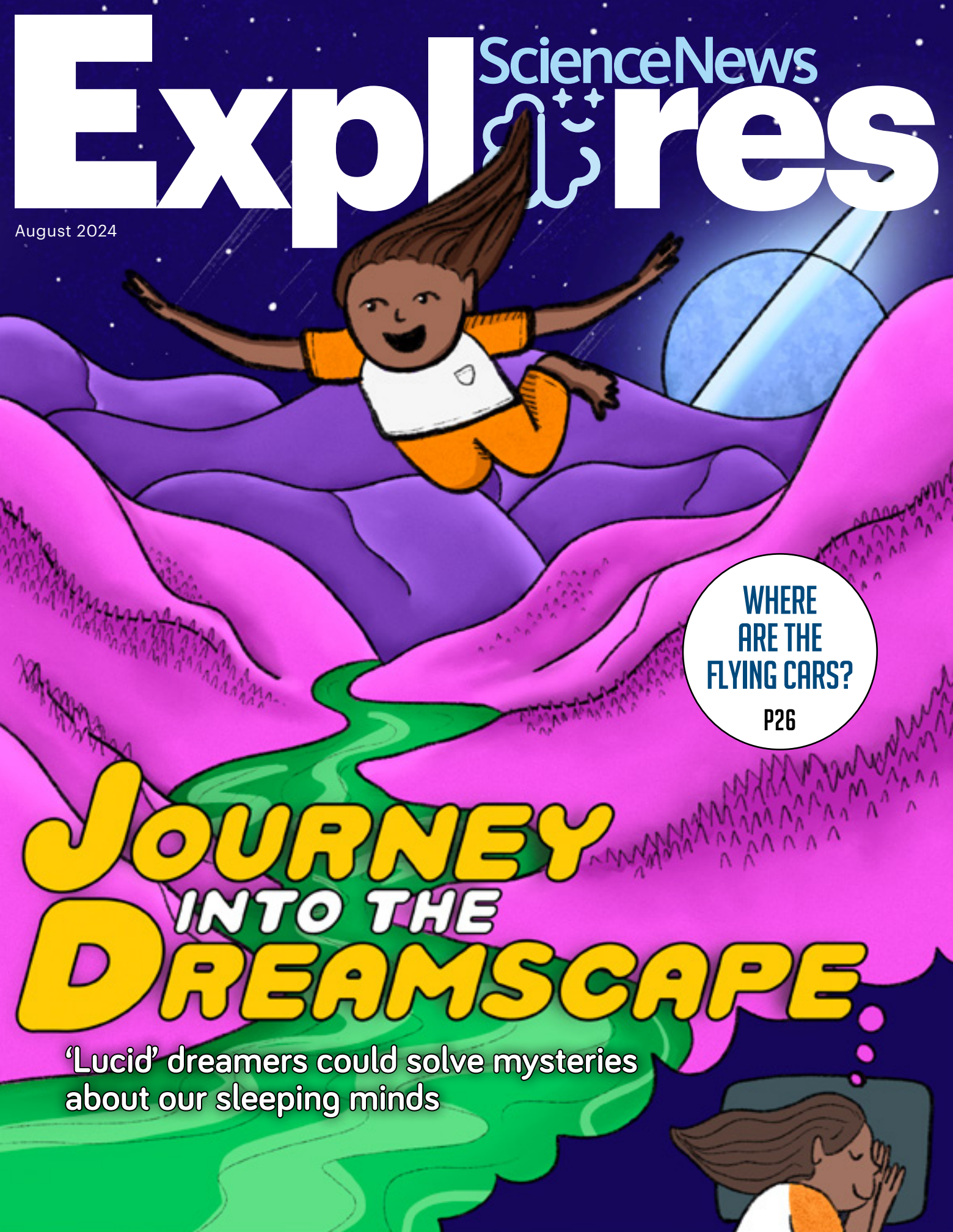
Science News Explores
August 2024



WHERE ARE THE FLYING CARS?
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JOURNEY INTO THE DREAMSCAPE

'Lucid' dreamers could solve mysteries about our sleeping minds

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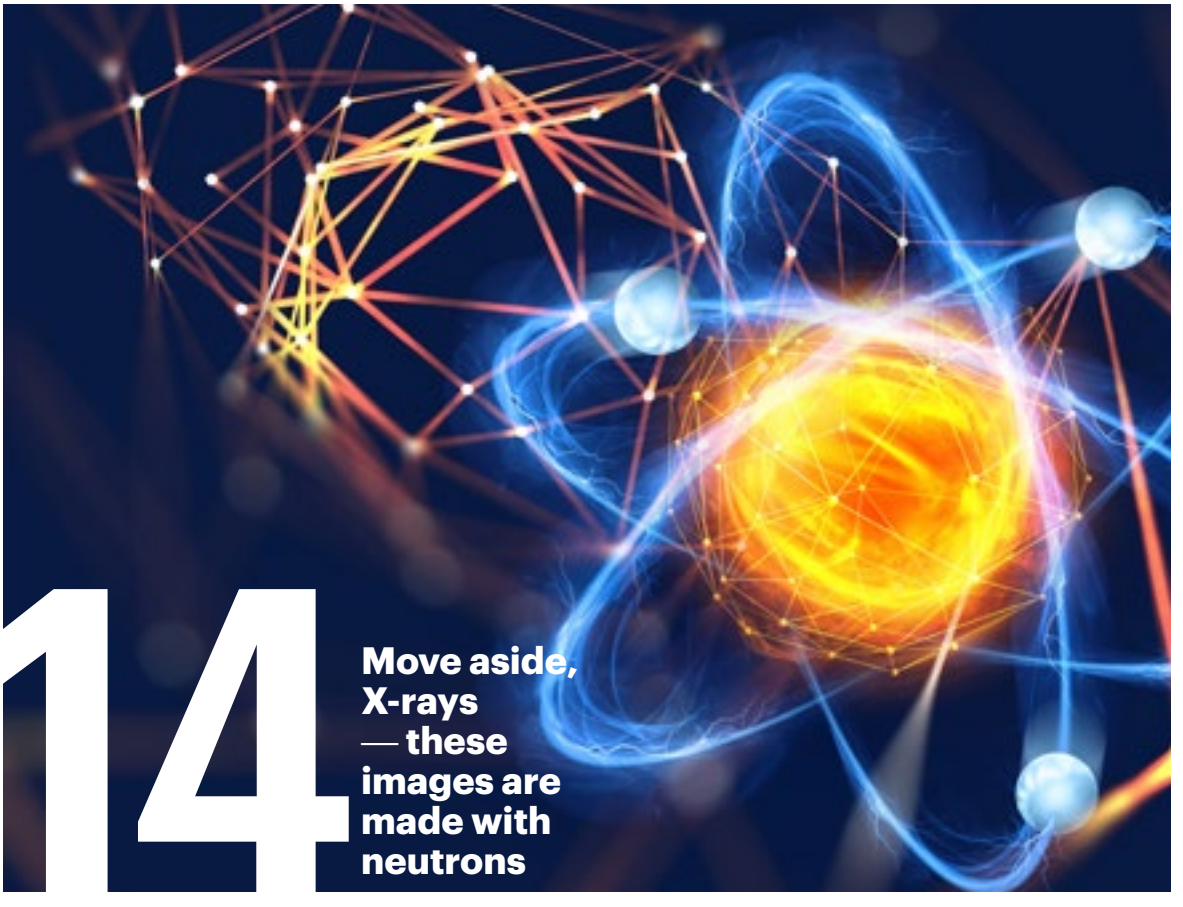

YURCHANKA SIARHEI/SHUTTERSTOCK

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Q Why do we have nightmares?

— *Lily S.*

A Scientists aren't entirely sure why we have nightmares. However, negative experiences and stress can trigger these frightening dreams, research has shown. Nightmares also tend to peak in childhood. For some, big events such as moving, starting a new school year or problems with friends can lead to nightmares. Others may have disturbing dreams after experiencing trauma or serious threats to the safety of themselves or someone they know. Medications, lack of sleep and certain mental health conditions can also prompt nightmares. Some nightmares can be weird or embarrassing, but the occasional scary dream is normal. Talking with a trusted adult about your scary dreams or worries can help.

Q Where do shooting stars come from?

— *Bradley S.*

A Shooting stars, or *meteors*, arise from bits of space debris falling into Earth's atmosphere. These pieces of debris, called *meteoroids*, may be fragments of comets or asteroids. When they hit Earth's atmosphere at high speeds, the fragments burn up and create streaks of light in the sky. On any given night, it's possible to see several meteors per hour. But at certain times of year, Earth is bombarded with many more meteors. These *meteor showers* happen when Earth's orbit around the sun passes through the dusty trail left by a certain comet or asteroid. The Perseid meteor shower, for instance, happens every mid-July to late August when Earth crosses the trail of comet 109P/Swift-Tuttle. The Geminid meteor shower happens each December when Earth crosses the path of asteroid 3200 Phaethon.

Q What would happen to the environment if we reduced the amount of plastic we use?

— *Likhith G.*

A Plastics harm the environment due to both their production and their disposal. Plastics are made from fossil fuels. Extracting and processing fossil fuels uses large amounts of energy and emits greenhouse gases. Shaping plastics into products, from toothbrushes to milk bottles to garbage cans, requires even more energy and other resources. These facilities also produce air and water pollution. Producing less plastic, therefore, would save energy, reduce greenhouse gas emissions and preserve natural resources. There would also be far less plastic waste. Most plastic is never recycled. It ends up in landfills or discarded as litter. Some of it makes its way into the oceans. Plastic makes up 70 to 80 percent of the waste found in the environment worldwide. That waste leaches toxic chemicals into water and soil. So reducing plastics could mean cleaner drinking water and healthier soil for plants.

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Sarah Zielinski
Editor, *Science News Explores*

OLLY KAVA/SHUTTERSTOCK

HEALTH

The chemistry of teenage body odor

From grassy to goatlike, armpit scents transform after puberty

Ah, puberty. Bodies get taller. Muscles get stronger. And often, body odor becomes more intense. Now, scientists have identified some of the compounds that give teenagers their signature scent.

Teenage body odor differs from that of infants and toddlers. In teens, it contains two smelly steroids. Those are molecules that often serve as chemical messengers in the body. Teen B.O. also has higher levels of carboxylic acids. Those chemicals form when armpit sweat and skin oils break down. Both carboxylic acids and steroids may contribute to B.O. changes throughout puberty.

Many compounds mingle in body odors, says Helene Loos. A chemist, she works at the Friedrich-Alexander-Universität Erlangen-Nürnberg in Germany.

Loos was part of a team that sampled body odor in teens 14 to 18 years old and young children up to age 3. The study's 18 teens and 18 young kids slept with cotton pads under their arms for a night. Other pads left in their rooms captured any smelly chemicals in the air. Analyses of the pads revealed the B.O. of young children and teens have more than 40 compounds in common.

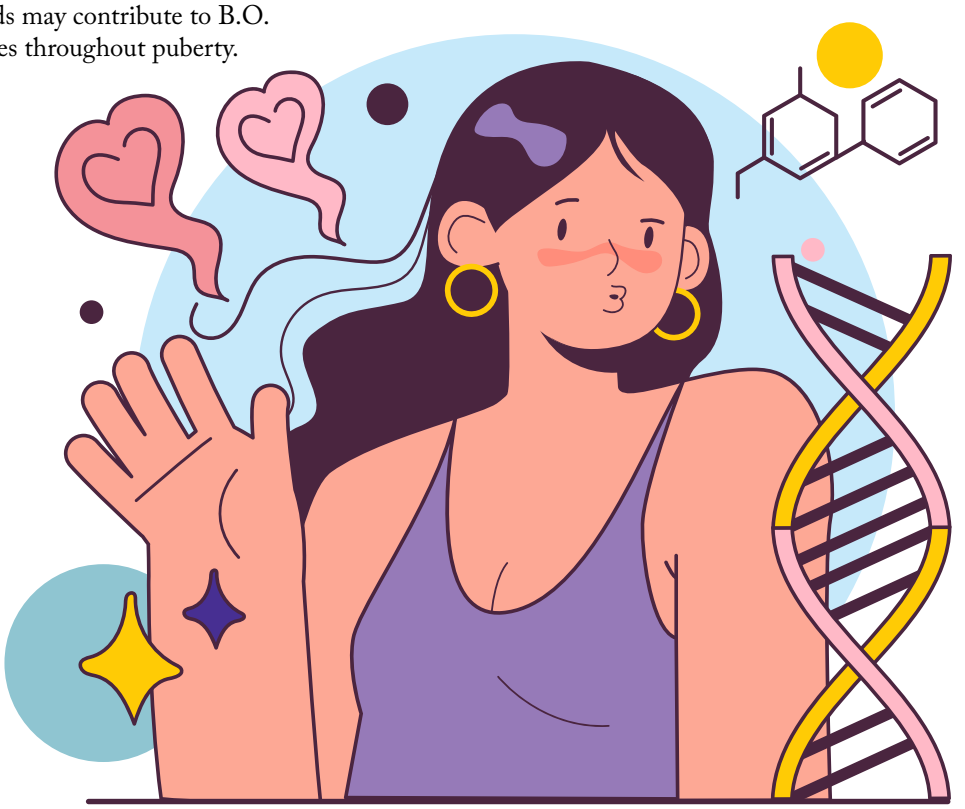
Some classes of chemicals showed no difference between age groups. But the scents of carboxylic acids were more prevalent in teens.

The team had six people trained in describing scents take a whiff of these compounds. Some carboxylic acids had pleasant scents that the panel described as fruity, soapy or grassy. But some yuckier smells were cheesy, musty or goatlike.

Researchers also identified two steroids present only in the teens' armpit aromas. One smells of sweat, urine and musk. Musk is a substance used in perfume that can smell earthy and warm. The other steroid smells of musk and sandalwood, which has a warm, woody and spicy scent.

Body odor continues to change across life. In future work, Loos hopes to study these changes and look for more stinky compounds.

— *Skyler Ware*



INSPIRING.TEAM/SHUTTERSTOCK

Becoming a teen brings lots of new experiences. One is a signature scent bestowed by a unique mix of smelly chemicals.

INSPIRING.TEAM/SHUTTERSTOCK

ANIMALS

Why tail wagging still hounds scientists

The complex behavior communicates more than just joy

A wagging tail may not always mean a dog is happy. And while a dog wagging its tail is one of the most common animal behaviors people see, questions about tail wagging still hound researchers.

Scientists know domesticated dogs (*Canis familiaris*) use their tails to communicate and even what certain wags mean. Learning more about how and why a dog wags its tail could help us learn not just about dogs, but about humans. From an animal-welfare point of view, it could help people better read pups' cues.

A lot of dog behavior still puzzles scientists, says Silvia Leonetti. Leonetti is an ethologist — someone who studies animal behavior — at the University of Turin in Italy. She studied tail wagging while in Nijmegen, the Netherlands. At the time, she was working for the Max Planck Institute for Psycholinguistics. That's the study of how language is used and understood in the brain.

Leonetti and her colleagues had read studies about tail wagging. From these, they tried to figure out what parts of wagging are not understood. They also hypothesized about the origins of this behavior. Perhaps tail wagging placates some human need for rhythm, they suggested. Or maybe the behavior goes along with other traits humans bred into dogs — like friendliness toward humans or curly tails.

Leonetti and her team put their findings and ideas in a new review of scientific studies. They published it in the journal *Biology Letters*.

"People think wagging tail equals happy dog. But it's actually a lot more complicated than that," says Emily Bray. She's an expert in canine cognition at the University of Arizona in Tucson. She did not take part in the study.

Wagging also means different things depending on how the tail wags. For instance, a dog might wag its tail more to the right side. That typically means the dog is interested or wants to approach something, the researchers note. A wag more to the left could signal uncertainty, or mean the dog wants to back away. A wag low and near the legs is a sign of submission.

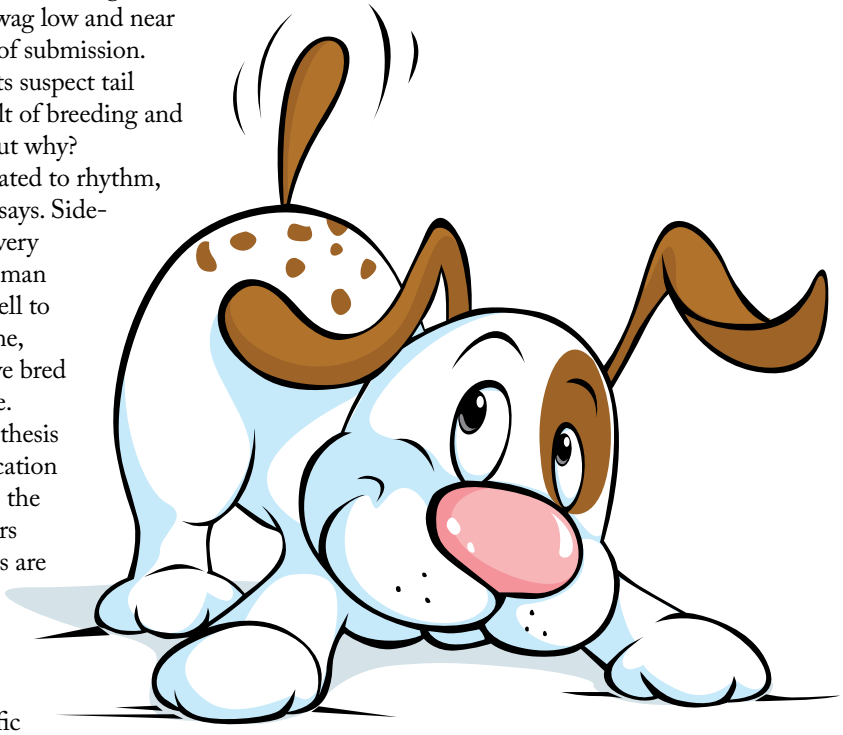
Some scientists suspect tail wagging is a result of breeding and domestication. But why?

It could be related to rhythm, Leonetti's group says. Side-to-side wags are very rhythmic. The human brain responds well to rhythm. Over time, people might have bred dogs to wag more.

Another hypothesis is called domestication syndrome. This is the idea that behaviors and physical traits are linked together in an animal's genes. So when people breed animals for specific behaviors or traits, others might tag along. Perhaps people bred dogs for friendliness or following orders — and tail wagging just came along for the ride.

Studying different aspects of wagging could point to answers, says Leonetti. Some clues might come from studies of how dog brains work. Others might come from studying tail motion. Plus, domestication involved both humans and dogs. So studying dogs' wagging behavior could reveal something about people, too.

— *Jude Coleman*



SCHWARZHANA/SHUTTERSTOCK

PLANTS

This thistle chills out in summer's heat

Its yellow flowers stay cooler than the air even on scorching days

In sunny southern Spain, one type of thistle seems to have built-in air conditioning.

This plant's flowers stay cooler than the air around them. On average, they're about 3 degrees Celsius (5.4 degrees Fahrenheit) cooler. But during the hottest part of the day, they chill even more. When the air reaches a blazing 45 °C (113 °F), the flowers can remain just 35 °C (95 °F).

In Spain's Sierra de Cazorla mountain range, scorching summers leave many plants dead, dried out or dormant. In this brown sea, bursts of yellow thistle flowers stand out.

While doing field research in the mountains, Carlos Herrera touched one of the thistle heads. Even in the peak of the day's heat, the bloom felt pleasantly cool. He became curious about why.

Herrera is an ecologist at the Spanish National Research Council in Sevilla. He measured the temperatures of seven thistles across two different sites. Herrera checked each bloom many times and on different days. The flowers got consistently cooler as the day heated up. He shared his findings in *Ecology*.

The flowers' cooling is "substantial," says ecologist Christopher Still. He works at Oregon State University in Corvallis and wasn't part of the study. He wonders how being cooler than the surrounding air helps the thistle. For example, does it attract pollinators trying to escape the oppressive summer heat?

Many plants beat the heat by letting water evaporate through tiny holes, or pores. This process is called transpiration. It's similar to how people sweat to stay cool.

The thistle flower's shape and structure might help it cool off so well, Herrera thinks. As water within the thistle evaporates, it likely takes heat with it. Because of the flower's shape, that heat isn't being replaced by the sun's warmth. This might allow the plant to cool below the air temperature. That idea remains to be tested.

— *Darren Incorvaia*

C. HERRERA

The flowers of the thistle *Carlina corymbosa* cool down the most during the hottest part of the day, perhaps to tempt pollinators looking to beat the heat.

Think you know what you're seeing? Find out on page

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By **Maria Temming**

Journey into the Dreamscape

'Lucid' dreamers could solve mysteries about our sleeping minds >>

RUNE FISKER

When Christopher Mazurek realizes he's dreaming, it's always the small stuff that tips him off.

The first time it happened, Mazurek was a freshman in college. In the dream, he found himself in a campus dining hall. It was winter, but Mazurek wasn't wearing his favorite coat. "I realized that, okay, if I don't have the coat, I must be dreaming," Mazurek says.

That epiphany rocked the dream like an earthquake. "Gravity shifted, and I was flung down a hallway that seemed to go on for miles," he says. "My left arm disappeared, and then I woke up."

The experience of knowing you're in a dream while still asleep is called "lucid dreaming." Most people rarely, if ever, lucid dream. But many enthusiasts have practiced techniques to become self-aware in their sleep and even control aspects of their dreams.

Mazurek, 24, has gotten better at molding his lucid dreams since that first whirlwind experience. Sometimes he uses them to try flying or say "hi" to dream versions of deceased family members. Other lucid dreamers poke around their subconscious minds. Or feast on junk food.

Now scientists have a new job for lucid dreamers: to explore their dreamscapes and report out their experiences in real time.

Dream research typically relies on asking people about their dreams after they wake up. But people often wake with only spotty, distorted memories of their dreams. And they can't customize their dreams for scientific studies.

"The special thing about lucid dreaming is that you can get even closer to dream content and in a much more controlled and systematic fashion," says Martin Dresler. He's a neuroscientist in the Netherlands. He works at the Donders Institute in Nijmegen.

Some lucid dreamers can do tasks and send signals to researchers in the waking world while they're still asleep. In this way, they become sort of like astronauts "radioing" ground control as they complete missions.

So far, tests in very small groups of lucid dreamers have helped reveal how people experience dreams. They've also offered insight into what people are capable of doing while dreaming.

With more lucid dreamers, scientists hope to probe how sleeping brains build their elaborate, often bizarre plots and settings. Lucid dreams might even offer clues about how dreams contribute to creativity, processing emotions or other mental tasks.

That, in turn, could help solve the grand mystery of why we dream.

Just getting started

Tales of lucid dreams date back to ancient times. But these self-aware dreams still seem rare. Only about half of people say they've ever had a lucid dream. A mere one in 100 or so say they lucid dream multiple times a week.

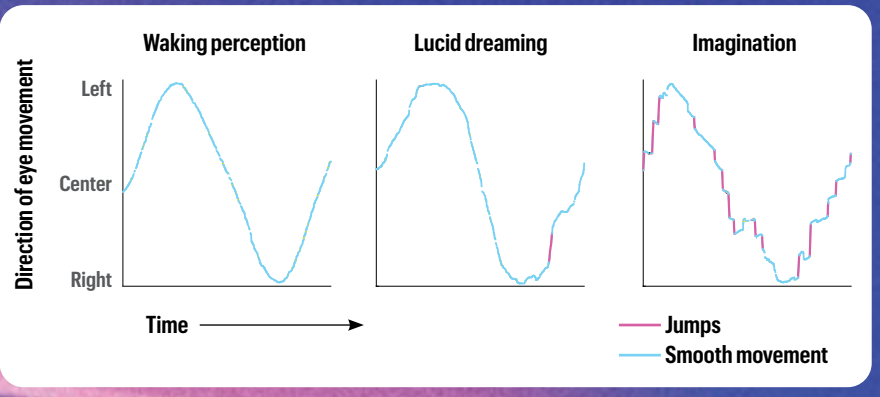
Lucid dreams are so elusive that, for a while, not all scientists were sure they ever happened. But experiments have offered proof that some sleepers can be self-aware.

When a dreamer sweeps their gaze all the way left, then all the way right, their eyes in real life may match those movements behind their closed eyelids. Electrodes near a person's eyes can detect those motions. Such big, sweeping movements stand out from the smaller eye motions typical of REM sleep — the stage when most lucid dreams take place.

While lucid dreamers like Christopher Mazurek (pictured) sleep, electrodes track their eye motions and monitor facial muscles to confirm the person is truly asleep. K.R. KONKOLY

EYES ON EYE MOVEMENTS

A person's eyes can smoothly track left and right movements when they are awake (left) or in a lucid dream (middle). But when someone closes their eyes and tries to imagine tracking that motion, their eyes pan in small jumps (right). This hints that in some respects, lucid dreams are experienced more like waking perception than imagination.



SOURCE: S. LABERGE *ET AL/NAT. COMMUN.* 2018; RUNE FISKER

This gives dreamers a crude way to signal they've become lucid or send messages to the outside world. For instance, they can tell scientists before sleep that when they become lucid in a dream, they'll look left-right-left-right.

Researchers can check that the person giving those eye signals really is asleep by looking at their muscle activity. "During REM sleep, the entire body is paralyzed," Dresler says. It's not possible to fake that kind of stillness when awake.

Scientists are just starting to harness lucid dreamers' ability to signal the waking world.

One team deployed experienced lucid dreamers to find out whether dream imagery is more like real-life visuals or imagined ones. While asleep, six lucid dreamers moved their thumbs in either a circle or a line. The dreamers traced that motion with their eyes. They did same task while awake with their eyes open and in their imaginations with their eyes closed.

People's gazes panned in jerky motions when they tracked the imagined movements. But in dreams, people's eyes tracked thumb movements smoothly — just as they did in real life.

"It's been debated really all the way back to the ancient Greeks, are dreams more like imagination? Or is it more like perception?" says Benjamin Baird. The eye-tracking data suggests that imagery is more like real-world perception. Baird is a psychologist and neuroscientist at the University of Texas at Austin. He and his colleagues shared the thumb-tracking study in 2018.

Studies like this offer a taste of what lucid dreamers could teach us. But any findings based on just a handful of people must be viewed with caution, adds Michelle Carr. She's a neuroscientist in Canada at the Center for Advanced Research in Sleep Medicine in Montreal, Quebec. "It needs to be studied in bigger samples," she says.

That means finding — or creating — more expert lucid dreamers.

Recipe for a lucid dream

People have used a range of techniques to boost their odds of lucid dreaming. One method is to tell yourself over and over before bed that you'll have a lucid dream. Another is to ask yourself if you're awake several times a day. (The idea is to get into a routine of checking whether you're awake. That way, if you do it out of habit in a dream, you might realize you're asleep.)

Some people also do "wake back to bed." This involves waking up super early, staying up for a while, then getting more shuteye. That jolt of alertness right before tumbling back into REM sleep may help people become lucid in their dreams.

But it's not clear how well those techniques really trigger lucid dreams, Baird says.

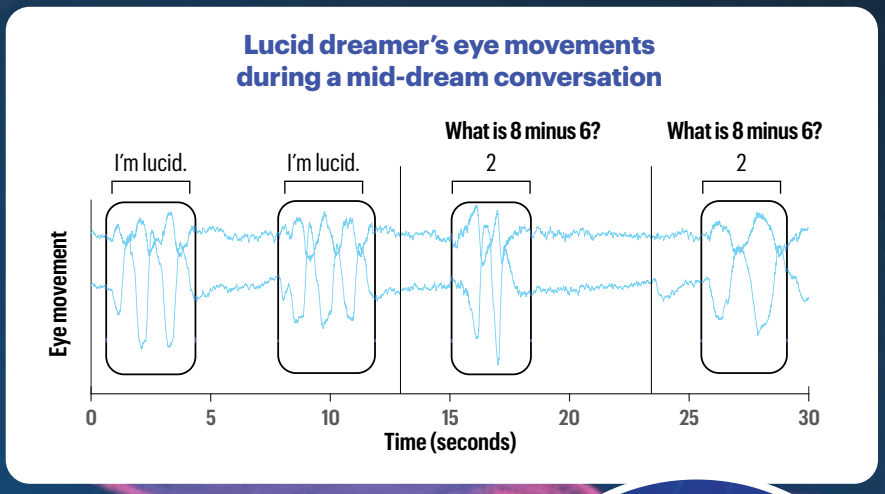
In 2020, Carr was part of a team that used a different technique to coax 14 of 28 nappers to become lucid in the lab. Before falling asleep, the nappers learned to associate a cue — such as a series of beeps — with being self-aware. Hearing the same sound again while sleeping reminded them to become lucid.

Another way to get more sleepers to lucid dream in the lab is to recruit people with narcolepsy. This condition is known for making people fall asleep a lot during the day. But narcolepsy patients seem to experience another side effect, too.

"They're just champions at lucid dreams," says Isabelle Arnulf. She's a sleep neurologist at Pitie-Salpetriere University Hospital in Paris, France.

ANSWERING QUESTIONS DURING A DREAM

While dreaming, Christopher Mazurek signaled the outside world by sweeping his eyes left and right. Electrodes on his face recorded those motions. On the graph, eye motions that show Mazurek is lucid appear as three big up-down sweeps. Eye signals answering "2" appear as two big up-down sweeps. Mazurek made those eye movements in response to researchers' simple math question, "What is 8 minus 6?"



In 2018, Arnulf's team shared a study in which an impressive 18 of 21 narcolepsy patients became lucid during lab naps.

Still, some lucid nappers couldn't control their dreams well enough to complete their assignment. They were meant to do something in a dream that made them briefly stop breathing — like swim underwater or speak.

One napper said after waking that they'd simply forgotten to stop breathing while diving off a cliff. Another said they tried to speak but couldn't.

Lucid dreamers often forget they're dreaming or struggle to control their dreams.

In one 2020 study, people were told to fill a dream room with objects, such as a clock or rubber snake. For some dreamers, the clock spun wildly or the snake slithered away. In another study, lucid dreamers were asked to practice throwing darts. But some said they had only pencils to throw in their dream, or were pelted with darts by a nasty doll.

"It's a lot harder than just passively lucid dreaming in your bed," says Mazurek, who has participated in several lucid-dream studies at Northwestern University in Evanston, Ill.

Despite these challenges, lucid-dream studies are forging ahead — and fast. In fact, a crew of dreamfarers including Mazurek recently embarked on their most ambitious mission yet.

Real-time dream science

In most lucid-dream studies so far, researchers assigned people a task to do in their dreams before they fell asleep. Then, the scientists sat back and watched what happened. But what if researchers could ask people about their experiences and get responses mid-dream?

People could report what dream foods taste like or what dream noises sound like moment-to-moment. Such details could reveal how closely dreams mimic the real world. And that might offer insight into how sleeping brains render dreams.

Karen Konkoly, meanwhile, hopes to assign sleepers tasks mid-dream. She's a neuroscientist at Northwestern. Imagine, she says, that researchers want to know whether dreams help people with creative problem solving.

If dreamers are assigned a problem before sleep, they're liable to think it over as they nod off. "Maybe it's really the time as you're falling asleep that helped you solve the problem," says Konkoly. Telling someone to solve a puzzle when they're already dreaming could better isolate how useful dreams are for helping the brain tackle such problems.

There's a whole bunch of theories about why people dream. Maybe they help us practice skills. Or tap into creativity. Or process memories or emotions. Assigning people tasks mid-dream could help tease out which kinds of things dreams are useful for.

A few years ago, Konkoly and others decided to find out if dreamers could hear and respond to people in the outside world.

Thirty-six people took snoozes in the lab. Once sleepers signaled that they were lucid, researchers gave them yes-or-no questions or math problems. Some questions were spoken. Others were conveyed through flickering lights.

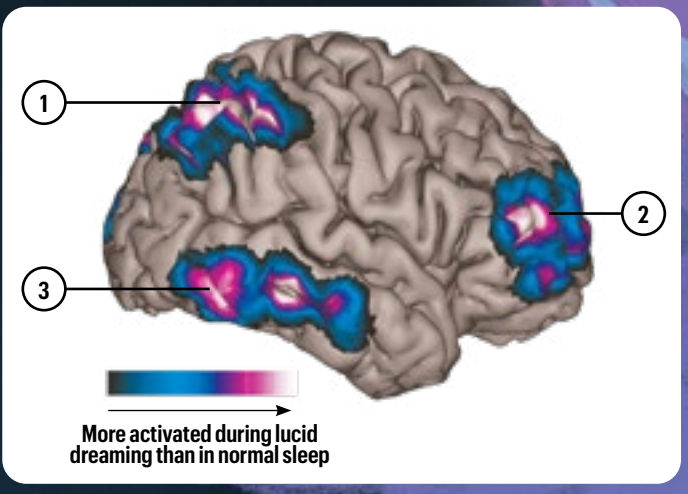
Before falling asleep, dreamers were told to answer whatever questions they received with left-right eye signals or by smiling or frowning. (Someone smiling in a dream may not make that expression in real life. But electrodes on the face can register tiny corresponding muscle twitches.)

RUNE FISKER; SOURCE: K.R. KONKOLY *ET AL/CURRENT BIOLOGY* 2021

BRAIN CLUES TO LUCID DREAMS

Scientists took brain scans of one sleeper's brain during lucid and nonlucid sleep. Those scans showed that some brain areas (highlighted) may be more active during lucid dreams than during normal sleep.

1. **The lateral parietal cortex is involved in working memory.**
2. **The dorsolateral prefrontal cortex and frontopolar cortex are involved in working memory and introspection.**
3. **Activity near the temporal cortex may make lucid dreams brighter and more detailed than normal dreams.**



Interviewing people about their dreams as they happen could help reveal just how realistic dreams look and feel.

On 158 occasions, scientists questioned dreamers who had signaled they were lucid. Most times, the scientists got no response. But 29 total correct responses came from six different people. Those six ranged from newbies to frequent lucid dreamers, including Mazurek. A panel of sleep experts confirmed the dreamers were asleep when they replied.

"I was astonished," says Robert Stickgold. This neuroscientist at Harvard Medical School in Boston, Mass., studies dreams (although not lucid ones). "I had no question but that these people are in fact listening and are in fact having lucid dreams at the time of the communication," he says. "That opens up all sorts of possibilities."

Limits of lucidity

Lucid dreams may be useful tools to study dreams. But they have one major limitation.

"The biggest issue is how far can you push these results to dreaming in general," Stickgold says. Imagine, for instance, that lucid dreamers get better at a skill by practicing it in their dreams. It's not clear that people who just happen to have normal dreams about doing those activities — without self-awareness — would get the same rewards.

Some data suggest lucid dreamers may have access to parts of the brain that normal dreamers don't. Brain scans of one person's lucid and nonlucid sleep hint that brain regions linked to self-reflection and memory are more active during lucid dreams.

But researchers like Dresler doubt that lucid and nonlucid dreams are profoundly different. "Lucid dreaming is not a strict all-or-nothing phenomenon," he says. People often flutter in and out of awareness. "That suggests that lucid and nonlucid dreaming are in principle something very similar."

Even if lessons from lucid dreams can't be applied to all dreams, Tore Nielsen still thinks they're worth studying. This neuroscientist works at the Center for Advanced Research in Sleep Medicine.

"It is a type of consciousness that has intrigued and amused people for centuries," Nielsen says. "It would be important for science to understand how and why humans have this extraordinary capacity for intentional world simulation."

READ MORE

Sleep: A Kid's Guide to the Science of Slumber

By Wendy Bjazevich, illustrated by Juliana Eigner

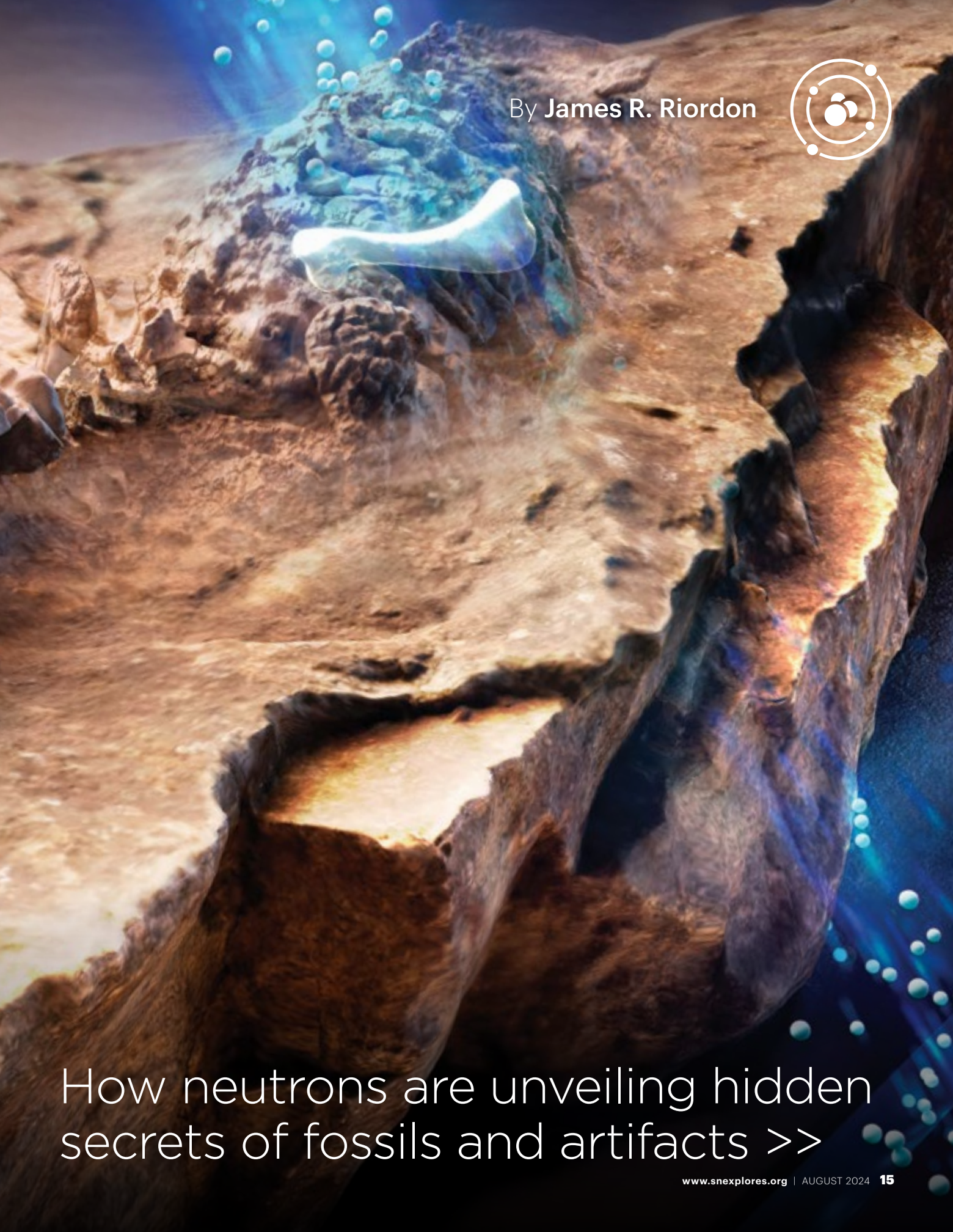
Not ready to snooze on sleep science just yet? Read more in this book about how sleep impacts health, how some animals slumber and how people around the world get ready to catch some Zzzzs.

MPI OF PSYCHIATRY; BUSHEL & PECK BOOKS

This artist's illustration imagines a beam of neutrons uncovering a hidden bone — part of an ancient fossil embedded in rock.

PEEKING INTO THE PAST

NATASHA MUTCH/SAYOSTUDIO



By **James R. Riordon**

How neutrons are unveiling hidden secrets of fossils and artifacts >>

Some 100 million years ago, a crocodile ate a dinosaur for dinner. The croc died soon after, still stuffed with its victim. Later, the pair's remains became encased in stone. This recently unearthed fossil has offered scientists a unique snapshot of life from the Cretaceous Period, when the crocodile prowled what is now Australia.

But the story of this last meal almost never came to light.

When Matt White first recovered the rock holding this fossil, his team scanned it with X-rays. White is a paleontologist at the University of New England in Armidale, Australia. Putting together multiple X-ray images of an object can create a 3-D map of its interior. White's group hoped to use these scans to pick out each bone in the fossil without having to remove them from the rock.

Those scans did reveal much of the fossil. But iron-rich stone surrounding some of the bones blocked out X-rays. Needing some other way to peer through the rock, they sent the fossil to Joseph Bevitt. He's a chemist at the Australian Centre for Neutron Scattering in Sydney.

Bevitt uses subatomic particles called neutrons to image ancient objects. His neutron scans uncovered the same croc bones that White's team had seen. But they also revealed one bone that looked like a dinosaur leg. It was where the crocodile's stomach would have been.

"When I saw the neutron result and the little dino femur, I was shaking with shock," Bevitt says. He was "both in awe and doubt" about what he'd found. But years of analysis — plus more X-ray and neutron scans — confirmed that first glimpse. Those neutrons revealed the remains of a never-before-seen species of dinosaur bitten into chunks. It was inside the croc's belly.

The discovery earned that crocodile — *Confractosuchus sauroktonos* — the second part of its name. *Sauroktonos* means "lizard killer."

White, Bevitt and their colleagues shared their finding in *Gondwana Research*.

Neutrons have long been used to peer inside manufacturing and military equipment. In fact, people have used neutrons for imaging since shortly after the neutron was discovered in 1932. But these particles have only recently started giving scientists stunning views inside fossils and ancient objects.

Look, don't touch

There was a time when studying fossils and artifacts required damaging or destroying them. Mummified remains were dissected. Sealed containers were cracked open. Fossils were pried loose from rock. X-rays offer a way to inspect precious samples without ruining them.

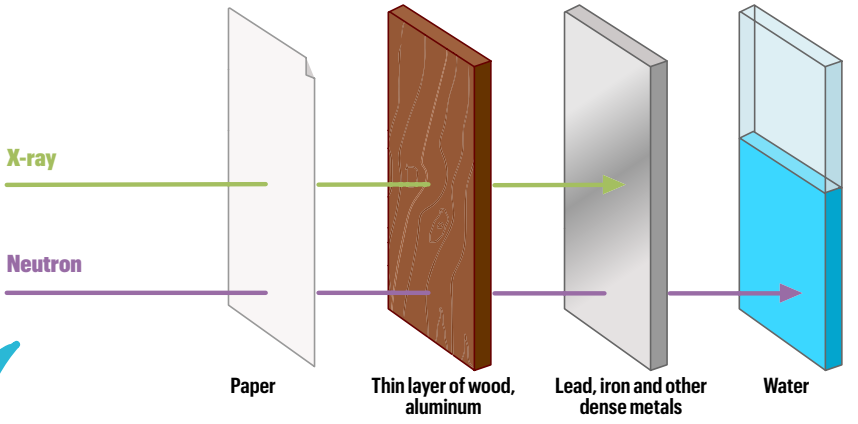
X-rays are high-energy light waves. They interact with electrically charged particles, such as the electrons inside atoms. This allows X-rays to create images of the insides of objects.

Say a doctor wants to take an X-ray of someone's leg to see if it's broken. A machine shines a beam of X-rays through the patient's leg. Those light waves get scattered or absorbed by the electrons in atoms that make up the leg.

Researchers determined that a crocodile ate a dinosaur (left, artist's illustration) by scanning rocks (center) with subatomic particles called neutrons. Scans revealed the remains of a crocodile (right, a 3-D digital reconstruction) with dinosaur remains in the croc's stomach contents (red).

JULIUS CSOTONYI; M.A. WHITE *ET AL*/*GONDWANA RESEARCH* 2022

Scientists rely on X-ray and neutron scanning to peer through materials that hide objects of interest. X-rays and neutrons interact with atoms differently. That's why neutrons, unlike X-rays, can pass through lead but get blocked by water.



Dense tissues are packed with lots of electrons. That makes it difficult for X-rays to pass through these tissues. As a result, dense body parts — like bones — stand out in X-ray images. Skin, muscle and other soft tissues are much less dense. Since they have fewer electrons that can scatter or absorb X-rays, this radiation easily zips through the soft tissue. Soft tissues essentially disappear in X-ray images.

X-rays have offered views into artifacts since this type of light was discovered in 1895. And in the 1970s, X-rays became the standard approach to studying fossils and artifacts.

For all that X-rays have revealed about the past, they still have some drawbacks. X-rays can't pass through super dense materials, such as lead or thick layers of other metals. So they can't help researchers see inside such materials. On the flip side, objects made of low-density material, such as soft tissue, are nearly invisible to X-rays.

Neutrons can fill in the picture.

Scatter!

Neutrons have no electric charge. So neutrons pass by electrons until they hit the cores, or nuclei, of atoms. Neutrons can bounce off an atom's nucleus or be absorbed inside the atom.

These interactions are more complex than the ones between X-rays and electrons. How neutrons interact with atoms depends on how fast the neutrons are moving. It also depends on complex rules of quantum physics. (Quantum physics is the weird, twisty math that governs very, very, very small things.)

For instance, neutrons easily pass through lead, iron, copper and other metals that block X-rays. But neutrons interact strongly with some low-density materials through which X-rays easily zip, such as lithium, boron and water.

"Water to neutrons is like lead for X-rays," Bevitt says. Full of hydrogen atoms, water is like kryptonite for neutrons. It blocks them. Too much hydrogen-rich material can hide details from neutron beams.

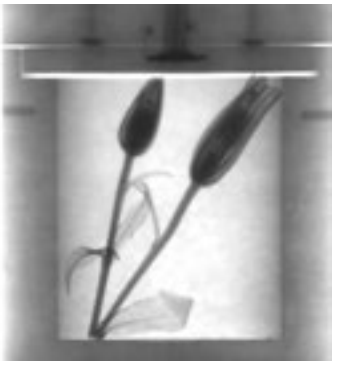
But remember how a bone stands out on an X-ray image because it scatters or absorbs so many X-rays? Hydrogen can likewise make some features stand out in neutron images.

Jacob LaManna works at the National Institute of Standards and Technology, or NIST, in Gaithersburg, Md. This physicist likes to show the difference between neutron and X-ray imaging with flowers. He uses both techniques to image Asiatic lilies that he's tucked inside a thick lead container.

"The neutrons can go right through the lead," LaManna says. "Then you can see basically all the water [in the] vascular structure of the flowers." But X-rays, blocked by lead, would show nothing but the opaque outer surface of the container.

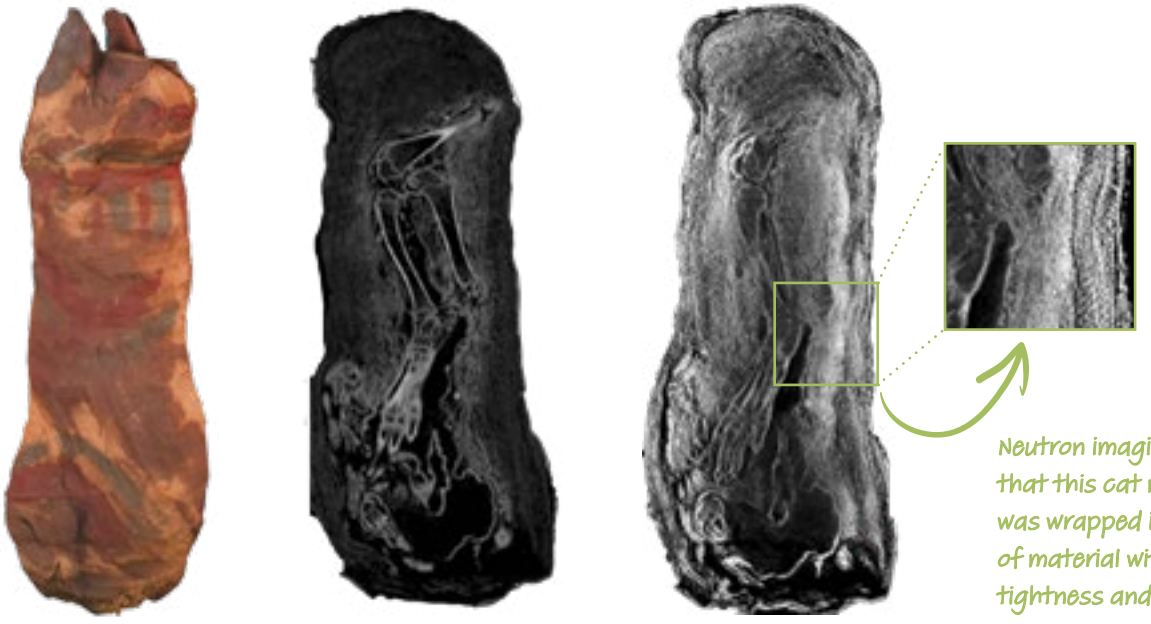
Neutrons' ability to glide through dense materials that block X-rays is their imaging superpower. It has made neutrons useful in the testing of cars and planes. The particles can reveal the flow of hydrogen-rich oil inside engine blocks. They can also expose flaws in metal castings.

At NIST, LaManna heads a facility that can run X-ray and neutron scans at the same time. These dual views provide different insights into things that contain multiple materials. Hydrogen fuel cells. Building materials. Soil samples. Such complex mixes of materials would be difficult to study with only X-rays or only neutrons.



Lilies in a lead container (left) demonstrate the abilities of neutron imaging. Unlike X-rays, neutrons can sail through the lead to reveal the flowers inside. Neutron imaging can even reveal water in the plants' vascular structure (right).

GRAYJAY/SHUTTERSTOCK; DANIEL HUSSEY/NIST



Neutron imaging revealed that this cat mummy was wrapped in layers of material with varying tightness and coarseness.

X-ray and neutron scanning provided an inside view of this mummified cat (left) from ancient Egypt, no unwrapping required. X-rays (center) revealed the cat's skeleton. Neutrons (right) showed details of the cloth wrappings.

Now, a growing number of paleontologists and archaeologists are taking advantage of this tech.

"We are really the new kids on the block," Bevitt says of neutron-imaging experts. So far, neutron scans have helped study the fabric swaddling still-wrapped cat mummies. Neutrons have also uncovered the most ancient vertebrate heart ever found. It was in a 380-million-year-old fish. Neutron beams have even helped experts spot fake ancient artifacts by finding signs of recently applied glues.

Rewards and risks

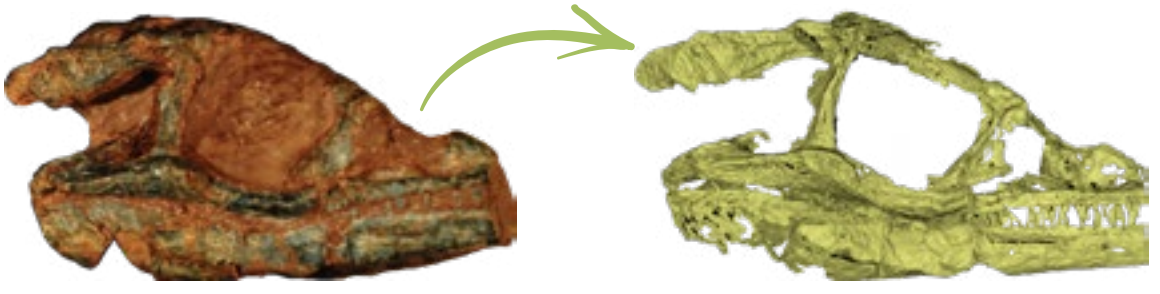
James Clark places a pair of fossilized crocodile skulls on the table in his basement lab. A paleontologist, he works at George Washington University in Washington, D.C. Clark's 165-million-year-old croc fossils are dwarfed by a nearby modern alligator skull. That skull is about as long as my forearm. The fossilized croc skulls are only slightly bigger than my thumb tip.

Clark collected the fragile skulls in Mexico about 40 years ago. They're embedded in hardened blobs of sediment with just a few bones and teeth peeking through. At first glance, the specimens look like wads of chewed gum. But they're made of gritty, iron-rich mudstone.

"One of the main problems," Clark says, "is you get what's called flaring if you have little iron inclusions." The result is blurs and streaks that mask the bones inside.

Clark could have hired someone to clean away the sediment around the delicate bones. But that's a slow and costly job. Plus, he notes, it can harm the specimen. It wasn't until 2019 that neutron imaging finally offered a good look at the hidden bones.

Iron is essentially transparent to neutrons, LaManna says. So "it's much easier to basically isolate just the fossil" with neutron scans than with X-rays. NIST's neutron scans revealed the intricate details of the tiny bones.



This ancient crocodile skull was embedded in gritty, iron-rich mudstone (left). "If you try to X-ray that, you basically end up with … these bright sparkles from all the iron," says Jacob LaManna. But iron is transparent to neutrons, making it easier to isolate the bones (right).

Researchers used neutrons to see the bones of an ancient crocodile embedded in iron-rich mudstone (left). Neutron imaging created a 3-D view of the croc skull without damaging the specimen (right).

C.A. RAYMOND AND J.J. BEVITT/*MATERIALS RESEARCH PROCEEDINGS* 2020 (CC BY 3.0); J. STIEGLER

This 3,000-year-old knife came from China's Shang dynasty. Scientists made a replica with jade, brass and other materials to test whether neutron imaging would be a safe method with which to study it.

In the case of Clark's crocodiles, it was the material around the objects that presented a problem for X-rays. But in other cases, the object itself can be the issue. Tissues, fibers, wood and other low-density materials can be difficult to spot using X-rays. And metals within an object can block other features from view. Both challenges plague researchers who are studying antiquities.

Digging into the details

Ariel O'Connor is an art conservator. She works at the Smithsonian National Museum of Asian Art in Washington, D.C. O'Connor was curious how some 3,000-year-old dagger-axes in the museum's collection were put together.

These ceremonial weapons came from China's Shang dynasty. They feature jade blades and turquoise-encrusted bronze handles.

X-rays can't tease apart the stone, metal, fibers and other materials that may be within the dagger-axes. Neutron imaging could help. But it also comes with a risk. Neutron beams make things radioactive. It's not always clear how radioactive a sample will become. But materials often turn more radioactive than is safe for people to handle — or even view in a museum. That radioactivity can last days to weeks after a neutron scan.

O'Connor's team decided to do a test.

They made a crude replica of an ancient dagger-axe. They used jade from Wyoming in place of the ancient Chinese jade. Brass from a door mimicked the bronze handle. The researchers even used some silk thread similar to the type that holds together some Shang dynasty dagger-axes. LaManna then scanned this dagger with X-rays and neutrons at NIST.

As expected, the brass completely blocked the X-rays. This hid features of the replica from view. But the neutron beam revealed key details, including jade inside the brass handle — even single silk threads.

The replica didn't show any significant radioactivity nine days later. That's normal, Bevitt says. Most samples are safe to send back to labs and museums within a few weeks. But it's unclear just how chemically similar the replica was to the antique dagger-axes. So O'Connor is not yet ready to risk scanning the actual artifacts.

"I am entrusted with the preservation and safety of these remarkable 3,000-year-old objects," O'Connor says.

A new window to the past

Despite the growing popularity of neutron scans, X-rays remain the go-to choice for many researchers. X-rays can uncover small details with no lingering radioactivity. What's more, X-ray machines are widely available and small enough to fit in most labs and museum research spaces.

Right now, there are only a few dozen neutron-imaging facilities on the planet. Neutrons from those scans come from particle accelerators and nuclear reactors. Such machines are therefore large and quite costly. They also require a lot of oversight to work safely.

LaManna thinks there's another major roadblock to more scientists using neutron imaging: They simply aren't aware of what it can do. "I try to recruit as broad a range of users as I can" to submit fossils and artifacts for imaging at NIST, he says.

In the last decade, Bevitt has sung the praises of neutron imaging globally through lectures and outreach efforts. Many researchers in his home country of Australia have already embraced the tech. They bring objects to Bevitt for neutron scanning, just like White's team brought their dino-eating croc fossil.

"Basically, in Australia, when a new dinosaur is discovered," Bevitt says, "the first thing that happens is it comes to our lab."

Researchers at the Smithsonian's Freer Gallery of Art want to know how 3,000-year-old dagger-axes (one shown above) from China's Shang dynasty were made. Neutron imaging could help reveal the dagger-axes' hidden interiors.

FREER GALLERY OF ART

This paleontologist studies ancient mammal movement — virtually

Anne Kort uses 3-D software to piece together pictures from the fossil record

Like most little kids, Anne Kort was fascinated by dinosaurs. But by high school, she had become interested in other kinds of prehistoric life. "I just wanted to learn about everything that wasn't a dinosaur," says Kort. "I like all the weird things."

She found that weird thing while working on her master's degree. She was studying fossils from an extinct mammal called *Patriofelis ulta*. This catlike carnivore stalked the U.S. West roughly 50 million years ago. CT scans revealed something special about the beast's vertebrae.

The backbones of animals have special protrusions that help them fit together. Called articulations, they help keep the spine stable. The vertebrae of *Patriofelis*, though, didn't look like those of today's mammals. They had interlocking parts that "fit together like a lock and key," says Kort.

Now a vertebrate paleontologist at the University of Michigan in Ann Arbor, Kort uses computers to study how mammals evolved to move. Studying fossils virtually allows Kort to examine specimens in ways that are impossible by hand. She even makes YouTube videos teaching others how to study fossils using 3-D software available to the public. In this interview, she shares her experiences and advice with *Science News Explores*. (This interview has been edited for content and readability.)
— *Aaron Tremper*

In graduate school, Kort used CT scans to study the lower backbones of the extinct predator, Patriofelis ulta. Protrusions bookending each vertebra (above) interlocked in a way not seen in today's mammals. A. KORT

Q What inspired you to pursue your career?
A In college, I wanted to do science but not physics or chemistry. Earth science sounded cool. I thought it was about trees, rocks and water. But it is just geology in disguise. During my junior and senior year, I ended up working on CT scans of modern rodent jaws. We were trying to identify similar-looking species from just their jaw bones. We could then go back and identify those same species in the fossil record. That let us track how their ranges changed during the Ice Ages. That's how I got started with 3-D data and paleontology.

Q What do you do in your spare time?
A I play an embarrassing amount of video games. Which, funny enough, is an interest connected with the 3-D scanning and virtual paleontology stuff. I've been playing *Animal Crossing* every morning for, like, half an hour before I start getting ready. I sit in my armchair with my cat on my lap and I have my coffee.

Outside of the lab, Kort enjoys playing video games, visiting museums and hiking. Here she takes on High Falls at Tettegouche State Park in northern Minnesota.

Q What advice do you have for our readers?

A I wish I had been told that networking is just making friends with people who have the same interests as you. It is very important, and you cannot downplay the importance of it. Those connections that I built up over time really are why I'm where I am. But it does not have to be this scary thing. You don't have to think of it as taking things from people.

Also, I think there's kind of an unfortunate perception that you must always have this perfect chain of successes in your career. Otherwise, you're going to fall out of a very competitive field. I see why people think that. But I've definitely met successful people who didn't have this perfect chain of successes. Success is based on chance and opportunity, to some extent. But it's also based on the ability to deal with setbacks when they inevitably happen. And I suspect there's very few people who have literally never had any sort of setback.

MATERIALS

How to make the brightest tie-dye

Which fabric will react most strongly with your dye?

By Science Buddies

Creating cloth with vibrant, long-lasting color requires chemistry. Some fabrics, such as cotton, are made of plant-based fibers. Others, like wool, are protein-based fibers from animals. Still others, like polyester, are humanmade. Dye molecules react differently with all these fiber types. Let's apply one dye to several different fibers and see which one reacts most strongly.

OBJECTIVE

Test how one dye colors different fabric types.

EXPERIMENTAL PROCEDURE

1. Cut three 20 x 20 centimeter (8 x 8 inch) squares from five types of white fabric.

2. Label each square with its fabric type. Wash and dry them all.

3. Cover your workspace with rags or newspaper (or work outside). Put on safety gloves and goggles.

4. Mix together 2 teaspoons of dye powder, 1 tablespoon of salt and 1 cup of warm water.

5. Put one square of each fabric type in three sealable plastic bags.

6. Pour the dye solution into the bags. Add ½ cup of water to each bag and seal it.

7. Gently squeeze the bags every 2 minutes to evenly coat the fabric with dye.

8. Mix together 1 tablespoon of soda ash and 2 cups of warm water.

9. After the fabric squares have soaked for 20 minutes, add ½ cup of the soda ash solution to each bag and reseal it.

10. Let the bags sit for one hour, gently squeezing every 10 minutes to mix the soda ash, dye and fabric.

11. Dump each bag out into a sink and rinse the fabric until the water runs clear. Wash and dry the fabric squares.

12. Look at the colors of each fabric type. Which one reacted best to the dye?

Find the full activity, including how to analyze your data, at snexplores.org/fabricdye. This activity is brought to you in partnership with Science Buddies.

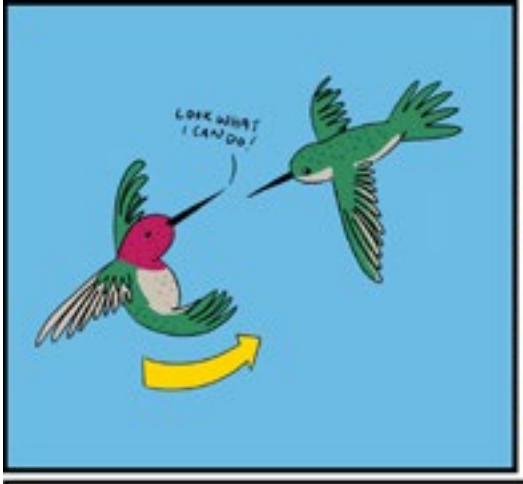
SCIENCE BUDDIES

PHOTO_CHAZ//ISTOCK

How Hummingbirds Flutter Through Small Spaces

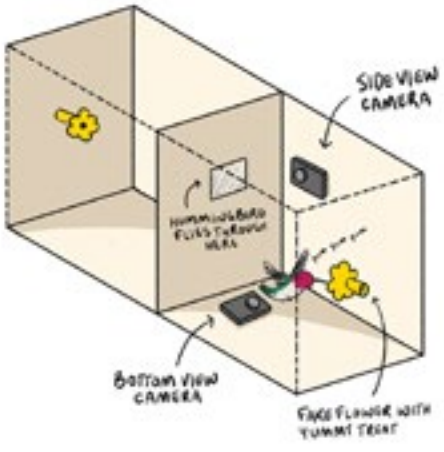
Written by Maria Temming
Illustrated by JoAnna Wendel

Hummingbirds are tiny acrobats. They can fly backwards and even zip around upside-down.

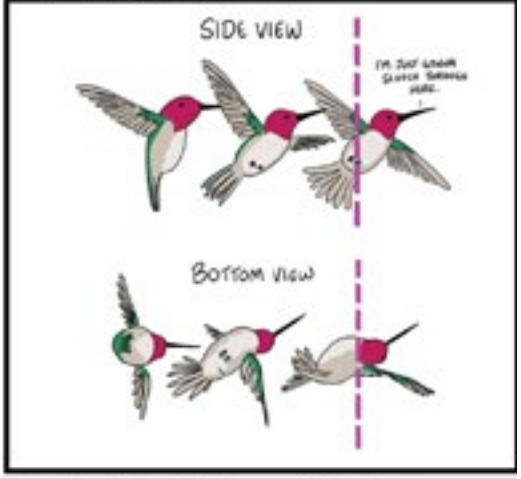


One thing they can't do is bend their wings as they fly. That's what allows other birds to squeeze through tight places. So it's been a mystery just how hummingbirds fit through gaps between branches that are smaller than their wingspans.

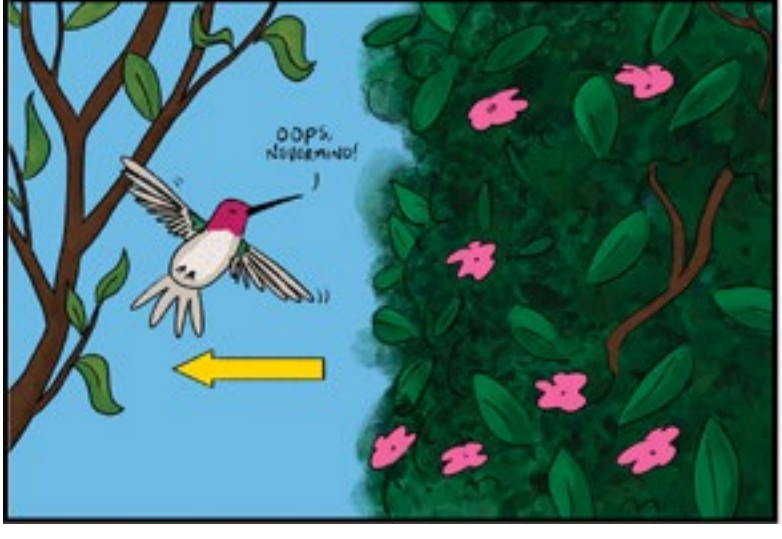
To find out, researchers at the University of California, Berkeley, trained four hummers to fly between two feeders inside an arena. The feeders were separated by a wall with a hole as wide as or narrower than the hummingbirds' wingspan.



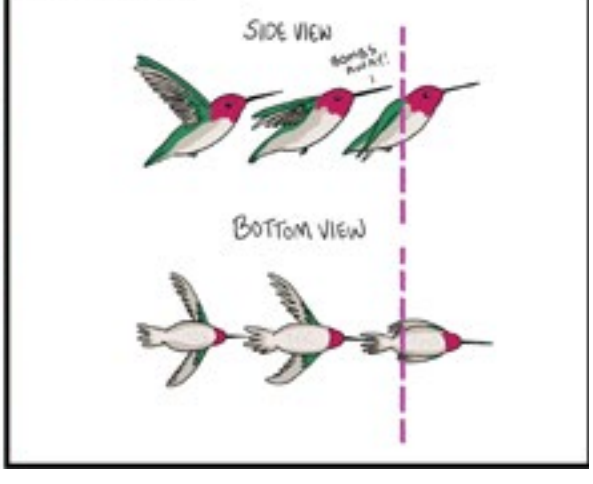
High-speed cameras revealed that, at first, the birds flapped their wings to fly through the gap sideways.



The method might allow hummingbirds to quickly backtrack if they run into obstacles and want to reroute.



After traveling through the gap a few times, though, the birds learned to flatten their wings against their bodies. And they shot through the hole like bullets.



CHEMISTRY

A 'greener' way to make jeans blue

A compound called indican can dye denim with sunlight — and fewer harsh chemicals

With a little help from the sun, blue jeans are going "green."

By accident, researchers stumbled on a new way to give jeans their iconic blue hue. The light-driven process could help dye denim with fewer harsh chemicals.

Denim is usually dyed with indigo. But indigo doesn't easily dissolve in water. Harsh chemicals are used to break it down into a liquid dye. Each year, tens of thousands of tons of these harsh chemicals go into making denim across the world. Many are then dumped into streams as waste.

"It's very toxic to both the environment [and] also the workers," says Katrine Qvortrup. She's a chemist at Technical University of Denmark in Kongens Lyngby. She and her colleagues wanted to find a safer way to make jeans blue.

A SURPRISING FIND

The researchers chose to use indican. It's the substance in indigo plants from which natural indigo dye is made. Unlike indigo, indican dissolves in water. So using it directly needs fewer harsh chemicals.

Other people have used bacteria to make indican. That only makes small amounts, though. To make enough for the big denim industry, the Danish team tried a new way: Tweak an indican-making enzyme found in indigo plants. This enzyme can make enough indican for factory-scale production, the researchers say.

Their first idea was to mix indican with a second enzyme that would convert it to indigo. Then they dipped yarn in this liquid. It worked — the yarn turned blue within a few minutes.

But the team also dipped some yarn in indican alone, without the second enzyme. A few of these samples got left on a windowsill in their lab. And to their surprise, these "were just turning blue without us doing anything," says Ditte Hededam Welner. "We were like, 'What's going on here?'" Welner is a biochemist on the team.

Watch the time lapse video here!

GOING BLUE

The team mixed indican with an enzyme that converts it to indigo. The mixture can dye denim fabric, like this sample. The indigo color develops over time, reaching a deep blue within 40 minutes.

CARLOTTA CHIESA, MANDY HOBUSCH, AND THE TECHNICAL UNIVERSITY OF DENMARK

SVETLANAIS/ISTOCK/GETTY IMAGES PLUS

Indican can also react with light to develop its iconic blue hue. More time in the light can yield a darker color.

It turns out that sunlight reacted with the indican on the yarn, converting it to indigo.

"The light will develop the color," Welner says. "Very slowly, over the next couple of hours, [the yarn] will turn blue, and more and more blue."

And it doesn't have to be the sun. Light from LEDs or even household bulbs work too. The researchers reported this in *Nature Communications.*

HOW 'GREEN' IS THIS BLUE?

Using indican as a dye — with either an enzyme or light — would reduce the harms of denim dyeing. The researchers calculated the environmental impacts of each approach. They looked at things such as waste, carbon dioxide emissions and worker exposures to toxic chemicals.

The enzyme-based method seems most promising. It could cut the harmful impacts by more than 90 percent compared to normal denim dyeing, the scientists estimate.

The light-driven method might cut the impacts by more than 70 percent. But it may use less land than the enzyme method. And using sunlight, not electric bulbs, could make this approach even better for the environment.

But both methods still use lots of water, notes Robert Vos. He's a sustainability scientist at the University of Southern California in Los Angeles. This is a concern because a lot of water also goes into growing the cotton used to make denim.

These methods will need more testing before either can be used in factories. But at least cost shouldn't be an issue. The light method may not raise the cost of denim dyeing at all, Qvortrup estimates. The enzyme method should cost only a few cents more per pair of jeans.

That's a good thing. "We don't want to develop sustainable jeans [just] for the rich people," Qvortrup says. "Our aim is to help to make it a cleaner process and not as polluting."

Welner hopes these methods will have an impact even before they reach factories. Just learning about more sustainable ways to make jeans may make denim-wearers think about where their clothes come from. "If you want to wear blue denim," she says, "be aware that there are better ways to make it" than are used right now.

— *Helen Bradshaw*

TECHNOLOGY

Where are the flying cars?

They might be closer than you think

Kids like Tola Martins in Disney's *Iwájú* don't drive to school; they fly. Harry Potter and Ron Weasley pulled a similar stunt when they missed the train to Hogwarts. As did Flint Lockwood when he had to stop a giant spaghetti storm in *Cloudy with a Chance of Meatballs*.

Flying cars have soared through sci-fi and fantasy stories since the early 1900s. But they're not yet flying across our actual skies. And if they do someday become commonplace, they might look a bit different than on-screen.

The technology to make flying cars already exists, says Xiaosong Du. He's an aerospace engineer at Missouri University of Science and Technology in Rolla. Hundreds of companies are working to make flying cars a reality. Some have even flown prototypes — such as Joby Aviation's air taxi and Airbus' Vahana.

The key to making flying cars work is a combination of helicopter and airplane technology, Du says. It would not be very practical for flying cars to take off like airplanes. For that, they'd need runways, which would take up lots of space. Instead, a flying car would use rotating blades to take off vertically, like a helicopter.

"Once it's completed takeoff," Du says, "you can fly like a normal airplane." Airplane wings could rotate out from the body of the aircraft, allowing for flight with less air resistance than a helicopter experiences.

Another option is to attach propellers to a flying car's wings. At first, the wings would be tilted upwards, so that the propellers could lift the vehicle. Then, once the car takes off, the wings would tilt to lay flat, like those on a normal airplane, says Pat Anderson. "It's like a Transformer." Anderson is the former director of the Eagle Flight Research Center at Embry-Riddle Aeronautical University in Daytona Beach, Fla.

Vehicles with rotating blades and propellers don't sound much like the flying cars of science fiction. Instead, these vehicles would look more like the two-winged choppers that military personnel pilot around Pandora in the *Avatar* movies, Anderson says.

Still, building airborne cars is about more than just bringing sci-fi to life. It's about using more of the available space in the world to get people where they need to go. Today's drivers can only travel in two dimensions: north-south and

Prototypes for flying cars (such as this EH216-S) often rely on propellers, rather than wings, for lift. This allows the vehicles to take off vertically, like a helicopter, instead of relying on an airplane's long runway.

TOMOHIRO OHSUMI/STRINGER/GETTY IMAGES NEWS

The Jetsons was a 1960s-era television cartoon show that depicted a family living in the future. Their flying car helped the Jetson family travel across Orbit City.

WARNER BROS./HANDOUT/HULTON ARCHIVE/GETTY

east-west. Flying cars could unlock a third dimension: up-down. Imagine a world where you could beat rush-hour traffic by simply lifting off the ground and zooming over the other drivers.

WHAT'S THE HOLDUP?

One of the biggest barriers to people commuting in flying cars is expense. Alef Aeronautics, for instance, plans to sell personal cars that can drive on roads and take off into the skies. But they come with a steep price tag. When they go into production as early as next year, the cars will likely cost around $300,000 each.

A handful of wealthy people may own cars like these, Anderson says. But most people could never afford one. Even repair costs would be much more expensive than for a normal car. "If you get in a fender bender, you just destroyed an airplane instead of a car," Anderson says.

Average people may still ride in flying vehicles one day. Anderson imagines that a rideshare service for flying cars — something like Uber or Lyft for the skies — may be more practical than everyone owning one.

Even though some companies plan to release cars sooner, flying Ubers probably won't be common for 10 or 20 years, Anderson says. First, aircraft need to be tested over and over for safety. And the U.S. Federal Aviation Administration will need to create regulations for flying cars. Rules of the road aren't enough. Flying cars will need rules of the sky. "You don't want airplanes falling on top of other people and hurting them," Anderson says.

Powering flying taxis is another holdup. Because of their sustainability, "people are kind of in love with batteries," Anderson says. But batteries are heavy, and — like those in electric cars — have a limited range.

Flying takes a lot of power, especially during takeoff. Current rechargeable lithium-ion batteries can only support flying cars for 20 to 30 minutes, Du says. And while a car that runs out of charge can simply pull over, a flying car would fall out of the sky. So it's extra important that these batteries last. That's why researchers like Du are trying to improve battery efficiency before flying taxis hit the market.

After making sure they're safe and energy-efficient, a big step would be to make flying cars self-driving. Even self-driving cars on the ground are still a rarity. But if self-piloting vehicles ever got off the ground, kids of the future might be able to skip a flying license test and head straight to the skies.

— *Helen Bradshaw*

EARTH

Plate tectonics shapes our planet

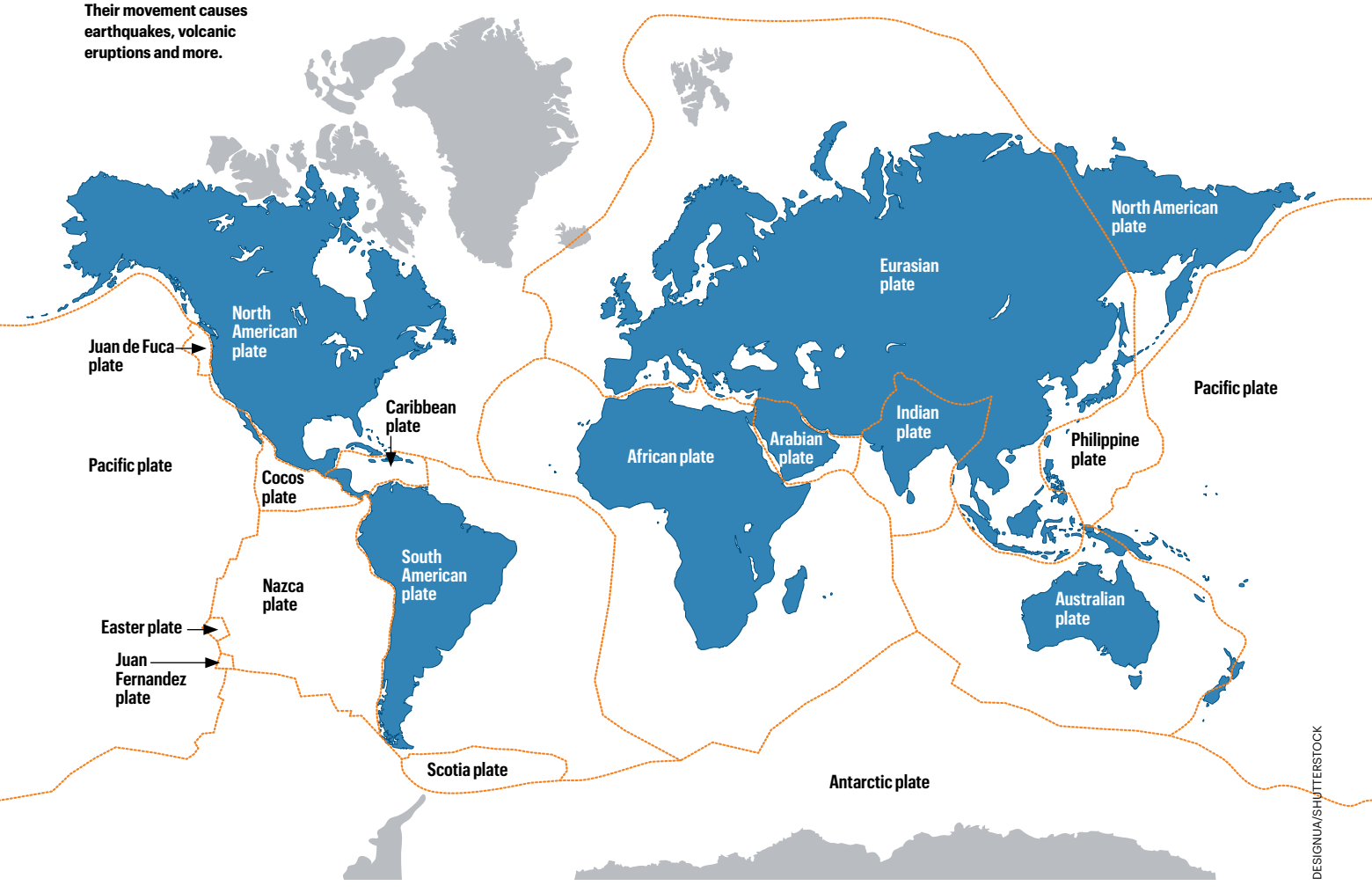
Earth's shifting plates build mountains, volcanoes, continents and more

Earth has been remodeling itself for hundreds of millions of years. Huge masses of molten rock rise from deep inside Earth, cool into a solid, travel along our planet's surface and then sink back down. The process is known as plate tectonics.

Tectonic plates are huge moving slabs that together make up Earth's outer layer. Some span thousands of kilometers (miles) across. Fifteen plates cover almost all of Earth's surface.

You might think of these plates like the cracked eggshell jacketing a hard-boiled egg. Like eggshell bits, plates are relatively thin — on average only about 100 kilometers (60 miles) thick. But unlike an egg's cracked shell, tectonic plates travel. They migrate atop Earth's mantle. Think of the mantle as the thick white part of a hard-boiled egg.

The Earth is covered in more than a dozen tectonic plates. Their movement causes earthquakes, volcanic eruptions and more.



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The plates move from less than 1 to up to 10 centimeters (less than 0.5 to up to 4 inches) per year. The average is about as fast as your toenails grow. Over millions of years, those centimeters add up. So over eons, Earth's surface has changed a lot.

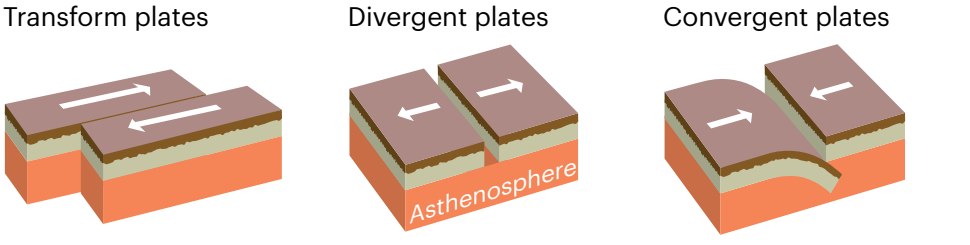
For instance, roughly 250 million years ago, Earth had one giant landmass: Pangaea. Plate movement split Pangaea into two huge continents, called Laurasia and Gondwana. As Earth's plates kept moving, those landmasses each broke apart more. As they spread and traveled, they evolved into our modern continents.

Although some people mistakenly talk about "continental drift," it's the plates that move. Continents are parts of plates that rise above the ocean.

Moving plates can trigger huge impacts. Colliding plates can crush against each other, pushing their edges up into mountains. Volcanoes can form when one plate slides beneath another. Upwelling of the mantle also can create volcanoes. Plates sometimes slide past each other at places known as faults. Usually these motions happen slowly. But sudden slips can cause large movements and trigger earthquakes. And, of course, volcanoes and earthquakes can cause massive destruction.

— *Kathiann Kowalski*

The edges of plates can interact in three ways. The plates can slide against each other (left), pull apart (middle) or push toward each other (right). These motions shape volcanoes, trenches, islands and other features on our planet (below).



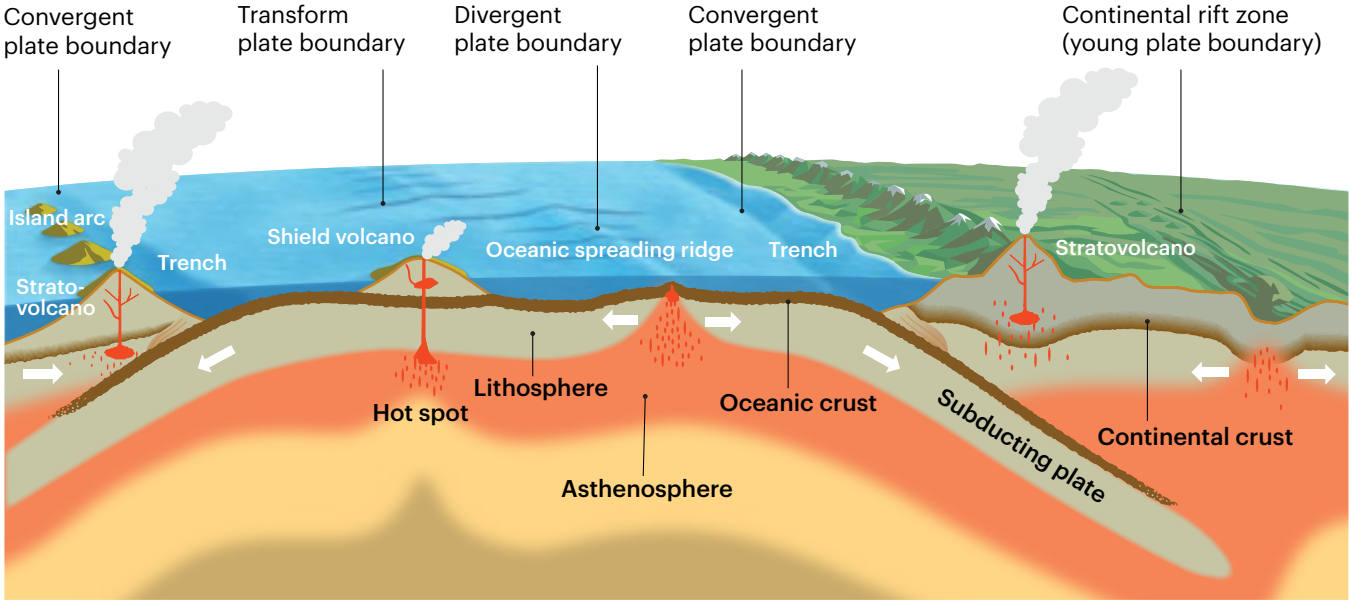


ILLUSTRATION BY STEVE MCCRACKEN

EARTH

Where are U.S. earthquakes most likely?

A new map shows the risk of damaging quakes in different places

The most damaging earthquake to ever hit the U.S. Southeast rattled Charleston, S.C., in August 1886. It killed dozens of people and destroyed many buildings. Better earthquake risk prediction could help people prepare for such natural disasters.

JOHN KARL HILLERS/USGS DENVER LIBRARY PHOTOGRAPHIC COLLECTION

Some 230 million people in the United States face the risk of damaging earthquakes in the next 100 years. That's according to the latest U.S. National Seismic Hazard Model, or NSHM. The NSHM estimates the risk of earthquakes based on historical data and seismic studies. The number of people expected to be at risk by the new NSHM is about 40 million more than NSHM had suggested in models from 2018 and earlier.

"This hazard model forecasts where we think the future earthquakes will occur," says Mark Petersen. A geophysicist, he studies earthquakes at the U.S. Geological Survey in Golden, Colo. The new work also reveals where there's any chance of damage from a quake.

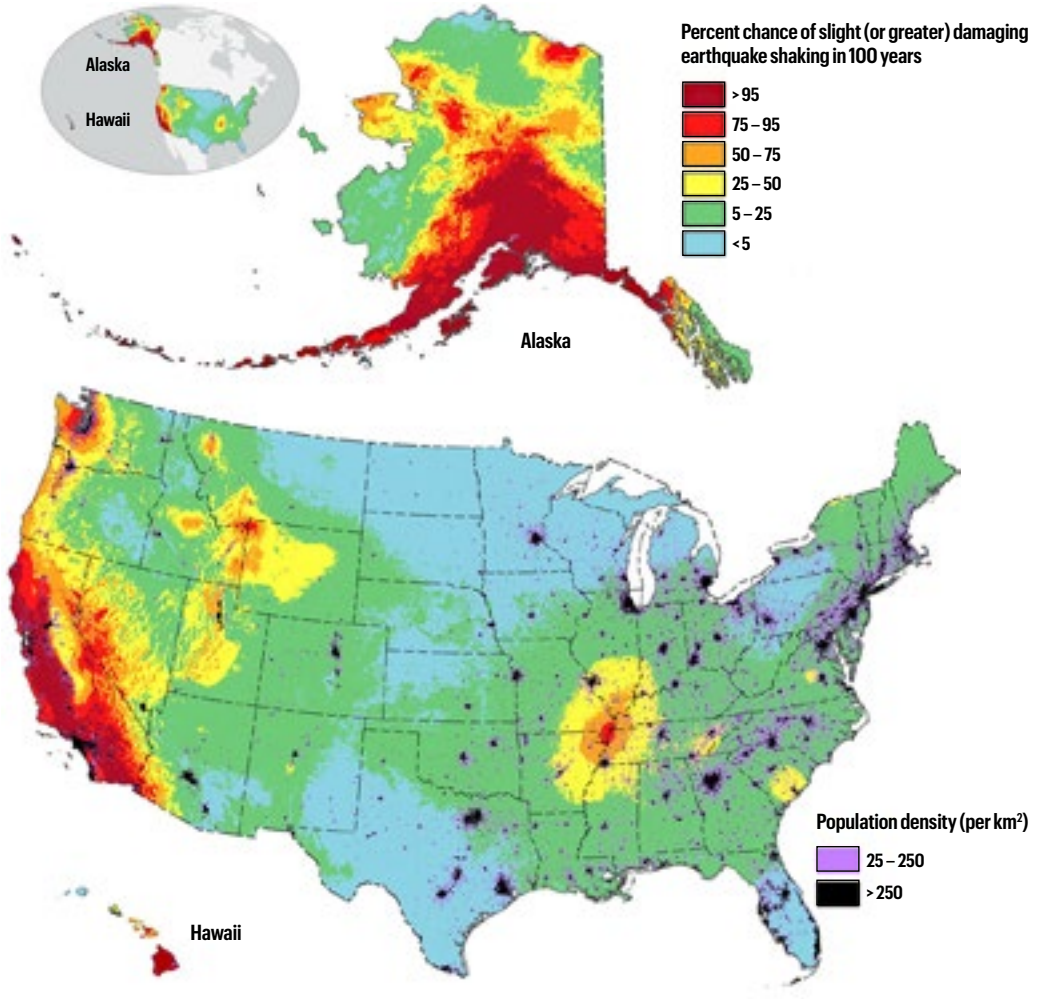
The NSHM draws from data on some 130,000 quakes. That includes recent ones and some that happened long ago. It also considers data from nearly 500 active faults. A fault is a split in Earth's crust where rocks rub past each other. The NSHM also uses new methods that estimate ground shaking at specific places during a quake.

All this new data revealed that, on average, earthquake hazards have increased across the United States. Petersen and his colleagues shared their findings in *Earthquake Spectra*. Their new map will help people prepare for possible temblors.

A quake's energy ripples out in ground-shaking vibrations called seismic waves. The updated model is better at estimating the shaking of sedimentary basins, Petersen says. Those places have deep soil that can amplify seismic waves. That can really boost certain waves from a quake, causing more damage to tall buildings and long bridges. Accounting for amplified waves increased the hazard forecast for cities such as Seattle, Wash., Los Angeles, Calif., and Portland, Ore.

But quake hazards aren't limited to the U.S. west coast. Or even to the places where tectonic plates meet. In the middle of the country, in southeastern Missouri, quakes sometimes rumble along ancient rifts in Earth's crust. And in 1886, a then-unknown fault near Charleston, S.C., caused a devasting temblor. It led to 60 deaths and damaged thousands of structures. The new map draws attention to the earthquake risks those eastern states may face in the future as well.

— *Carolyn Wilke*



This map shows the probability of a damaging earthquake occurring anywhere in the United States in the next 100 years. It's based on the updated National Seismic Hazard Model. An earthquake counts as "damaging" if it is a level VI or higher on the Modified Mercalli Intensity, or MMI, scale. MMI ratings describe earthquakes' severity based on the effects observed during a quake. An earthquake rated as VI is felt by all in the area and can be frightening. It moves some heavy furniture and may knock a bit of plaster off walls. Overall, it results in slight damage.

DATA DIVE

1. Look at the figure's legend. What does it mean when an area is dark red? What does it mean when an area is blue?

2. What places in the United States have the highest risk of a damaging earthquake in the next 100 years?

3. Which of these high-risk places have high population densities? Which of these places have low population densities?

4. Which areas of the United States have the lowest chance of a damaging earthquake in the next 100 years?

5. What other information would be useful to those in places at high risk of damaging earthquakes?

6. What is the risk of a damaging earthquake where you live?

U.S. GEOLOGICAL SURVEY NATIONAL SEISMIC HAZARD PROGRAM

ANSWER

Magnetic fields surround our galaxy's central black hole

A new Event Horizon Telescope image reveals magnetism around Sagittarius A*

Astronomers have gotten their best view yet of magnetic fields around the supermassive black hole at the heart of the Milky Way. Sagittarius A* — or Sgr A* for short — lies some 27,000 light-years from Earth and weighs as much as 4 million suns.

The Event Horizon Telescope, or EHT, took the new image. EHT is a global network of radio telescopes. It gave us the first picture of a black hole back in 2019.

In the new research, scientists looked at EHT data on polarized light coming from around Sgr A*. Polarized light is made up of light waves that wiggle in the same direction. Up and down, for instance. Mapping the polarized light from a source can offer clues to that source's magnetic properties.

The magnetic fields around Sgr A* arise from the stuff near the black hole, not the black hole itself. A huge disk of gas and dust circles Sgr A*, spiraling into the black hole. Hot, dense plasma shrouds that disk. That plasma is made up of charged particles. And the motion of those charged particles whips up magnetic fields.

Researchers shared their findings in two papers published in *Astrophysical Journal Letters*.

— *Adam Mann*

EHT COLLABORATION

The magnetic structures around Sgr A* (pictured) look much like those seen around another black hole in the elliptical galaxy M87 — despite that black hole being about 1,500 times bigger than Sgr A*.

INSIDE THE MIND OF A YOUNG SCIENTIST

A Regeneron Science Talent Search finalist answers three questions about her science

Science competitions can be fun and rewarding. But what goes on in the mind of one of these young scientists? Charisse Zou, a finalist at the 2024 Regeneron Science Talent Search, shares her experience.

Q What inspired this project?

A "It was kind of a chance encounter," Charisse says. "I was at my local flea market, and there was a vendor there who was selling his natural, homegrown honey." She asked him some beekeeping questions, and he invited her to one of his workshops. "As I got more involved in my local beekeepers' community," Charisse says, "I actually learned more about how pesticides or insecticides were affecting [honeybees] ... which kind of spurred my project."

Q What's been your favorite part of this project?

A "Working with the bees. I was out there basically every afternoon," Charisse says. "At first, I was kind of apprehensive about working with bees." But she came to love caring for her two beehives. "I still have my honeybees in my backyard, and we still produce honey," Charisse says. "Out of my research, beekeeping has definitely become a lifelong hobby."

Q Any advice for other research newbies?

A "My advice would be to truly believe that science and innovation can really spur from humble roots," Charisse says. "You don't need a Ph.D. to do amazing research." Charisse did her research from home. Her bee mazes were made from recycled materials, such as toilet paper rolls. "It was definitely not anything extremely fancy," she says.

Regeneron Science Talent Search Finalist

Charisse Zou

Charisse, 18, was curious how two common pest-killing chemicals might affect honeybees. She built mazes in her backyard and trained bees to fly through them. This helped her test the bees' memories. She hopes her research will discourage people from using these chemicals where they could hurt honeybees — which are important pollinators. Charisse attends Dougherty Valley High School in San Ramon, Calif.

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What are three reasons lightning bugs glow?
Why are giraffe tongues blue?
Why do we knead bread?