon atoms are blue; hydrogen, white). ↙

Kaplan agrees. "When these things seem to arise spontaneously in nature, I think it's absolutely fascinating," he says. "It feels like you found a glitch in the matrix."

But the molecule isn't aperiodic the same way the einstein tile is, Kaplan says. The pieces don't fit together precisely and it's unlikely that they can tile *only* with nonrepeating patterns. Even without achieving true aperiodicity, the novel patterning may still grant the material some seemingly magical properties, he says.

Two tricks make the molecule abnormally versatile: It can convert between two distinct mirror-image shapes and it forms very weak intermolecular bonds, allowing it to switch between configurations with relative ease. Together, these properties mean that there are many possible ways for the molecule to arrange itself without repeating, Ernst says.

The key to the material's irregular behavior is entropy — a measure of its structural disorder. The molecule orders itself in the most disorderly way possible, flocking to higher-entropy, nonrepeating patterns.

The findings could improve scientists' understanding of irregular ordering in nature, says physicist Felix Flicker of the University of Bristol in England.

Quasicrystals, for instance, have atomic structures that exhibit large-scale order but lack repeated patterns, giving the materials unique properties. Flicker's team built a computer simulation that predicted a quasicrystal based on the einstein tile would act like a tricked-out sheet of graphene. Insights from the new study could point scientists toward better ways to build quasicrystals on demand, he says. ✖

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Tran Lam '25, **Computer Science & Data Science Major**

Undergraduate Research Assistant studying mathematical modeling of network flow

Questions?

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Native Americans drive bison over a cliff to their deaths in this painting from 1914. Stone Age Europeans also devised this and other communal hunting tactics (see Page 64).

Features

CHARLES M. RUSSELL, ARTGEN/ALAMY


GLP-1

The Shadowy Online Market for GLP-1 Drugs

Shortages have driven patients to unconventional sources of the diabetes and weight-loss medications. Doctors are raising safety concerns

By Meghan Rosen

ILLUSTRATIONS BY EOIN RYAN

In late 2022, pharmacist Joseph Lambson got an unusual call from a poison control specialist.

He said, "Hey Joe, I'm getting these weird calls about semaglutide." According to the specialist's calculations, people were giving themselves 10 times the correct dose. But that didn't make sense. The drug is the key ingredient in the blockbuster diabetes and weight-loss medications Ozempic and Wegovy. Both come in prefilled injector pens, which typically take the guesswork out of dosing.

Lambson, a board-certified toxicologist, knew right away what was going on. "This drug is probably being compounded," he remembers thinking. He was right. After investigating, Lambson's team at the Utah Poison Control Center in Salt Lake City reported that people were overdosing on compounded semaglutide. That means "a lot of nausea, a lot of vomiting, a lot of diarrhea," he says.

Ozempic and Wegovy, made by Novo Nordisk, had both been on the U.S. Food and Drug Administration's drug shortage list since 2022. Across the boundless wilds of the internet, online sellers sprang up to meet demand. Some sold compounded medications. When pharmaceutical companies can't keep up with demand for their FDA-approved drugs, compounding pharmacies can step in to fill the gap. These pharmacies measure and mix a drug's active ingredient, creating a product that's essentially a copy of the brand-name drug. Outside of shortages, compounding pharmacies routinely provide medicines that aren't otherwise available or need to be tailored to a particular patient.

But even with legal, compounded forms of semaglutide, which require a prescription and usually come premixed in a vial with a syringe, patients can run into trouble, as Lambson found. People weren't always sure how to take the drugs, so "they just went for it," he says.

Last year in *Clinical Toxicology*, emergency medicine doctors reported similar issues in a few cases. One man injected 20 times the correct dose of semaglutide because he misunderstood instructions.

Semaglutide belongs to a class of medications known as GLP-1 receptor agonists. Even when used correctly under doctor supervision, they come with potential side effects. And when patients have to pull up the correct dose with a syringe, the risks go up. Soon, the situation could get even dicier.

In February, the FDA removed semaglutide from the drug shortage list. By May, pharmacies will no longer be able to dispense compounded versions, though that depends on ongoing litigation. It's a similar story with another GLP-1 drug, tirzepatide, the main ingredient in Mounjaro and Zepbound, Eli Lilly's diabetes and weight-loss drugs. The FDA erased tirzepatide from the drug shortage list in October.

But just because a drug is off the list doesn't mean supply is guaranteed. And even with new discounts offered by pharmaceutical companies, the drugs' prices keep them out of reach for many patients — especially since insurance won't always cover them.

High prices could drive people to seek out more affordable versions from less-than-reputable sources. "That's what I'm worried about," says C. Michael White, a pharmacist and researcher at the University of Connecticut in Storrs. People reliant on legitimate compounded products may soon "go further down the rabbit hole."

That rabbit hole includes websites that sell GLP-1 drugs "for research only," like powdered semaglutide or tirzepatide that's intended for use in the lab, not for humans. With just a few clicks, anyone with an internet connection can purchase a vial of the drugs for about a hundred bucks — and without a prescription. Consumers

With just a few clicks, anyone with an internet connection can purchase a vial of the drugs for about a hundred bucks — and without a prescription.

don't need to verify they're a researcher or offer proof that they belong to a scientific institution. All they need is a credit card.

Scientists around the country have raised concerns about drug quality, dosing and scams. Buyers must rely on themselves to reconstitute and inject these drugs, without physician guidance. That means buying a specific type of sterile water, calculating how much to add to the vial of freeze-dried powder, mixing it and then figuring out exactly how much to draw up in a syringe and inject into the body. It's a recipe for confusion — and potentially danger.

But for many people, the benefits of GLP-1 drugs are well worth the risks. They can be a lifeline, helping people lose weight, lower the risk of heart attack and improve their all-around quality of life. For Melanie T., a 70-year-old woman on compounded tirzepatide, the drug has transformed her body and her life. "I feel so good now," says Melanie, who is using only her first name to protect her privacy. "I feel healthier now than I felt when I was in my 40s."

When her compounding pharmacy stops dispensing tirzepatide, she's open to exploring her options. "What is my alternative if I don't have this?" she says. "I don't really have one."

Life-changing effects

Melanie injected her first dose of compounded tirzepatide into her abdomen on August 8, 2024.

She had always been petite, 5 feet, 3 inches tall, and between 115 and 120 pounds, but "menopause changes everything," she says. At 70 years old, she weighed 174 pounds and felt terrible. Her knees hurt, her back hurt, she was short of breath, and she had a laundry list of other health issues, including hypothyroidism, fibromyalgia and swelling in her legs.

For years, Melanie went from doctor to doctor, trying all sorts of therapies and diets. There were supplements, IV drips of vitamin C, intermittent fasting (when she ate only during certain times of the day) and water fasting (when she consumed only water and electrolytes for days at a time). Nothing seemed to help. She was sick and not getting better, Melanie says. "The weight was not going down."

Finally, she says, "I said the hell with this." Her daughter told her about GLP-1 drugs, and Melanie ordered compounded tirzepatide from an online telehealth company. That involved completing an online intake form and video chatting with a doctor, who prescribed the medication.

Melanie T. shows a syringe and a vial of compounded tirzepatide, which she got with a prescription from a telehealth company.

MELANIE T.

GLP-1 drugs imitate an assortment of gut hormones involved in metabolism and act on the body in myriad ways; they can cause food to stick around in the stomach longer, lower blood sugar and tell our brains that we're not hungry. Semaglutide mimics one hormone, GLP-1. Tirzepatide mimics two, GLP-1 and GIP. And retatrutide, still in clinical trials, mimics those two plus an additional hormone called glucagon. Generally, more hormones mimicked means more weight lost.

After Melanie's first week on tirzepatide, she lost five pounds. By week two, she had dropped nine. When I talk to Melanie in March, she has gone down to 116 pounds. Her joint pain has disappeared, as has her fibromyalgia. But one of the biggest changes has been her relationship with food. Ice cream, once a favorite treat, is now "so overpoweringly sweet that it's disgusting," Melanie says. Food overall is just not as enjoyable. "I eat because my brain tells me I need to eat. I don't eat for cravings."

That silencing of food noise, the relentless buzz of food-related thoughts in the brain, is a common effect of GLP-1 drugs. So are Melanie's weight-loss results. On average, people on a high dose of tirzepatide lose about 20 percent of their body weight. With such drastic results, it's not surprising that some 6 percent of U.S. adults may be on a GLP-1 medication, according to a 2024 poll.

As Melanie discovered, GLP-1 drugs can help the body in other ways, too. A study of nearly 216,000 U.S. veterans found that people on the drugs were less likely to have substance use disorders, psychotic disorders, seizures,

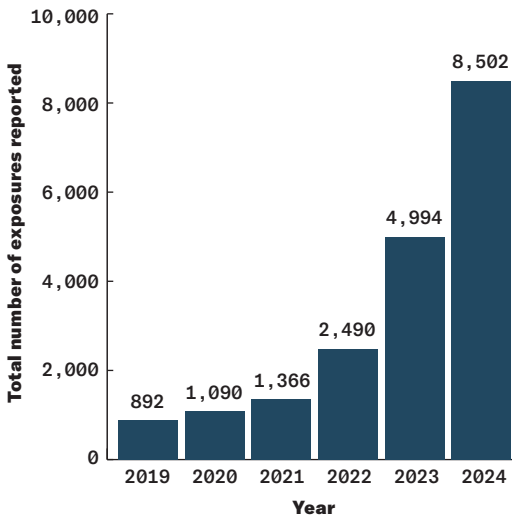
dementia and infections, among other health benefits, researchers reported in January in *Nature Medicine*.

But the medications aren't without side effects. The study uncovered the usual gastrointestinal issues linked to GLP-1 drugs, like abdominal pain, nausea and vomiting, as well as less well-known conditions, including stomach paralysis and diverticulitis, where bulging pouches of the large intestine become inflamed. Such side effects may help explain why 65 percent of people without type 2 diabetes who take a GLP-1 drug quit within a year, scientists suggested in January in *JAMA Network Open*. Serious problems are likely to be rare, though. Less than four emergency department visits occur for every 1,000 patients dispensed semaglutide, researchers estimated in April in the *Annals of Internal Medicine*.

For Melanie, the first two weeks on tirzepatide were the roughest. She had no appetite and severe nausea. "It felt like somebody donkey-kicked my stomach," she says. "I thought I was going to die." She stayed inside, laid on the couch and rode it out. By the third week, most of the side effects had disappeared.

Today, Melanie's got a compounded product she trusts — and can afford — and feels comfortable using a syringe and vial. But recent data suggest that not everyone is so adept.

GLP-1 EXPOSURES REPORTED TO U.S. POISON CENTERS, BY YEAR



In 2024, there were 8,502 GLP-1–related cases reported to poison control centers across the United States. That's nearly 10 times as many cases as in 2019.

AMERICA'S POISON CENTERS NATIONAL POISON DATA SYSTEM, GRAPH BY T. TIBBITTS

Dosing errors

In New Mexico, where Lambson is now the director of the state's Poison and Drug Information Center, GLP-1–related calls have doubled every year since 2021. That trend holds up nationally. In 2024, poison control centers across the United States managed 8,502 GLP-1–related cases, says Kaitlyn Brown, clinical managing director of America's Poison Centers, a national nonprofit organization that represents the 54 accredited poison centers in the United States. That's compared with 892 cases logged in 2019 — an 850 percent increase.

It's impossible to say how many of these cases stem from compounded or other versions of the drugs. But about 75 percent were due to unintentional therapeutic errors, meaning people used the wrong dose or otherwise administered the drug incorrectly. From a poison control perspective, Brown says, "it's obviously more of a risk when you're giving a patient a syringe and a vial."

As of November 30, the FDA has received nearly 800 reports of adverse events linked to compounded semaglutide or tirzepatide. These reports aren't proof of causation, but it's possible some adverse events may be due to dosing errors. And dosing is just part of the confusion. Vendors selling compounded GLP-1 drugs sometimes have

incomplete or misleading information on their websites, researchers reported in January. A Super Bowl commercial spotlighted these issues in February, when two U.S. senators sent a letter to the FDA raising concerns over a telehealth company's ad about compounded weight-loss medications. The ad made no mention of risks or side effects.

"Everyone's trying to make money — manufacturers, compounding pharmacies, counterfeiters, everybody," says Tim Mackey, a public health researcher at the University of California, San Diego. "I really think the patient is the victim here."

That's where responsibility for vetting online vendors and pharmacies tends to fall. Patients can check if a compounding pharmacy in their state is legitimate and licensed, says pharmacist Tenille Davis, chief advocacy officer at the Alliance for Pharmacy Compounding. That industry trade organization has developed an online tool for this task and has suggested questions consumers can ask when choosing a compounding pharmacy.

Compounded drugs, though legal, are not FDA-approved. According to the agency, it doesn't "review compounded drugs for safety, effectiveness or quality before they are marketed." That doesn't make them inherently dangerous, Davis says. "Compounding is a part of the practice of pharmacy," she says. "Pharmacists jump in and help with drug shortages all the time." But never like what's happened with GLP-1 drugs.

Even though Ozempic, Mounjaro and Wegovy are off the shortages list, pharmacies have reported difficulty obtaining enough of these drugs to meet demand, Davis says. Without compounded versions to shore up supply, "we worry that patients are going to have access issues with this medication."

That could push patients from the sometimes-complicated world of compounded drugs into far-less-certain territory. With brand-name GLP-1 drugs either out of supply or too expensive for some patients to afford, more people may seek out the shadowy universe of GLP-1 peptides. These chemicals include the same active ingredient as the brand-name drugs and compounded versions, but don't require a prescription. That's because vendors say these peptides are for research use only or not for human consumption.

And with neither physician nor pharmacist for support, people are hunting for medical advice on these peptides in unconventional places, like private Facebook groups and secret social media chats — where drugs are given code names and users test unapproved chemicals on themselves.

A community of peptide users

As part of my reporting for this story, I joined multiple peptide groups online. I was kicked out of the first one I got into on Facebook. It's a private group with more than 22,000 members, and the rules stipulate that any talk of research peptides for human use is not allowed.

But group members exchange advice on where to buy peptides and how to administer them. Some people refer to them as S$ma or T!rz and say they're for an "RS," or "research subject," a way to avoid calling attention to human use. Others are more direct, recommending peptides for weight loss and describing their experiences using them.

These include the usual suspects, like semaglutide and tirzepatide, but also retatrutide, the GLP-1 drug still being tested in clinical trials. It might help patients shed more weight than anything currently on the market. "I just started Reta last week," one member posted. "Felt better than when I was taking sema."

When I identified myself as a writer for *Science News* and asked if anyone would speak about their experiences, people called me a snitch, a cop and a Big Pharma shill. One member suggested that this story could shut down peptide-seller websites. "Don't ruin what we have," another said. The concerns underscore just how difficult it can be to access medications like Wegovy and Zepbound — and how important they are to people's lives.

Selling these drugs under the guise of research is a huge loophole.

Despite the benefits, people may face negative attitudes about using drugs for weight loss. They may be "stigmatized for taking the 'easy way out,'" A. Janet Tomiyama, a UCLA psychologist, wrote in the January *Annals of Behavioral Medicine*.

That's not how we should treat people who want to go on these medications, says Kai Jones, an endocrinologist at Washington University in St. Louis. In her practice, she and her colleagues talk with patients about stigma, weight and how obesity requires chronic management. "Often, folks are blamed because of the way they look or their body composition," she says. "I think it's important to reach out to folks with empathy, to understand where they're coming from." That includes figuring out what barriers people face when trying to access these medications.

A big price tag

GLP-1 drugs are big business. In February, Novo Nordisk reported a 25 percent jump in sales from 2023 to 2024, largely thanks to Ozempic and Wegovy. Eli Lilly's revenue rose 32 percent, driven by sales of Mounjaro and Zepbound.

Though many insurance plans pay for the meds for type 2 diabetes, coverage can be spotty for people who are overweight or obese but do not have diabetes. That's why Melanie's insurance didn't cover a GLP-1 prescription. For her, paying out-of-pocket was out of the question. And because people may remain on the meds indefinitely, costs can pile up.

The list price for GLP-1 drugs runs from around $1,000 to $1,300 per month. To expand access, pharmaceutical companies have begun offering discounts. Eli Lilly now sells Zepbound, its tirzepatide obesity drug, directly to consumers for $349 or $499 per month, depending on the dose. But the deal is cash only, and the medication comes in a single-dose vial, not an injector pen. That's still too high of a price for Melanie — double what she's currently paying for compounded tirzepatide.

In March, Novo Nordisk announced a similar plan for Wegovy. Cash-paying customers can buy injector pens for $499 per month.

Costs for people on Medicare may also go down — eventually. In January, the U.S. Department of Health and Human Services said it would negotiate the price of Ozempic and Wegovy covered by Medicare Part D, which helps people 65 and older pay for prescription drugs. Medicare covers Ozempic for diabetes and Wegovy for heart disease, but neither drug is covered for weight loss. Any price updates wouldn't become effective until 2027.

Even with new discounts, though, purchasing peptides from "research only" sellers may still be the cheapest option. A one-month supply can cost less than $100.

Lambson says he understands the frustration of consumers who can't afford or don't have access to either brand-name or compounded versions of GLP-1 medications. But he worries about people tracking down their own peptide supply. Going online and buying the drugs from unvetted sources that don't require a prescription "can really put you at harm's risk," he says.

Reason for concern

Last year, Mackey, the public health researcher at UC San Diego, and colleagues reported purchasing semaglutide from six online vendors that

didn't require a prescription. "We got scammed on three of the six orders," Mackey says. Vendors would fake tracking numbers that showed packages held up at customs and then demand hundreds of dollars in fees to release the medication.

Of the three orders that did arrive, one had high levels of endotoxin, a sign of contamination. All three orders had low purity levels; in one case, just 7.7 percent purity, compared with the 99 percent purity claimed by the seller, Mackey's team reported last year in the *Journal of Medical Internet Research*. "Such a low purity is concerning," Mackey says, "because you have no idea what the rest is and whether it could be harmful when injected."

And though the semaglutide peptide sellers included "research use only" on their labels, one seller offered injection guidance, and others touted the potential health and weight-loss benefits of their products. "It's clear that they're advertising for human use, but they're trying to skirt the rules," Mackey says.

Websites like the ones Mackey ordered from aren't hard to find — anything but. "Once you start looking, they find you," says White, the University of Connecticut pharmacist. Just Googling how to buy these drugs without a prescription brought up ads on his and his colleagues' Facebook and Instagram feeds.

Of 38 websites that sold GLP-1 drugs "for research purposes," only four asked buyers to check a box stating that they were a researcher, White's team reported in the *Annals of Pharmacotherapy* last September. And none of the 38 sites verified that buyers were actual researchers. Some of the companies White and colleagues investigated display customer testimonials on their websites or social media ads trumpeting how well the products work for weight management or suggesting they could be used by humans for non-research purposes.

Selling these drugs under the guise of research is a huge loophole "that the FDA really needs to fill," White says.

The FDA has already issued warning letters to several online vendors. After a December warning to Summit Research Peptides, the company still sells tirzepatide and semaglutide peptides but no longer includes health claims on its website. And US Chem Labs, which the FDA warned in February 2024, removed language from its website extolling their products' weight-loss powers, though its product pages for semaglutide still include information about therapeutic uses.

For Melanie, buying from peptide-selling websites like these seems like a workable option. She's not worried about measuring out the water or mixing the drug. Though she's not at that point, yet. Her current supply of compounded tirzepatide will take her almost to September. She's stretching the time between doses, injecting herself every week and a half or so. Melanie has considered going off the meds completely, but she's not sure how her body would respond.

Melanie is not flippant about where her drugs come from, nor is she careless with her medical decisions. She's a thoughtful person who takes her health seriously. It's just that, for her, the risk of not having tirzepatide is greater than the risk of buying it from an unvetted source.

"I can't go back to feeling the way I was feeling for all those decades — because I got a taste of feeling healthy now," she says. "I can't go back." ✖


REIMAGINING
SPINOSAURUS

The blockbuster notion of a swimming dinosaur is fueling scientific debate and movie magic

BY CAROLYN GRAMLING

ILLUSTRATION BY DAVIDE BONADONNA

SCENE: A small patrol boat cruises through the water, just offshore of an island somewhere in the Caribbean. Cue the pounding drums, movie-trailer speak for danger approaching.

ENTER: *Spinosaurus*. Three large spiny sails slice through the cerulean sea and begin to circle the boat. The water roils.

"What the hell are those?" a passenger asks with trepidation.

Cut to: Another passenger clinging precariously to the rigging as the boat lists. Suddenly, one of the spiny-sailed terrors surges from the ocean, jaws snapping.

That scene from the trailer for *Jurassic World Rebirth*, set to appear in theaters this summer, brings the controversial dinosaur back to the *Jurassic Park* franchise. During its previous cameo — in *Jurassic Park III*, released in 2001 — *Spinosaurus* chased the movie's heroes through the jungle.

But this time, based on a recent wave of scientific evidence, *Spinosaurus* gets to swim.

The concept of a swimming dinosaur is a game changer to paleontologists. The Age of Dinosaurs lasted from about 245 million years ago to 66 million years ago, or most of the Mesozoic Era. That's when dinosaurs dominated Earth, stomping and grazing and scampering across every continent, including Antarctica. There are around 700 known species of extinct dinosaur (excluding birds). And every one of them was a landlubber. The seas, the rivers — those were the domains of other creatures.

That changed in the last decade, when a group of paleontologists proposed that *Spinosaurus*' anatomical peculiarities make the most sense when you look at them through a watery lens. This unusual dinosaur, they argued, lived its life mostly submerged.

It's a hypothesis that remains highly controversial, but there's no doubt it has fueled ongoing research, along with popular interest in this quirky creature.

Spinosaurus didn't need to be a swimmer to stand out from other dinosaurs. It was a striking animal, the kind of fierce-looking, sharp-toothed predator that draws large museum crowds. To begin with, it was huge. At 15 meters long, it is

LOST FOSSILS

These stunningly detailed sketches are the only record of the original *Spinosaurus* fossils, which were destroyed when Allied forces bombed Munich during World War II.

E. STROMER

the longest predatory dinosaur ever found, with a body bigger than a *Tyrannosaurus rex*. It had a narrow, crocodile-like snout, a great big sail on its back that was about as tall as an adult human and a long, flat, paddlelike tail.

"It's bizarre looking, even by dinosaur standards," says Thomas Holtz, a vertebrate paleontologist at the University of Maryland in College Park. It looked absolutely nothing like *T. rex* or *Velociraptor* or other familiar predatory dinosaurs. Even among its closest relatives, collectively called spinosaurids, *Spinosaurus* was ... kind of extra.

"The proportions — what we know of them — are weird, even for a spinosaurid. It's not quite like any of the others," Holtz says. "It's not the sort of dinosaur most people are used to."

A swimming *Spinosaurus*, like the version that's going to be on-screen a lot this year, would be a blockbuster discovery — if it could be confirmed.

READING THE BONES

Any attempt to reimagine an extinct creature's habitat and lifestyle must begin with the bones. That's a problem, because "unlike other well-known carnivorous dinosaurs, we do not yet have a single good *Spinosaurus* skeleton," Holtz says.

The first *Spinosaurus* fossils were found in 1912 in the Bahariya Oasis of western Egypt. It was just a partial skeleton — a lower jaw, some croclike teeth and a handful of vertebrae bearing spines up to 2 meters tall. The fossils were so distinctive that German paleontologist Ernst Stromer determined that they must belong to a newfound creature. He named it *Spinosaurus aegyptiacus*, which to date remains the only agreed-upon species in the *Spinosaurus* genus.

For decades, those fossils, installed at a museum in Munich, were the only remnants of *Spinosaurus*. In 1944, during World War II, Allied forces bombed the city, destroying much of the museum and the fossils along with it.

Fortunately for future paleontologists and dinosaur enthusiasts, Stromer made detailed sketches of the bones. "Stromer did such beautiful illustrations, and often in multiple views, that we can reasonably reconstruct the size of *Spinosaurus*," says Paul Sereno, a vertebrate paleontologist at the University of Chicago.

Until about 2009, the sketches were nearly all that researchers had to go on. New *Spinosaurus* bones proved elusive. Fragmentary fossils — isolated teeth and bits of jaw and snout — that were ascribed to *Spinosaurus* turned up in Tunisia, Morocco and Niger between the 1970s and 2000s.

Species with similar croclike snouts but lacking such tall neural spines — long extensions of the vertebrae — were found and grouped into a larger spinosaurid family tree. One 2003 study even proposed that, given the difficulty of replicating the creature, Stromer's original *Spinosaurus* skeleton might have been a chimera, a mishmash of bones from other dinosaurs.

The extreme scarcity of bones might have something to do with the fact that *Spinosaurus* lived in a part of the world that now, some 95 million years later, is the Sahara, says Nizar Ibrahim, a vertebrate paleontologist at the University of Portsmouth in England.

Paleontologists returned to the Bahariya Oasis again and again, searching in vain for more evidence. Then, Ibrahim says, he was visiting a museum in Milan in 2008 and spied a set of recently acquired jawbones that he recognized as belonging to *Spinosaurus*. The bones, he learned, had been purchased from a Moroccan freelance fossil hunter. Ibrahim

A chance encounter with a fossil hunter in a bazaar led paleontologists (Diego Mattarelli, shown) to the Kem Kem beds of Morocco, where they unearthed an exciting trove of *Spinosaurus* fossils.

was determined to track this man down — although he knew little of him aside from the fact that he was mustachioed.

Against the odds, Ibrahim spotted the dealer in a bazaar in Morocco and persuaded the man to lead him to the remote escarpment in the country's Kem Kem region where the bones had been found.

It was a site deep in the desert, near the border with Algeria. Ibrahim followed the fossil hunter's puttering motorcycle "up these very steep slopes, up again and down again," he says. Hours passed, gas began running low and he wondered if they'd be able to get back out again.

But it was well worth the trip. The Kem Kem beds turned out to harbor a wealth of fossils that collectively revealed fresh surprises about *Spinosaurus*.

THE LIFE AQUATIC

Ibrahim and colleagues described their analyses of the newfound *Spinosaurus* bones in a 2014 study in *Science*. New *Spinosaurus* material was exciting enough after years of scant findings. But the real headline-grabber was the team's suggestion that the creature might have been largely aquatic.

Water was almost certainly nearby. Today's arid, windswept Sahara was much wetter in the past. Around 100 million years ago, Earth's average sea level was about 200 meters higher than it is today, giving rise to vast inland seas and waterways. North America was split in two by the Western Interior Seaway, extending from Mexico to Canada. Across the Atlantic Ocean, western Africa was divided by the Trans-Saharan Seaway, which covered much of Algeria, Mali and Niger.

Chemical analyses of previously discovered teeth had already suggested that *Spinosaurus* ate a lot of fish. Ibrahim and his team outlined various lines of new evidence that they said pointed to a primarily aquatic lifestyle. *Spinosaurus*' limb bones were dense, like the bones of penguins or manatees, animals that evolved to become water denizens. Such dense bones help those animals control their buoyancy.

Spinosaurus also had smaller hip bones than other large predatory dinosaurs, along with short, muscular hind limbs (at the time, no forelimbs had yet been found or described). These features suggested that it wasn't actually bipedal, like other carnivorous dinosaurs, but used all four limbs for locomotion, as might be needed in the water.

Other possible aquatic adaptations included its cone-shaped teeth, which would have been adept at snagging slippery fish, and the position of its nostrils, well back from the tip of the snout, which could have helped *Spinosaurus* breathe easy while swimming.

Over the next few years, Ibrahim went back again and again to the Kem Kem site. In 2020, he announced another headline-grabbing find: a nearly complete tail. Staying on-brand, it was a very weird tail, nearly the same length as the creature's body, with its own set of tall spines forming a tail fin.

And to Ibrahim and colleagues, that tail helped flesh out the picture they were building of a dinosaur that was adapted to spend its time in the water. The tail was ideal for water propulsion, they reported in a 2020 study in *Nature*. Surprisingly flexible, it allowed for a wide range of movement, such as a sideways swinging motion.

A robotic version of the tail, tested in a water tank, outperformed simulated tails of other dinosaurs when it came to propulsion and was close to the performance of the tails of semiaquatic swimmers such as crocodiles. *Spinosaurus*, the team concluded, used its tail to slice powerfully through the water, actively swimming to pursue its prey. It was, in short, a water monster rather than a land terror.

Artistic sketches of this version of *Spinosaurus* leaned even more heavily into the idea of a watery lifestyle. The dinosaur was depicted chasing prey underwater, jaws snatching, legs paddling, long tail powerfully slashing sideways to propel it forward. The public snapped up this version of *Spinosaurus*: It was compelling and fun and dynamic.

But to some paleontologists, this vision went a bit too far.

WATERY WHIPLASH

The tail paper was too much for Holtz and vertebrate paleontologist David Hone of Queen Mary University of London. The pair penned a swift response to it in 2021. The

GABRIELE BINDELLINI

evidence was compelling but far from conclusive, they wrote in *Palaeontologia Electronica*. Sure, *Spinosaurus* may have been semi-aquatic, living near and hunting in the water, but there simply isn't enough evidence that *Spinosaurus* would have been capable of full-on swimming or underwater prey pursuit.

Instead, the pair proposed that the dinosaur was more like a heron than a crocodile, wading in the water and fishing from the shoreline or from the shallows. As for the tall sail and the paddle-shaped tail, those weren't so much adaptations for swimming as flamboyant displays for mating or other social behaviors, Holtz and Hone argued.

Sereno was also skeptical that this dinosaur could swim. In a separate study, he and colleagues reexamined *Spinosaurus*' buoyancy using skeletal and flesh models based on the fossils and interpolated muscles. Dense bones in and of themselves aren't necessarily indicative that an animal can swim. Hippos have dense bones too, but they walk on riverbeds or lake bottoms. At any rate, Sereno says, his team's examination of *Spinosaurus*' bones suggested they weren't actually as dense as thought.

"We wrote a long rebuttal," he says. The bones are solid, yes, but also contain significant air pockets. Dense as the hind limbs might have been, they were relatively small, reducing their effectiveness as ballast or buoyancy control. The models, Sereno's team reported in 2022 in *eLife*, showed an animal that walked on two legs on land, was unstable and slow in the water and was too buoyant to be able to dive.

The debate rages in part because there's both science and art in extrapolating from bits of bone to an animal's life — how it moved, how it ate, how it interacted with other animals.

Without one single complete skeleton, every time a new bit of *Spinosaurus* turns up, there's a frenzy as people scramble to reimagine what the whole dinosaur might have looked like or how it might have behaved.

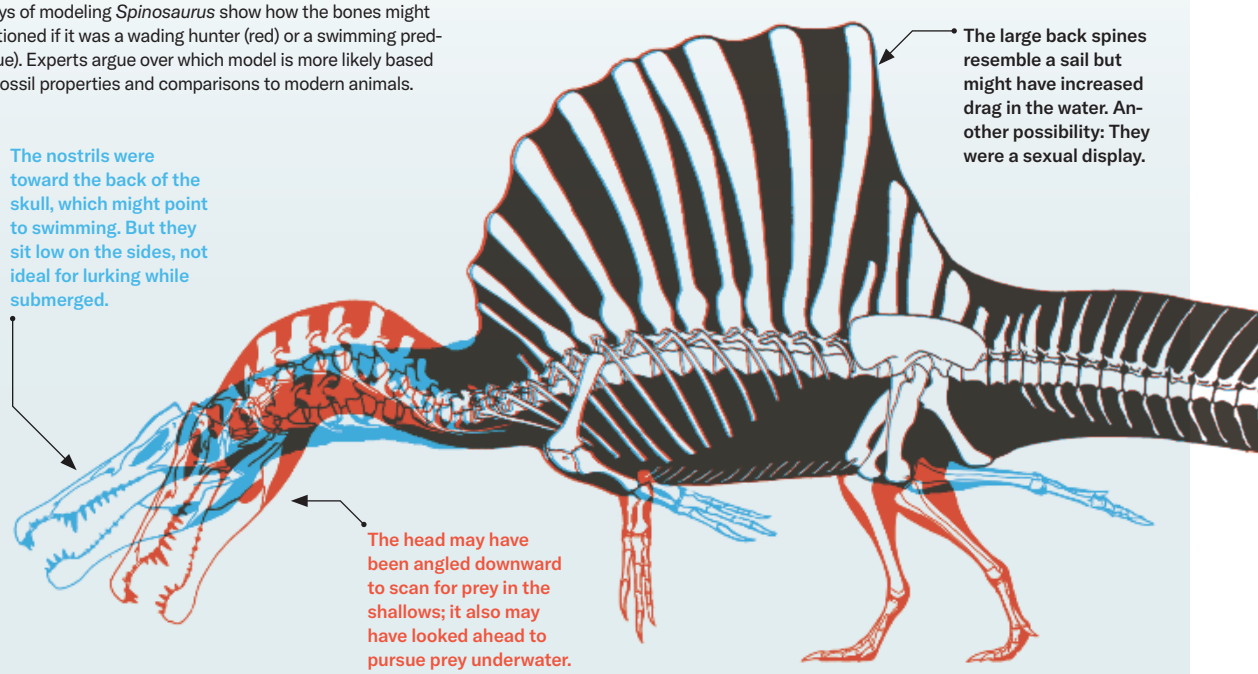
"In dino fandom, that's been a running gag over the last 11 years," Holtz says. Honey, wake up, new *Spinosaurus* fossils just dropped! "What radical changes of anatomy will there be this time?"

Any attempts to reconstruct how *Spinosaurus* moved and lived, including whether it swam, are going to run up against uncertainties about the missing bits of soft tissue — the volume of fat, muscles and so forth — that help researchers reconstruct accurate body mass. That is compounded by the lack of a complete skeleton that could put it all together, showing how all the different bodily components fit to create a whole animal.

And the utter weirdness of *Spinosaurus* means that there really aren't any obvious living analogs to help things along. Researchers have compared its various body parts

SKELETAL SMACKDOWN

Two ways of modeling *Spinosaurus* show how the bones might be positioned if it was a wading hunter (red) or a swimming predator (blue). Experts argue over which model is more likely based on the fossil properties and comparisons to modern animals.



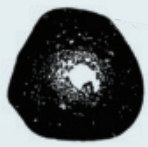
D.W.E. HONE AND T.R. HOLTZ/*PALAEONTOLOGIA ELECTRONICA* 2021, ADAPTED BY B. PRICE

SINK OR SWIM?

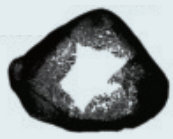
One clue to underwater hunting behavior: dense bones. Viewed in cross section, *Spinosaurus* femur bones appear denser than those of other dinosaurs and modern animals.

Spinosaurus
Very dense

Baryonyx
Denser than most dinos



Alligator
Semiaquatic swimmer



Tyrannosaurus
Spongy to help bear weight

Extinct penguin
Underwater diver

Puffin
Flier, underwater diver

Swan
Flier, surface water hunter

and functions with everything from crocodiles to herons to newts to eels, but none are a solid match.

"It is an animal that's so different from anything alive today, and that's a wonderful thing," Ibrahim says. "If extinct dinosaurs were simply replicating living animals, I wouldn't be a paleontologist."

For example, "how many muscles do you pack on a *Spinosaurus* tail?" he asks. "We can go feature by feature: Yes, it kind of looks like it could be used this way, maybe it could be this, maybe it could be that. With *Spinosaurus*, we have got a paddle-like tail, we have lots of aquatic features. And yet someone might publish a paper and say maybe the tail was used to play Ping-Pong. Can I disprove that? No. With extinct animals, people can make all sorts of claims that they can never prove."

Ibrahim sees the debate on just how aquatic *Spinosaurus* was as, to a degree, hair-splitting. "It's semantics," Ibrahim says. "What do people mean when they say semiaquatic? How do we define a polar bear versus a seal?" Dolphins, marine iguanas, seals — all have varying degrees of adaptations to spending time in the water. The bottom line, he says, is that *Spinosaurus* "is an animal with lots and lots of aquatic adaptations."

OFFBEAT FAMILY

There is one other line of research that might help illuminate *Spinosaurus*: studying its extinct family members.

As *Tyrannosaurus rex* is to tyrannosaurids, so *Spinosaurus* is to the spinosaurids. It's the one you think of when you picture this group of dinosaurs. It's bigger, stranger, more mysterious than its cousins. Like *T. rex*, it's just a little bit more.

Spinosaurids were theropods, that fierce, charismatic branch of the dinosaur family tree that includes other sharp-tooths like tyrannosaurs, allosaurs and velociraptors. There are about a dozen or more different types of spinosaurids, including *Spinosaurus*, *Suchomimus*, *Baryonyx* and the aptly named *Irritator*, so dubbed because the dinosaur's only known skull was doctored up by fossil poachers to make the snout longer, annoying the scientists trying to study it.

This whole family of dinos is an enigmatic bunch, says Jingmai O'Connor, a vertebrate paleontologist at the Field Museum in Chicago. "There's a lot of things that we don't know about this group."

Spinosaurus' relatives also seem to be extraordinarily unlucky when it comes to preservation. For example, the only known fossils of the spinosaurid *Oxalaia quilombensis*, found at the edge of the Amazon, were destroyed in a 2018 fire at the National Museum of Brazil in Rio de Janeiro.

What we do know is that all spinosaurids showed some semiaquatic adaptations. The other spinosaurids have been found all around the globe, except in North America. Like *Spinosaurus*, they all had long, narrow, crocodilian skulls, with nostrils positioned well back on their heads — farther back than other theropods — and a bony crest near the middle of the skull. Many, but not all, spinosaurids also had a distinct feature that gave the group their name: a row of elongated neural spines along the back, sketching out to form a sail — though none had one as tall as *Spinosaurus*'.

Then there are the teeth: conical and straight, without obvious

FABBRI *ET AL*

serrations, designed for snatching food rather than sawing through it. "They're an unusual group of dinosaurs because they're the only group of dinosaurs that seems to be specialized to primarily eat fish," O'Connor says.

In the absence of other options, researchers have used these close relatives, particularly *Suchomimus* and *Baryonyx*, to try to better understand *Spinosaurus*' ecology and behavior. Vertebrate paleontologist María Ciudad-Real of the National University of Distance Education in Madrid and colleagues created a brain cast for *Spinosaurus* with some missing parts of the cranial cavity filled in by *Suchomimus* skull material. Compared with other dinosaurs living in the same area at the time, *Spinosaurus* had reduced olfactory bulbs but larger eye sockets, possibly supporting an aquatic lifestyle. Moreover, *Spinosaurus* appeared to incline its head downward like a heron or other wading bird would as it scans the water for food, but not at all like a crocodile would, Ciudad-Real reported in 2023 at the annual meeting of the Society for Vertebrate Paleontology.

Tooth analyses also seem to support the idea that the dinosaur was not particularly croclike. Both *Spinosaurus* and *Baryonyx* had relatively skinny teeth and jaws that weren't particularly powerful, and most of *Spinosaurus*' crushing bite force was toward the back of the jaws, according to Evan Johnson-Ransom, a paleontologist at the University of Chicago who presented his team's analysis at the 2023 paleontology meeting. That suggests, he said, that crocodiles aren't a great analog for spinosaurids in general.

Analyzing the skull alone isn't enough to interpret feeding behavior. Feeding is a whole-body effort: skull, neck, hind limbs, Sereno says. "If it's a heron, it should have a skull, neck and hind limbs that allow it to be a heron." So he and colleagues measured these different skeletal features for *Spinosaurus* and *Suchomimus* and plotted the measurements, along with similar data for other nonbird dinosaurs, modern reptiles including crocodiles, and modern birds of prey.

That analysis revealed clusters of anatomy and feeding behaviors among the different groups, Sereno and colleagues report in a study to appear in *PLOS ONE*. Both spinosaurids plotted right alongside long-necked, semiaquatic birds like herons.

Taken together, these lines of evidence suggest that spinosaurids were, perhaps, spending a lot of time near the water, but they were waders, Sereno says. It may be that the group was becoming more and more aquatic over time—but they never quite made it to swimming.

"*Spinosaurus* was the glory, the capstone of this group," he adds. "It's the farthest it's gone in this direction." But as for swimming, "I just don't think it's gone that far."

ENDURING MYSTERY

Ask any paleontologist what's needed to better understand an extinct animal, and they'll all tell you the same thing: more bones.

For Ibrahim, part of the appeal of *Spinosaurus* is its enduring mystery. It has no close living analog to make things easier, and the available fossils are just bits and pieces that create a tantalizing puzzle, with no picture on the box cover to illuminate what it should look like.

> "The thrill of working on *Spinosaurus* is discovering all these new things."
>
> **—Nizar Ibrahim**

"The thrill of working on *Spinosaurus* is discovering all these new things," Ibrahim says. "You go into this to see where the evidence leads you."

His repeated voyages to Morocco's Kem Kem beds continue to turn up treasures, comprising hundreds of new bones that he and colleagues are working to put together into a whole. The puzzle-box cover may be elusive, but he is determined. "We can't discard anything," Ibrahim says. "Even the smallest fragment can actually be the missing piece."

Additional researchers are also still on the hunt, including Sereno and others who are less convinced about a swimming *Spinosaurus*.

Meanwhile, in popular imagination, *Spinosaurus*' star continues to rise, fueled by its ongoing mystique. In addition to the *Jurassic World* movie, Ibrahim notes that *Spinosaurus* is getting its own dedicated episode in the BBC's upcoming nature documentary *Walking With Dinosaurs 2*. The new series, whose release date hasn't yet been announced, is a sequel to the 1999 miniseries, which combined computer-generated imagery with live-action footage to simulate the lives and times of dinosaurs.

The follow-up series was, in part, built around the desire to feature this oddball animal, says Ibrahim, who served as scientific consultant for the *Spinosaurus* episode. It was the first dinosaur the documentary crew chose to include in the new series, Ibrahim says.

"*Spinosaurus* is very much the superstar." ✖


P.PAJUMBO

SMART HUNTERS

Coordinated ambushes of prey attest to the intellectual prowess of our Stone Age ancestors

BY BRUCE BOWER | ILLUSTRATION BY DAVID PALUMBO

Communal hunting of horses in Europe 300,000 years ago required sophisticated planning and coordination.

↑ Wooden spears found at Schöningen in northern Germany are among the oldest spears in the archaeological record.

On a bright, late-summer day in north-central Europe around 300,000 years ago, a team of perhaps a couple dozen hunters got into their assigned positions for a big kill.

Little did they know that remnants of this lethal event would someday contribute to a scientific rethink about the social and intellectual complexity of Stone Age life.

Some of the hunters ascended a ridge where they gazed across a vast, marshy grassland below. Trees dotted the landscape and bordered a braided stream leading to a nearby lake.

From their elevated perch, these close evolutionary relatives of people today watched a herd of wild horses traipse across the grassy floodplain, heading for the lake. Descending slowly from the ridge, the hunters closed in from behind on their prey — a family consisting of a stallion, several mares and two of their young.

Sensing a distant threat, the mares picked up speed and continued straight ahead. The rest of the family followed behind in a single line, a behavior the hunters had observed many times before. Sentries positioned at key spots guided the queue of fleeing horses to a predetermined ambush spot.

As the animals neared the lakeshore, hunters armed with wooden spears leaped out from hiding places in clumps of tall reeds and sedges. Uneven, sloshy lakeshore soil slowed the four-legged targets and kept them off-balance. Other hunters blocked escape routes. A frenzy of wooden-spear throwing and thrusting dispatched the entire horse family.

The hunting party then ate or carried away only what was needed. A few months later, hunters returned to ambush another horse family.

This unusually detailed reconstruction of an ancient communal hunt and its aftermath comes from a new analysis of an archaeological site in Germany called Schöningen. The latest findings at the site, which has been excavated over the last 30 years, fuel a growing conviction that a flair for planning and collaboration comparable to that of people today arose far earlier in our evolution than traditionally thought.

"We keep finding evidence of 'modern human behavior' in *Homo* species other than *Homo sapiens*, especially [Neandertals]," says Jarod Hutson, a zooarchaeologist at the MONREPOS Archaeological Research Center and Museum for Human Behavioral Evolution in Neuwied, Germany.

Bucking archaeological orthodoxy

Archaeologists have traditionally held that an ability to plan and organize communal hunts, along with other aspects of so-called modern human behavior, emerged only about 50,000 years ago. Some researchers suspect still unspecified brain-related genetic changes at that time rapidly transformed thinking abilities in *H. sapiens*.

But that sudden mental and behavioral revolution relatively late in our species's evolution may never have happened.

A growing number of reports have concluded that many hallmarks of modern behavior, including artwork and other symbolic acts, originated even earlier, during the Middle Paleolithic, a

MINKUSIMAGES, CHRISTA FUCHS, MATTHIAS VOGEL, © NLD

period that started at least 300,000 years ago and ran until at least 50,000 years ago. For instance, a South African cave has yielded a 73,000-year-old crosshatched line drawing etched on a rock, 75,600-year-old shell beads and 100,000-year-old remnants of pigment paint. Even earlier, Neandertals built ring-shaped structures out of stalagmites deep inside a French cave around 176,500 years ago. Neandertals may also have painted on cave walls at least 66,700 years ago.

Evidence of ancient communal hunting at Schöningen and elsewhere corrals further clues to the behavioral sophistication of ancient humans and our evolutionary relatives.

In their new study, published last year in the *Journal of Human Evolution*, Hutson and colleagues analyzed animal bones, ecological data, hunting weapons and butchery tools at Schöningen. Some parts of the hunt and the planning behind it undoubtedly eluded investigators. That's understandable — the hunters lived 12,000 generations ago in a poorly understood culture.

No *Homo* fossils have turned up at the German site, leaving Hutson unsure about the hunters' evolutionary identity. They might have been direct ancestors of Neandertals or common ancestors of Neandertals and *H. sapiens*. Some researchers assign European and African *Homo* fossils from about 700,000 to 200,000 years ago to a species called *Homo heidelbergensis*.

Whatever their species, Schöningen's horse hunters undermine a popular view that Stone Age folks eked out a living gathering plant foods and scavenging animal carcasses abandoned by large predators. In that scenario, one or a few hunters from small, mobile groups occasionally secured a meaty bonus.

Not so at Schöningen. Communal hunts there included all able-bodied men, women and children, Hutson suspects. That's what's been documented among recent and historical hunter-gatherers. Everyone could play a role in tracking horses and driving them toward ambush sites, even if only the physically strongest individuals speared trapped animals to death.

"Schöningen shows our Middle Paleolithic ancestors already had great knowledge of their environments, used the immediate topography to their advantage and had a sophisticated understanding of animal behavior, making them successful communal hunters over and over again," says Ashley Lemke, an archaeologist at the University of Wisconsin–Milwaukee. She

Since the 1990s, scientists at Schöningen have recovered more than 1,000 stone artifacts and thousands of horse fossils. ↓

JULIAN STRATENSCHULTE/PICTURE ALLIANCE VIA GETTY IMAGES

studies structures that ancient human groups built to assist in driving and trapping prey at other sites.

Family ambushes

Preserved wooden spears found at Schöningen, which now number 10, have attracted worldwide attention. Coal mining operations led to the initial discovery of three spears, as well as stone tools and animal bones, in the 1990s.

Spears at the German site are among the oldest known such weapons. A long piece of wood with one end shaped into a point, discovered in England in 1911 and known as the Clacton spear, dates to roughly 400,000 years ago, about 100,000 years earlier than the Schöningen finds.

In addition to wooden spears, excavations at Schöningen have uncovered six double-pointed sticks, which hunters may have used as spears or daggers. Partially preserved wooden implements displaying intentional splits near pointed or rounded ends have polished edges and other wear consistent with hide preparation.

Around 1,500 stone artifacts unearthed at Schöningen include sharp-edged flakes suitable for cutting apart carcasses. Hutson's group suspects hunters employed a variety of bone tools to sharpen stone flakes and break bones for marrow.

Researchers have found no remnants of fireplaces or burned bones at the site. Hunters might have eaten what they could without cooking it on the lakeshore before carrying equine edibles back to a camp. But it remains unknown whether these ancient folks could light controlled fires.

Hutson's team delved into what happened before, during and after Schöningen's ancient horse hunts. The investigators focused on about 9,000 excavated bones, including lower jaws retaining teeth, that belonged to wild horses. Butchery marks on smaller numbers of bones from red deer, bison and wild cattle indicated that hunting of those creatures, either individually or in herds, occasionally occurred.

Among the horse specimens, which represented at least 54 individual animals, the researchers found several families. Tooth size and the extent of tooth wear pegged 22 horses as juveniles up to 2 years old, 29 as adults mostly between 5 and 6 years old, and three as seniors older than 15.

Tellingly, few signs of 3- to 5-year-old adolescent horses appear at Schöningen. Adolescent male horses leave their families to form bachelor groups or travel solo until they reach full maturity. Rather than queuing up family-style in response to threats, bachelor groups tend to disperse haphazardly. Communal hunting of horse families would leave behind limited evidence of slaughtered adolescents, as Hutson and colleagues found.

Given a family-friendly age profile for the Schöningen horses, it's reasonable to conclude that hunting teams exploited the animals' predictable behavior in family groups to drive them into lakeshore ambushes, the investigators say.

Clusters of butchery and scraping marks, as well as intentional bone breaks to remove marrow, appear mainly on remains of prime-age adults. Hunters limited the amount of protein-rich lean meat consumed at kill sites, the researchers suspect. Eating too much protein can cause weight loss, ill health and death.

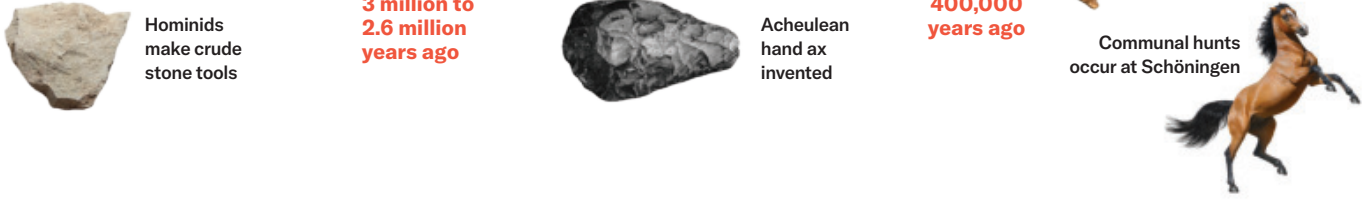
Tool marks on horse ribs indicate that hunters cut through the chest to remove and eat internal organs, such as the vitamin C–containing liver. Fat crucial to a balanced diet may have been removed from parts of horses that do not preserve butchery marks, such as the neck and abdomen.

Despite attracting little interest from hungry hunters at kill sites, young horses at Schöningen provided crucial clues to how often hunts

FROM LEFT: HARMAND/MPK/WTAP; T.W. PLUMMER *ET AL/SCIENCE 2023; VICTORIA COUNTY HISTORY OF KENT*/WIKIMEDIA COMMONS; GENI/WIKIMEDIA COMMONS (CC BY-SA 4.0); ABRAMOVA_KSENIYA/ISTOCK/GETTY IMAGES PLUS

THE HISTORY OF HUNTING

Some scientists argue early hominids wielded stone tools to scavenge meat before true hunting began about 2 million years ago, close to the advent of the Acheulean hand ax. Hunting tactics grew increasingly sophisticated after that.



occurred. Based on the timing of modern horse births in late spring, juvenile horse deaths in the ancient sample occurred in every season but peaked in late summer and early autumn.

"This evidence implies that the Schöningen [hominids] were present at the lakeshore year-round, or nearly year-round," Hutson says. Hunting parties probably ensnared horse families over several consecutive generations, he adds.

Talking teamwork

Other ancient Eurasian sites contain signs of communal hunting that align with a picture of intricately planned and executed horse ambushes at Schöningen.

Numerous bones of butchered fallow deer and other relatively large prey that accumulated along an ancient lakeshore in Israel raise the possibility of communal hunts even before the Middle Paleolithic. Around 780,000 years ago, hominids at Gesher Benot Ya'aqov regularly hunted herd-forming animals and mainly butchered adults in their prime.

In northern Spain's Atapuerca Mountains, Neandertal ancestors conducted communal bison hunts around 400,000 years ago, researchers reported in 2017 in the *Journal of Human Evolution*. In several organized events, hunting groups drove bison herds to the edge of an underground cave called Gran Dolina where the animals plunged to their deaths or were finished off on the cave floor by individuals wielding weapons, according to archaeologist Antonio Rodríguez-Hidalgo of the Catalan Institute of Human Paleoecology and Social Evolution in Tarragona, Spain, and colleagues.

Their analysis of at least 60 bison identified from over 22,500 Gran Dolina fossils detected young, prime-age and old individuals consistent with predation on entire herds. Tooth wear placed the deaths of young bison mostly in the late spring and early summer and again in early fall, suggesting at least two communal hunts.

Rodríguez-Hidalgo suspects that 50 to 100 individuals participated in some aspect of Gran Dolina mass hunts, whether driving bison herds to their fatal nosedives, butchering carcasses or carrying the considerable yield to nearby camps.

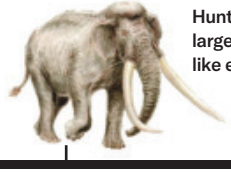
Communal hunting requires larger groups and far more planning, anticipation and teamwork by individuals with different roles than the cooperative hunts of animals such as wolves, orcas and chimpanzees, Rodríguez-Hidalgo says.

The ability to speak a language and understand that words symbolize objects and actions made communal hunts possible, he contends. When language originated has long inspired heated debates, but scholars have often assumed that spoken tongues developed only in *H. sapiens*.

An ability to think symbolically lies at the root of supernatural and religious beliefs as well, Rodríguez-Hidalgo says. "Does this mean the [hominids] of Gran Dolina or Schöningen believed in God or the Great Spirit?" he asks. "No, in my opinion, but they were no longer wolf packs hunting by instinct."

Increasing evidence, including those ring-shaped structures and wall art inside European caves, suggests that Neandertals held symbolic beliefs of some kind. In line with those clues, excavations at Middle Paleolithic sites dating to between about 130,000 and 50,000 years ago indicate that Neandertals formed teams that effectively hunted a range of herd animals.

At five European sites, our close evolutionary relatives ambushed groups of bison, wild cattle, rhinos, horses and reindeer, according to work by archaeologist Mark White of Durham University in England and colleagues. Much like the Schöningen horse hunters, Neandertals



Hunters target large land animals like elephants

125,000 years ago

80,000 to 60,000 years ago

Bow and arrow in use

10,000 years ago

Hunters build structures to trap animals

2,600+ years ago

Hunters ride horses to stalk big game

Late 19th century

Firearms largely replace muscle-powered weapons

CONT.: BAPEROOKAMO/WIKIMEDIA COMMONS (CC BY-SA 4.0); FOCUS_ON_NATURE/ISTOCK/GETTY IMAGES PLUS; © MICHAL GRABOWSKI; OSAMA SHUKIR MUHAMMED AMIN FRCP(GLASG)/WIKIMEDIA COMMONS (CC BY-SA 4.0); ARTHURRH/WIKIMEDIA COMMONS (CC BY-SA 3.0)

slaughtered prey indiscriminately but preferred to eat prime-age adults. White's group dubbed Neandertals "excellent tacticians, casual executioners and discerning diners."

↑ Studying aspects of horse teeth revealed the sex and age of hunted horses and even the timing of hunts. The large canine tooth near the front of this lower left jaw (shown from two angles) indicates the horse was male.

Tactical advantages

Even presented with Schöningen's butchered bones, cutting tools and reconstructed marshy lake, archaeologists can only partially untangle how communal hunts played out hundreds of thousands of years ago. Although far from being Stone Age relics, modern hunter-gatherers and Indigenous groups can help fill in some blanks.

Throughout the world, nonindustrial societies have frequently used communal hunting tactics with great success, archaeologist Eugène Morin of Trent University in Peterborough, Canada, and colleagues reported last year in *Current Anthropology*.

Communal hunts in recent centuries included anywhere from two to several hundred people. In many recorded instances, some hunters drove prey to locations bounded by lakes or cliffs where others ambushed them, much like Neandertals and the ancient Schöningen horse hunters.

Hunters could conduct drives on foot, on horseback, in motor vehicles or by setting fires that forced prey toward ambush spots.

Some communal hunts trapped small prey such as rabbits in nets. In other cases, hunting communities built stone walls or fences that formed paths through which larger animals were driven into corrals. Human-made structures designed to trap animals may date to 10,000 years ago or earlier.

Morin's group analyzed 139 extensive written descriptions by explorers and ethnographers of communal and solo hunts dating from the 1600s to the 2000s. Most accounts concerned hunter-gatherers in North America, Africa, South America, Australia and Pacific Ocean islands.

Communal hunts were common until being largely replaced by hunters who relied on repeating rifles and dogs in the late 1800s, the researchers say. Compared with solo hunting, communal tactics produced much larger and more predictable yields of animal foods, they estimate. In open settings, horseback riding increased communal hunting ranges and the ability to divert herds.

Men, women, children and the elderly from different local communities joined forces in communal hunts studied by Morin's group. These gatherings also served social purposes, helping adults to find mates and make trade contacts.

Researchers currently cannot specify the size and makeup of ancient communal hunting groups or untangle how hunters socialized with one another, says archaeologist Lutz Kindler of the MONREPOS research facility. Kindler, who was not part of the new Schöningen study, coauthored a 2023 report describing evidence of straight-tusked elephant hunting and butchery by large groups of Neandertals at a site in Germany called Neumark-Nord.

"After a horse hunt, did the Schöningen people just sit down, slice meat, break bones and recharge their energy, or did they pat each other on the back, laugh and celebrate?" Kindler asks.

Ancient communal hunters certainly worked hard. Perhaps they played hard, too. ✖

ARITZA VILLALUENGA

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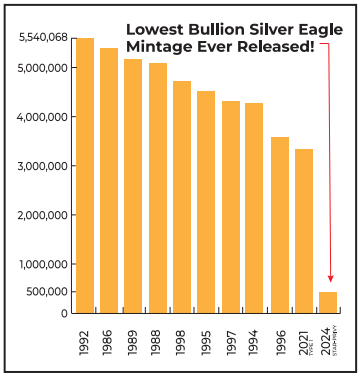

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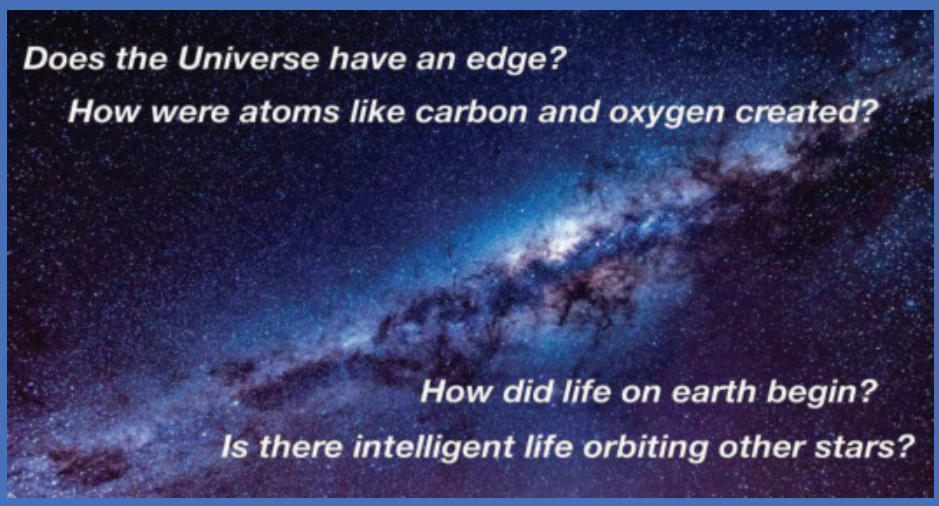

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VOL. 207 NO. 05 | MAY 2025

All about AI

● *Scientists are working on AI technology that has brain-inspired hardware, architecture or algorithms. Such neuromorphic AI could be nimbler, more efficient and more capable than traditional AI, freelance writer Kathryn Hulick reported in "Making AI think more like your brain."*

Hulick reported that mainstream computers, which currently run most AI, separate memory and processing. Some burgeoning neuromorphic technology, such as spiking neural networks, combine the two.

This concept reminded reader Gary Pokorny of an early experience with computers. "The first computer I used ... was an Apple IIe, in which I would insert one floppy disk to load word processing instructions, then take it out and insert a blank floppy to save my work, and back and forth while writing," Pokorny wrote. The personal analogy helped Pokorny "understand why mainstream AI requires huge resources for both memory and processing. I have a harder time grasping, but am fascinated by, the idea of spiking [neural networks combining both], hence more efficiently, and more like our brains."

Neuromorphic experts' work to streamline computing systems struck a nerve with reader Linda Ferrazzara. "All the while, I couldn't help thinking of how human brains develop, with an initial surfeit of neurons and connections that get gradually pared down as the brain is pruned into a more efficient configuration, from prebirth to adulthood."

Ferrazzara wondered if quantum computers could be adapted to neuromorphic computing systems.

Quantum computers perform powerful computations by leveraging quantum principles, such as superposition, the idea that subatomic particles can exist simultaneously in multiple states, and entanglement, a type of ethereal link between particles.

Quantum and neuromorphic computing are very different technologies, says Daniela Rus, a computer scientist at MIT. "I don't think you can directly adapt quantum computers into neuromorphic computers, but we might be able to use neuromorphic processes to control quantum computers," Rus says. What's more, "ideas from quantum mechanics may be useful to design new chips for neuromorphic computers."

"Ideas from quantum mechanics may be useful to design new chips for neuromorphic computers."

Quantum and neuromorphic computers could be used to perform different but complementary computations, says computer scientist Prasanna Date of Oak Ridge National Laboratory in Tennessee. "For example, quantum computers could be used to train spiking neural network models, which get deployed on a neuromorphic computer for energy-efficient, real-time machine learning computations."

March 2025

Corrections

✖ In the February feature "Holding back a glacier," the opening image was incorrectly identified as Thwaites Glacier. The image was actually of Pine Island Glacier.

In the March issue's "Have 5 years of COVID-19 readied us for what's next?" the last sentence of the second paragraph had a missing word. The sentence should have read: Nearly 17,000 people in the United States died of COVID-19 the last week of that year.

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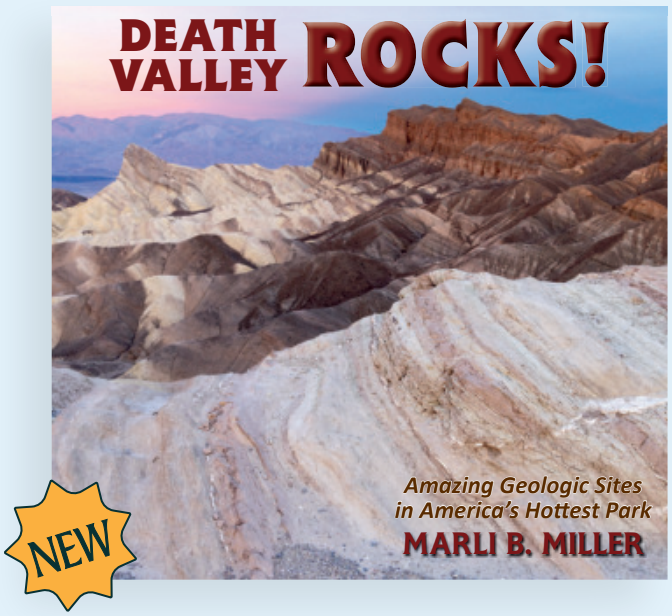

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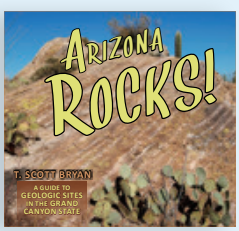

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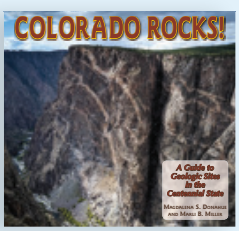

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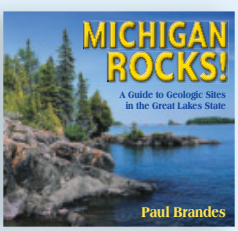

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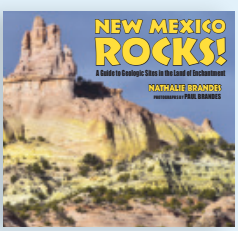

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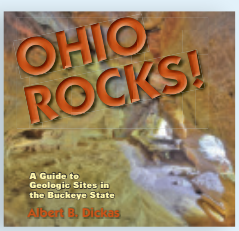

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VOL. 207 NO. 05 | MAY 2025

UNCOILING THE SURPRISING RELATIONSHIP BETWEEN SNAKES AND HUMANS

By Victoria Jaggard

SLITHER | *Stephen S. Hall*
Grand Central Publishing | $30

Snakes don't often get to be the protagonists. From the biblical tempter in the Garden of Eden to the eponymous snakes on a plane, your stereotypical serpent often gets cast as a villain — cunning, treacherous, cruel, deadly. But human views of snakes are full of contradictions. In mythology, snakes whispered secrets about the healing arts to the Greeks and established the concept of linear time in Mesoamerica. In the real world, they continue to inspire scientists in fields as diverse as pharmacology, reproductive biology and disaster relief.

Drawing from a rich vein of history, anthropology and cutting-edge biology, science writer Stephen S. Hall uncoils the complexity of snakes and humans' love-hate relationship with them in his new book, *Slither*. Each chapter explores a facet of snake biology — such as locomotion and the chemistry of venom — that shows why the limbless animals evoke fear and fascination in seemingly equal measure. Personal histories of snake researchers and enthusiasts, along with Hall's own field reporting, bring the science to life. Sidebars dubbed "Snake Road" offer a set of real roads as geographic examples of humans' and snakes' interconnection. One such road is Eastern Parkway in New York City, which leads to the Brooklyn Museum, the home of the Snakebite Papyrus. The ancient Egyptian medical handbook describes the dangerous snakes of the time, symptoms of their bites and suggested cures.

Crucially, Hall does not shy away from the very real danger of snakes. He describes the ruinous and often lethal effects of snakebites in sobering detail. He also flicks at the scientific theory that early primates evolved to rapidly detect motion because they needed to be wary of snakes. The implication is that humans are hardwired to be alarmed by the reptiles.

Hall balances this cautionary note with meticulously researched tales of historical and ongoing snake science and its benefits to humans. For example, the first ACE inhibitor, a class of drugs used to lower blood pressure, was derived from a South American pit viper. And studies of the sidewinder are helping engineers build snakelike robots that can wriggle into tight spaces to search for survivors after a disaster.

Humans are also taking a toll on snakes, from global habitat degradation to rattlesnake roundups in Texas. In a chapter about people who hunt Burmese pythons in the Florida Everglades, Hall asks readers to rethink the word *invasive*. After all, these Southeast Asian pythons did CONT. ON PAGE 79

Your stereotypical serpent often gets cast as a villain — cunning, treacherous, cruel, deadly. But human views of snakes are full of contradictions.

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Abstract

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CONT. FROM PAGE 77 not ask to become residents of the Sunshine State, and probably landed there due to the pet trade.

Hall's journalistic training is evident in his need to cite sources, sometimes to the narrative's detriment. Some passages can be so stuffed with names, affiliations and factual asides that readers may lose the plot at times. But Hall makes up for this with clear science, drama-filled anecdotes and deep pathos. It is the Year of the Snake, after all, and *Slither* makes sure these oft-maligned animals get a fair shake. ✖

SILICON VALLEY'S VISION OF THE FUTURE IS FLAWED—AND DANGEROUS

By Ashley Yeager

MORE EVERYTHING FOREVER | *Adam Becker*
Basic Books | $32

In the eyes of tech billionaires, our future is clear. We will be an ever-growing society living in outer space, our every need answered by superintelligent AIs. This vision may seem like science fiction. But around the world, a league of financial elites believes that such a transhumanistic future—one where technology enhances human capabilities and lets us surpass biological limitations—is inevitable.

Science journalist Adam Becker counters this fantasy in *More Everything Forever*. In a deeply researched and engaging narrative, Becker dives into AI's limitations to show that this vision of the future is not only unrealistic but also laden with racism, sexism and "endless capitalism of the most brutal sort."

Take AI hallucinations, inaccurate information produced by a chatbot. Large language models like ChatGPT often make these mistakes. And they will continue to do so, Becker writes, until an AI comes along that truly comprehends the connection between words and the concepts they represent. Some tech leaders argue that the solution is to just train AI on more data. But this thinking is flawed, Becker notes. Training these models on more and more internet content, which now includes the faulty content generated by AI chatbots themselves, could make some models spew nonsense. Such training could also exacerbate existing cultural biases within the tech, including hate speech, gender bias, racism and sexism.

More Everything Forever contends that tech billionaires' seductive visions of a sci-fi future divert our attention from the real challenges that plague humankind—global warming, massive inequality, potential nuclear war. These political and social problems can't be solved by technology, Becker argues. "There's no genie inside a computer" that will heal the world, he writes. "We must do it ourselves." ✖

Conversations with Maya

Maya Ajmera, President & CEO of the Society for Science and Executive Publisher of Science News, chatted with Anna-Katrina Shedletsky, Founder and CEO of Instrumental, a company that helps other companies optimize their manufacturing process. Shedletsky is an alumna of the 2004 Science Talent Search (STS) and the 2003 and 2004 International Science and Engineering Fair (ISEF), both programs of Society for Science.

HOW DID STS AND ISEF INFLUENCE YOU? In high school, I signed up for an independent science research class that met after school. I had a great teacher, who taught me a lot about science research. As an adult looking back, he taught me a lot about life too. I started competing with my work and learned I loved competition. ISEF and STS were part of that journey. It was through these experiences that I learned how to fail and to keep going anyway until I achieved success. I also found I liked taking a problem with no solution and inventing one. My research teacher taught me how to break a large problem down into small pieces. My project involved creating a computer model to investigate how contagious diseases spread. I simulated different parameters of populations and diseases to identify new ways to combat pandemics.

WHAT IMPACT DID COMPETING HAVE ON YOUR CAREER TRAJECTORY FROM ENGINEER TO ENTREPRENEUR TO EXECUTIVE? I started developing an incredibly important skill while doing science fairs: pitching and defending my work. Looking back, my entire career has involved pitching and defending my work. As an engineer at Apple, I had to justify and pitch what I was designing to people who had more experience and power than me. As an entrepreneur, I pitch our ideas to investors, pitch our vision to candidates so they want to work for us and pitch our products to prospective customers. Learning to build persuasive arguments about the merits of your work is important in business. And I got lots of practice in high school with science fairs.

AFTER GRADUATING FROM STANFORD WITH YOUR UNDERGRADUATE AND MASTER'S DEGREES IN 2009, YOU WORKED AS A PRODUCT DESIGN ENGINEER AT APPLE. WHAT WAS YOUR EXPERIENCE DEVELOPING LANDMARK PRODUCTS SUCH AS IPODS AND THE FIRST APPLE WATCH? Apple was an amazing place to grow up as an engineer. I was responsible for what I describe as "packing the suitcase." We received a shell for a new product and then it was our job to design and to fit all the parts inside. We also designed the assembly line process.

Apple product design engineers manage both design and process. We would travel to factories in Asia to see the ramifications of our design choices on the line. Sometimes our first ideas were not great, so we would iterate on them. Apple valued the customer's experience, so spending a bit more money to make a much better product was encouraged. We used the scientific method to experiment with different technologies, materials or designs to see which ones would give us the best ultimate performance or results. I loved it.

WHAT INSPIRED YOU TO FOUND INSTRUMENTAL? At Instrumental, we make software that enables engineers to find and fix issues on their manufacturing lines. We work on consumer

electronics, AI infrastructure such as servers and power systems, and defense electronics.

As an engineer at Apple, I learned that shipping a new product often came down to a lot of heroism. It became clear that individual engineers were making diving saves to ensure products were released on schedule. You can't patch hardware. It must be good going out the door. Apple is excellent at execution. They have figured out how to engineer a process and develop a team of people who can do those diving saves at the right time to get the product across the line.

That kind of heroism relies on luck, which isn't a strategy. It seemed like there was an opportunity to build something where we didn't have to rely on luck and instead, leverage data and smart algorithms to find the problems earlier.

YOU'VE DESCRIBED MANUFACTURING WASTE AS AN $8 TRILLION GLOBAL PROBLEM. HOW CAN ORGANIZATIONS AND SOCIETY AT LARGE SOLVE SUCH A DAUNTING CHALLENGE? Eight trillion dollars is probably an underestimate. The waste comes from inefficiencies in our ability to find and solve manufacturing problems. Instrumental is focused on electronics, but manufacturing is half of the gross world product. Identifying the problems that cause these inefficiencies early makes them much cheaper and easier to fix. Here is an example: It's very common for an electronics assembly line to run at a 95 percent yield. For every 100 units, five can't ship. Those five are called fallout, which usually becomes waste. Now think about the hundreds of parts that go into your laptop or phone – each one has an upstream supplier that has fallout too. Identifying the problems that cause the fallout is the first step to eliminating them. Eliminating the fallout eliminates the waste.

ARE YOU USING AI AT INSTRUMENTAL? The core of what we do is what is now known as AI. When I started the company 10 years ago, we couldn't call it AI because people didn't believe AI could work in the real world. Our AI identifies problems and inefficiencies.

THROUGHOUT YOUR CAREER, YOU'VE BEEN VERY PASSIONATE ABOUT ADVANCING GENDER EQUITY IN STEM FIELDS. FOR EXAMPLE, YOU FOUNDED THE WOMEN IN STEM MENTORSHIP PROGRAM. HOW WOULD YOU DESCRIBE THE IMPORTANCE OF THAT WORK? Although I experienced something close to gender parity in my mechanical engineering major at Stanford University, when I was interviewing for a job, I was surprised to find there were companies that had never even hired a female engineer. When I landed at Apple, there were two women in my group of 70 who reported up to the VP. It wasn't until a few years into my job that I started wondering why there were only two of us.

I'll tell you a story: When we started working on the Apple Watch, the team bought all the smartwatches on the market, and they all looked ridiculous on my fifth-percentile female wrist. I'm not saying that I am responsible for the fact that Apple has a small- and large-size watch, but I am saying that there is value in having a diversity of perspectives (and bodies) around when designing new products.

At Apple, I did not have female executive role models providing examples of how authentic female leaders should behave – which meant I had to stumble forward on my own. I believe it's important to help young women who are entering the industry find mentors and role models they can learn from.

WHAT ADVICE DO YOU HAVE FOR YOUNG PEOPLE JUST STARTING OUT IN HIGHER EDUCATION? Start with the mind-set of learning and exploring. Soak everything in, even stuff you didn't expect. Take that archaeology or dance class. You never know where you might learn something that could change what you do next.

AS A MEMBER OF THE SOCIETY FOR SCIENCE'S NATIONAL LEADERSHIP COUNCIL, YOU'RE WORKING TO ESTABLISH THE INAUGURAL ALUMNI SPECIAL AWARD COMMITTEE, WHICH WILL FUND, JUDGE AND AWARD A FINALIST AT REGENERON ISEF 2025. WHAT'S YOUR VISION FOR SUCH A COMMITTEE AND WHY DO IT? Two reasons. First, I've judged at ISEF for a decade and it's an incredibly rewarding experience. I leave every year feeling like humanity's going to be OK because of just how inspiring all the student finalists are. I wanted to create an opportunity for more alumni to have that experience. That's the altruistic reason. The second reason is to remind alumni that Society for Science has value and needs to exist in this world. Once you go through these programs, it can be easy to move on and not think about the Society again. But the Society needs you to remember it and to support it to ensure it can thrive for the next 100 years.

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Society for Science is a nonprofit organization best known for our award-winning journalism, world-class STEM competitions and suite of Outreach & Equity programming activities. For more than a century, our mission has been to promote the understanding and appreciation of science and the vital role it plays in human advancement: to inform, educate, and inspire.

COULD THE MAGIC OF MEMORY MANIPULATION BECOME REAL?

BY ANDREA TAMAYO

In the world of *Harry Potter*, memories can be manipulated with the flick of a wand. Albus Dumbledore reels wispy memories out of his head and puts them in a Pensieve. If he later dunks his head in that magical basin, he can see his past experiences with lifelike clarity. Hermione Granger, meanwhile, uses the spell "Obliviate" to remove herself from her parents' memories to protect them from the wizarding world.

In real life, memories are not storable liquids or files that can simply be deleted. Memories are made when a person has an experience that triggers electricity to course through connections between the brain's neurons. The more exposure to an experience someone has, the stronger the connections become. But they can also weaken over time, leading to forgetting.

The power to make someone perfectly remember or completely forget something is still mere fantasy. But some researchers have taken early steps to strengthen or weaken memory. That work could help people suffering from diseases like Alzheimer's or mental health conditions like PTSD.

Neuroscientist Robert Hampson is inspired by Dumbledore's Pensieve. "I love to see the idea of being able to pull a memory, store it, look at it, examine it," says Hampson, of Wake Forest University School of Medicine in Winston-Salem, N.C.

He and colleagues haven't found a way to store past experiences like leftovers in magical dishes. But they have found that applying electric zaps to the brain could help people form stronger memories.

The team recorded electrical activity in the hippocampus — a brain structure involved in memory — of nine people with epilepsy who had brain implants. As the volunteers took a picture-based memory test, the team documented neuron-firing patterns linked to seeing specific images.

Next, the group applied tiny electric zaps that mimicked those patterns to the hippocampus in eight other volunteers as they took the same memory test. Those participants' memories for images paired with the small jolts improved by 35 to 40 percent. Their memory did not improve for pictures not paired with zaps.

TIM MCDONAGH

In the future, brain implants might deliver tiny zaps to help boost memory in people with Alzheimer's or brain injuries, Hampson says.

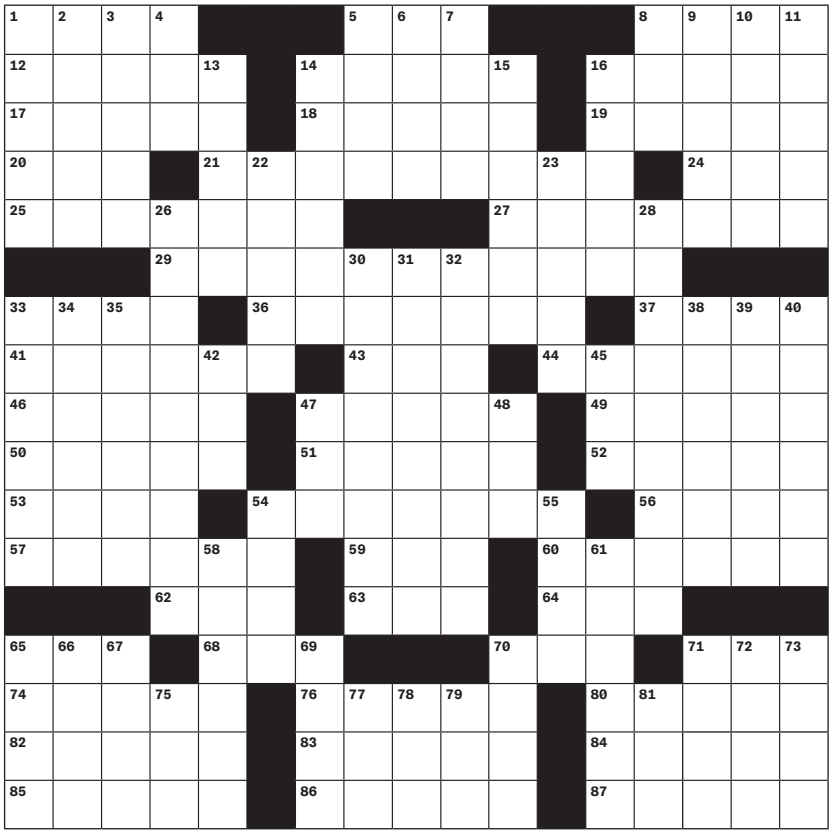
Other scientists are looking into whether it's possible to help people forget certain memories.

Experiences can change how neurons connect to each other. Changes in these connections encode, or store, the memory of the experience, many researchers think. But "you can interfere with that encoding," says neuroscientist Samuel Schacher of Columbia University.

His team studied neurons from mollusks called sea hares: Two sensory neurons each connected to the same motor neuron, which controls muscle movement. Each connection is moderated by a different form of a molecule called PKM. By stimulating these cells in lab dishes and inhibiting one type of PKM molecule, the team could selectively block a connection without affecting the other. The findings hint that it's possible to erase some memories while leaving others intact.

Someday, new therapies might coax human neurons into letting go of unwanted memories. That would be useful for treating PTSD, in which traumatic memories cause the mind to link a neutral experience to a dangerous one. "But you don't want to erase the fact that other behaviors associated with the bad event may be useful to remember," Schacher says.

The ethics of manipulating people's memories "are very thorny," says André Fenton, a neuroscientist at New York University. Our lived experiences — and memories of them — make us who we are. Changing a person's memories could, in some ways, cause them to be a different person, he says. "We must proceed very carefully." ✖



LIMITS OF KNOWLEDGE

BY SID SIVAKUMAR

One must closely study the edge of the universe to unlock the secrets held within.

ACROSS

1 NFL player J.J. or T.J. [*power*]
5 Unilever soap brand [*illuminance*]
8 Family nickname similar to "Nana" [*mass*]
12 Phishing medium
14 Myanmar, alternatively
16 Output from a CT scanner
17 Protrusion
18 Like trees with more rings
19 Acknowledge nonverbally
20 Halting keyboard key
21 Some mounted shelving pieces … or what can be found around the perimeter of this puzzle?
24 "___ done it!"
25 Breathe
27 More like people at a craft fair, perhaps
29 Reference with a troubleshooting section
33 Little fight
36 Place to jot down observations
37 Volunteer's words
41 Corrections to articles
43 Doechii's genre
44 Skewer
46 Meal with a discounted drink, maybe
47 Passport additions
49 "It was obvious to me"
50 Egg-shaped
51 Honda luxury brand
52 Not suitable
53 ___ out (talk passionately)
54 With 31-Down, drastic actions … or what can be found around the perimeter of this puzzle?
56 Term for research on a political rival
57 Desiccate
59 Electric ___ (fish)
60 Overdue to send in
62 Doctors Without Borders or the American Red Cross, in brief
63 Blog feed letters
64 Conditional starters, in logic
65 Pet doc
68 Insect in a formicary
70 What might be jam-packed?
71 Most common lang. of scientific literature
74 Its belt is thought to consist of more than just three stars
76 Lauder who started making beauty creams with her chemist uncle
80 Painter whose last name becomes a robotics component if you add an S in front
82 Fatty acid, e.g.
83 Run after
84 Vintage photo filter
85 Inventor Nikola [*magnetic flux density*]
86 Alamo or Avis competitor [*frequency*]
87 Any of four Shakespearean kings [*inductance*]

DOWN

1 Big name in barbecue grills [*magnetic flux*]
2 Bring a smile to
3 Minerals with a Mohs hardness rating of 1
4 Comedian Notaro
5 Less active period
6 National language of Pakistan
7 Marvel superheroes with DNA mutations
8 Product of a bioengineering lab, for short
9 The r's in $2\pi r$ and πr^2
10 Succulent native to the Americas
11 Rhythmic structure in poetry [*length*]
13 Chicago labor leader Karen
14 Spanish dance in 3/4 time
15 Grande with Grammys
16 App with Reels and Stories, familiarly
22 Big concert venue
23 Fantasy author Canavan
26 Tried to buy, at an auction
28 Starting points for crocheting
30 Like protocols that have less room for error
31 See 54-Across
32 Provides clothes for, quaintly
33 Silver medalist's place [*time*]
34 Theorem ___ (computer program that logically verifies mathematical statements)
35 Storehouse
38 Starter on a cocktail party platter
39 Syrian city with an ancient citadel
40 Nabisco cookie with a fig variety [*force*]
42 "The Fox and the Hound" fox
45 Nintendo avatar
47 Shot that induces an immune response, informally
48 Singer/songwriter Smith
54 British boarding school
55 Film director Kazan
58 Country containing part of Lake Victoria
61 From scratch
65 Plug-in Chevy model [*electric potential difference*]
66 Warmest of the Great Lakes
67 Thanks for waiting?
69 Lab ___ (research team member, for short)
70 "Come on now!"
71 TV channel with live court proceedings?
72 Dark film genre
73 Nimbostratus cloud color [*absorbed dose*]
75 Fossil fuel found in fields
77 ___/her pronouns
78 Roofing material
79 Winter clock setting in DC or NYC
81 Formerly known as

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mens et manus

mind and hand

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