ScienceNews Explores
June/July 2024

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SPACE OBJECT PUZZLES SCIENTISTS
P30

TELEPORTATION
IS IT POSSIBLE?

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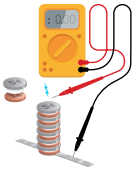

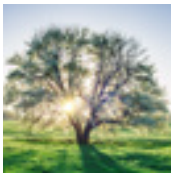

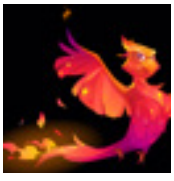

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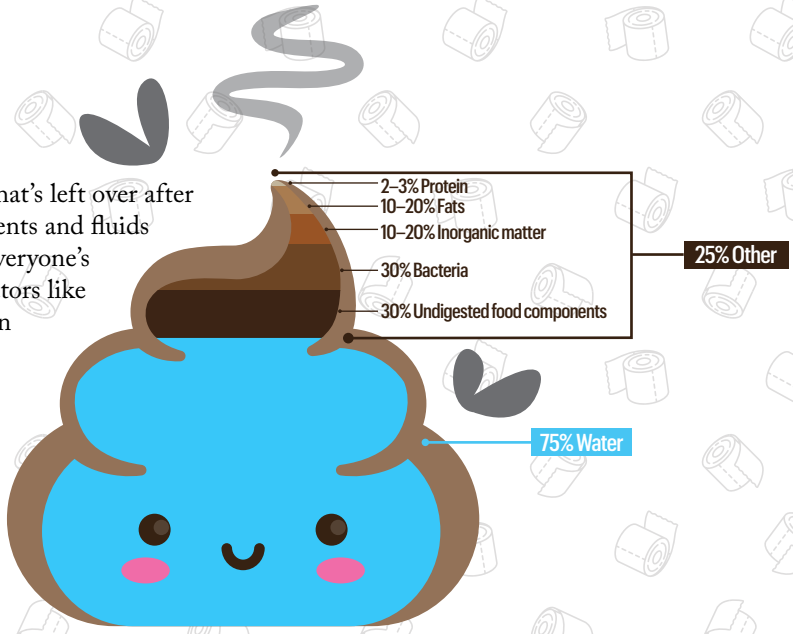
Q What is poop made of?

— Davi S.

A Poop consists of everything that's left over after your body has absorbed the nutrients and fluids it needs from the food you eat. Everyone's poo is different, depending on factors like their diet and whether they're sick or not. But on average, poop is about 75 percent water and 25 percent solid matter. The solid material contains undigested fiber, proteins and fats, as well as bacteria that were living in a person's gut. Poop is often brown thanks to a pigment that is created when a fluid called bile is released into the small intestine. And poo often smells bad thanks to chemicals, such as skatole, that are created by bacteria during digestion.



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Q Why do computers need water?

— Max W.

A In some computers, water is used to absorb heat from warm electronic components and carry it away from the machine. This keeps the computer from overheating, which might otherwise cause the device to slow down or break. Computers have traditionally used fans to keep cool. That's what you'll find in your common laptop or desktop. But water transfers heat more efficiently than air does. It can help a computer keep cool more consistently and make less noise. Water cooling also takes up less space than a fan. So, computers with fast processing and detailed graphics — such as those used by gamers or video editors — might use water cooling systems rather than fans. The computers in remote data centers also use lots of water to keep cool. Data centers are warehouses where computers store much of the world's digital information, such as photos and documents. A large data center might use several million gallons of water each day to keep its army of computers from overheating.

Q How long does it take for a human cell to be reproduced?

— Arizona B.

A About 200 kinds of cells are found in your body. How often a cell reproduces depends on how quickly it needs replacing. Skin cells reproduce about once a day. This helps replace the 50 million or so dead skin cells we lose daily. In contrast, cells found in some internal organs multiply much more slowly, if at all. Liver cells, for instance, only reproduce about once per year, while mature nerve cells never do so. We call the process that cells undergo to grow and divide the cell cycle. Cells spend most of this time growing, copying their DNA and preparing to divide. The actual division of a cell into two identical daughter cells is short-lived, though. Called mitosis, this split only takes about 90 minutes in a human skin cell.

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Do you have a science question you want answered? Reach out to us on Instagram (@SN.explores), or email us at explores@sciencenews.org.

Sarah Zielinski
Editor, *Science News Explores*

ELENA LATKUN, CNUISIN, RAMOSH ARTWORKS/SHUTTERSTOCK

PLANTS

Are blueberries truly blue?

Though the fruit's skin has dark red pigment, tiny structures in the berry's waxy coat scatter blue light

Roses are red and blueberries look blue. But the berry's color is not really true. The fruit's waxy coat just masquerades as blue.

A waxy covering coats some blue-colored fruits — such as blueberries, dark grapes and certain plums. This wax contains a host of tiny structures, each a thousandth the thickness of a piece of paper or less. Such nanostructures scatter blue to ultraviolet (UV) light. To our eyes, that makes these fruits look blue.

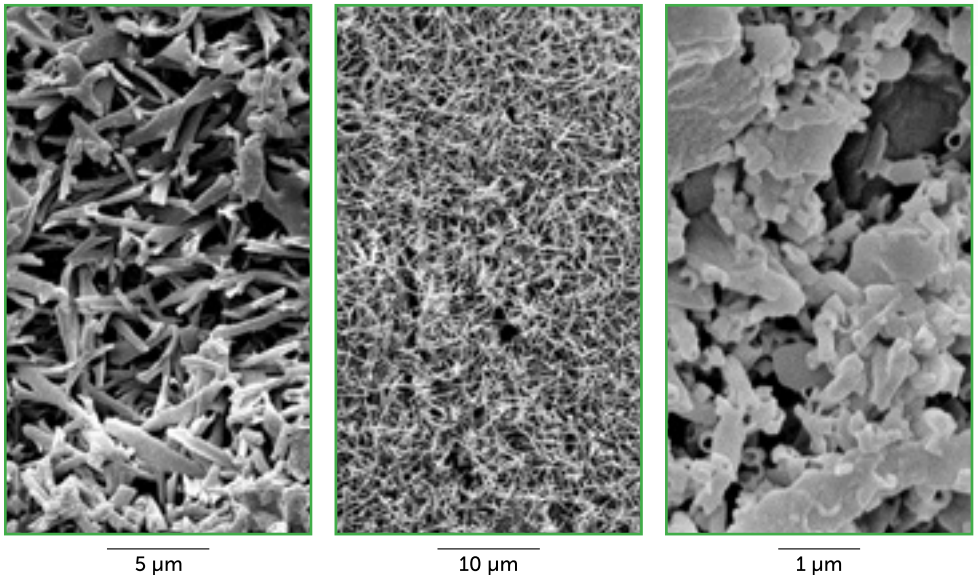
Blue is not a common color in nature. Some fruits appear blue. Few contain pigments in that color. Blueberries, for instance, contain lots of anthocyanin. That pigment usually appears dark red.

But if you rub off the outer layer of wax, a blueberry no longer looks blue — or red. Instead, it's completely dark, Rox Middleton says. Middleton is a physicist who did the work at the University of Bristol in England and at Dresden University of Technology in Germany. Structures in the fruits' waxy outer layers create blue hues that are faux. Her team shared its findings in *Science Advances*.

The researchers zoomed in on the skin of a variety of fruits using a high-resolution microscope. This action revealed tiny molecular structures. Additional experiments revealed that these nanostructures scatter blue and UV light.

Creating materials that mimic a blueberry's coating might prove useful. "This kind of coloring is cool because it doesn't stain," Middleton says. It could provide a new way to tint plastics or makeup blue.

— *Erin Garcia de Jesús*



Researchers viewed blue-colored fruits under a microscope. That revealed textured nanostructures on the fruit skins that reflect blue and ultraviolet light. These nanostructures cover red pigments underneath the waxy coat on each fruit's skin.

R. MIDDLETON *ET AL/SCIENCE ADVANCES 2024*; TIM UR/SHUTTERSTOCK

HUMANS

Writing by hand may boost memory

Compared to typing, students who wrote words with a pen showed more links between brain regions

Writing things out by hand might seem boring and slow. But handwriting can boost links across brain regions. That includes some regions that have roles in learning and memory. The new finding adds to growing evidence of handwriting's benefits.

Scientists snooped on the brain activity of college students who wrote by hand or typed words. Compared with when they typed, more of the students' brain regions worked together when students scribbled with a pen. This trend also showed up in brainwaves — patterns of electrical activity — that have been linked with forming memories. That might mean writing notes by hand could boost memory of the material for a test, for instance.

Previous research had shown that handwriting improves spelling and the ability to remember what you've learned. Handwriting also strengthens the understanding of concepts. Writing out letters and words by hand is slower. Scientists think that gives people more time to process and learn material while activating brain patterns that are important for memory.

This new study hints at why handwriting seems so good for memory. The scientists shared their results in *Frontiers in Psychology*.

Audrey van der Meer and Ruud van der Weel are psychologists. They study the human mind at the Norwegian University of Science and Technology in Trondheim. The pair recruited college students for their new study. They showed students a word on a computer screen, then asked them to type or handwrite it in cursive with a digital pen. All the while, sensors in caps they wore recorded electrical activity in their brains.

Brainwaves look like wiggles of electrical activity. The scientists examined the waves' frequency, which is how many times the waves pulsed per second. The team was looking for different brain regions whose waves were in sync. When those waves have the same frequency at the same time, it hints at how strongly the areas are linked while working on some task.

With handwriting, the researchers expected to see activity increase in brain areas involved with movement. But they also saw a boost in some waves related to learning and memory in certain parts of the brain.

Handwriting — but not typing — strengthened connections throughout the brain, particularly between the brain's outer and central parts. The findings suggest these brain areas could be active during handwriting in a way that they aren't during typing.

The team did not test whether the students remembered the words they wrote or typed. More study is needed to understand how the increased brain activity affects learning.

Students and teachers alike should decide, based on the task, whether to write it out or type, van der Meer says. For example, handwritten notes might help you retain information, but typing an essay gets ideas down on the page faster, before you forget them.

That's why van der Meer says handwriting should not be left behind in the digital age.

"We want the next generation to be able to at least write a grocery list or a love letter by hand. I really think that that is important for us." — *Claudia López Lloreda*

In a lab, college students typed or handwrote a word they saw on a screen. Each student wore a cap outfitted with 256 electrodes that monitored their brain.

NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

PHYSICS

Science explains the burble of pouring water

The sound depends on how much a falling stream ripples

Ah, the refreshing sound of a cool drink of water being poured. You might feel thirsty just thinking about it. Or, if you're a scientist, you might feel curious.

Mouad Boudina certainly was. He's a mechanical engineer. He and his colleagues at Seoul National University in South Korea wanted to know how pouring conditions affect the loudness of cascading water. The key, they learned, was how much a stream of water rippled as it fell.

As a smooth stream of water falls, it tends to form lumps and bumps. Then, it breaks into droplets. (This happens due to a physics effect called the Rayleigh-Plateau instability.) As that rippling water hits the surface of another liquid — such as a cupful of water — air bubbles form. The vibrations of those air bubbles make sound.

Boudina was part of a team that poured water from a tube near the surface of a container full of water. In lab experiments, this pour could not be heard. That's because the incoming stream of water hadn't fallen far enough to form ripples.

When the team poured water from a greater height, things changed. The falling stream of water became bumpy. This increased the sound of the pour.

The researchers shared this finding in *Physical Review Fluids*.

The width of a poured stream of water matters, too, it turns out. Thinner jets were louder than thicker ones poured from the same height. Why? As thin streams fall, they become wiggly more quickly than thicker ones do.

Once the pouring height was large enough that the streams broke up into droplets, what mattered was the size of those drops. Thicker jets pinch off into bigger drops. And they were louder than thinner ones.

— *Emily Conover*

As a stream of water falls, it first forms ridges, then breaks into droplets. This affects how air bubbles form in the liquid receiving the pour (bottom left). That, in turn, explains the different sounds of water poured from different heights.

HO-YOUNG KIM *ET AL*, APS 2023

Think you know what you're seeing? Find out on page 32

Go Outside

By **Alison Pearce Stevens**

Spending time in green spaces can provide big health benefits >>

FATCAMERA/ISTOCK

When did you last spend time in nature? We're not talking about walking down the street or riding in a car or bus. Perhaps you were playing in a field or hiking in a woodland. Maybe you were just lying on the ground, watching birds flit among the branches of a tree. Or observing bees and butterflies as they sip nectar from flowers. If it's been a while, you might want to try it — because research shows we get big health benefits from spending time in such natural spaces.

It's not just about the health benefits of playing sports or doing other outdoor exercise. The simple act of being out in nature can make you feel better, both mentally and physically.

"The idea," explains Anne Schutte, "is that because we evolved in nature, then nature is actually where our brains operate the best." A developmental psychologist, Schutte works at the University of Nebraska–Lincoln. There, she studies the effect of nature on attention and memory.

Research is now revealing that people who spend time in nature tend to breathe cleaner air. But there's more. That outdoor time also can help people once they move indoors again. They are better able to stay focused, soothe stress and much more.

Finding focus

There's some evidence that when we're indoors, in cities or in other built environments, our brains have to work harder to focus. One reason may be that these places are full of people, vehicles and other things that surround us with constant movement and sound.

Those things use up our focused attention, Schutte says. "It's kind of a finite resource. And when we get to a certain point, we have to take a break and let it rest," she says.

Natural environments are different, she notes. Being in nature may come with potential risks, but those are few and far between. "Green spaces — the plants and the trees and so on — are thought to be more restful and relaxing to our attention," Schutte says. So is listening to birds singing in the trees. We can let our minds wander in this environment. And that recharges our ability to focus, she says.

Schutte and her colleagues found data to support this among children who took tests of attention and memory. On one visit to Schutte's lab, kids took those tests indoors. Another time, the kids took them outside where they faced a green space with trees, grass and gardens.

Both times, the children wore a net of sensors on their heads. These recorded electrical activity in their brains. The printout of this is known as an EEG. That's short for electroencephalogram. Specific peaks in the EEGs pointed to spikes in brain activity.

The children successfully completed their tasks whether indoors or out. But the EEGs revealed a difference between the two settings. And the researchers homed in on one specific peak. Its height is thought to be "a measure of the strength of their attention," Schutte explains. A higher peak suggests the brain worked harder to complete a given task.

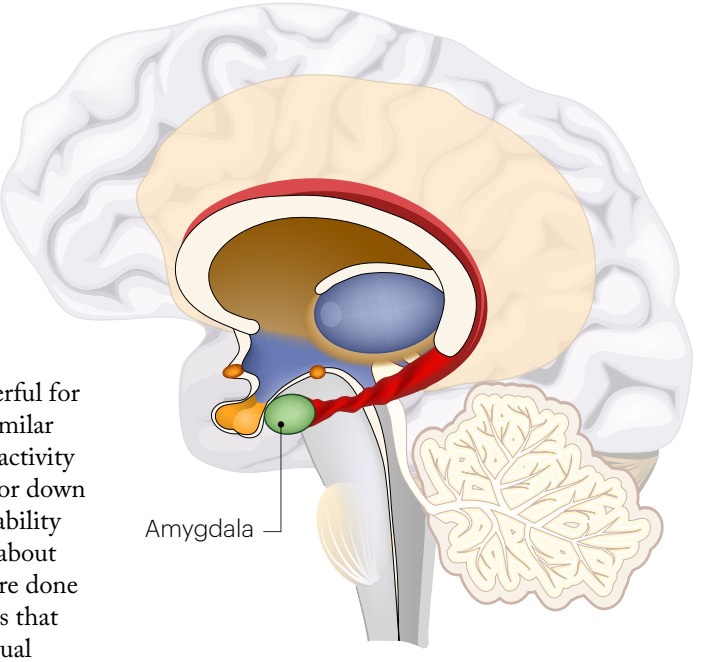
This peak was lower when the children did their tasks outdoors. "They didn't have to work as hard on it as they did indoors," Schutte says. That's despite the fact that their indoor space had been a quiet room. In fact, the outdoor space had "all the sounds of nature," such as calling birds and blowing breezes.

In that study, working outdoors seemed to help all the kids focus.

While completing attention and memory tasks, kids in Anne Schutte's experiment wore an electrode-studded EEG cap, similar to the one above. Peaks in an EEG indicate spikes in brain activity.

FOTOGRAFIXX/E+/GETTY IMAGES

The amygdala, named after the Greek word for "almond," helps you process emotions, make decisions and form memories. Each person has two, one on either side of the brain.



But the benefits might be even more powerful for kids who find it tough to stay focused. In a similar experiment, kids with attention-deficit hyperactivity disorder (ADHD) went for a walk in nature or down a city street. The nature walk improved their ability to complete a task, Schutte says — it helped about as much as medication might. These tasks were done indoors later on, after the walks. That suggests that nature's recharging effects last beyond the actual time spent outside.

Remaining calm

Nature doesn't just improve attention. It boosts mental health in other ways, too. People in cities are more likely to experience mood disorders, anxiety and depression than those living in rural areas, research has shown. Sonja Sudimac wanted to know why. What was happening in the brain to lead to such changes? An environmental neuroscientist, Sudimac works at the Max Planck Institute for Human Development. It's in Berlin, Germany.

People taking part in Sonja Sudimac's study had their brains scanned in an MRI machine, like this one. An MRI can show which parts of the brain are active during various tasks.

PORTRA/E+/GETTY IMAGES PLUS; DESIGNUA/SHUTTERSTOCK

Sudimac recruited young adults for this study. When they arrived at her lab, each answered questions about their stress levels and mood. Then they completed a memory task. They also had their brains scanned in an MRI machine. While in the machine, they answered questions about how much they thought about negative things. They also viewed photos of people who either looked neutral or fearful. And they performed a task that made them feel stressed.

Afterward, they went out for a 60-minute walk. Half strolled through a forest. The other half walked down a busy city street. Then they went back to the lab for more brain scans and tests.

Those scans revealed activity in the amygdala. This brain region tends to light up in brain scans when people feel stressed or encounter something fearful, such as a scary face. All participants' brains showed amygdala activity before the walk (from tasks they completed while in the MRI machine). That level of activity remained the same for test-takers who were scanned after their hour-long walk in the city. But it dropped in people who had walked through the forest, even though the tests they took after the walk were just as stressful as they had been before.

Sudimac's team thinks nature calms the amygdala. It could be that it's just more difficult for the amygdala to get activated after a walk in nature, she says.

Her team doesn't know exactly why nature might soothe this part of the brain. But other research has drawn similar conclusions.

One study looked at the effects of doing something socially stressful. It might be giving a speech when you're not prepared. People in rural areas showed less amygdala activity during such a task than those who lived in cities. Apparently, it's simply easier to become stressed or frightened in cities.

But there's an easy fix, Sudimac adds. "It's incredible how easily we can contribute to our mental health just by adding green spaces."

Physical health perks

The benefits of nature go beyond mental health, says Marcia Pescador Jimenez. She works at Boston University in Massachusetts. As an epidemiologist, she studies the causes of disease. And she's especially interested in how nature might help.

The lower stress levels that people experience in nature can improve physical health, in part by lowering blood pressure. Outside, people also may be more likely to socialize with neighbors. Those connections can help people feel less lonely and generally happier. They also may lead to more exercise when someone starts up a game of tag or frisbee — or maybe suggests a bike ride. Physical activity brings additional benefits, such as better sleep and a stronger immune system.

Nature itself may boost physical health in other ways, too, Pescador Jimenez says. Breathing in dirty air can boost levels of stress hormones and lead to other harmful changes. But plants, data show, can absorb some air pollutants linked to heart and lung problems.

DNF STYLE, GROUND PICTURE, JOSEP SURIA/SHUTTERSTOCK

The benefits of nature go beyond mental health, says Marcia Pescador Jimenez. The lower stress levels that people can experience outside can also improve physical health, such as lowering blood pressure. Riding a bicycle or going for a hike is great, or visiting a city park. Even indoor houseplants can help.

GIMAS/SHUTTERSTOCK; ALBATROS MEDIA

Plants even reduce loud noises that can be stressful and perhaps even cause tinnitus, or a ringing in the ears. Here, the type of green space may make a difference. As you might expect, Pescador Jimenez says, "noise can be better absorbed by trees as opposed to grass."

Some studies even suggest that time outside can aid our vision by giving us things to shift our literal focus — from near to far and back again.

And when you can't get outside

Sometimes we can't make it outside. But being able to view green spaces from a window is still good for us.

One study looked at people recovering from surgery. Some had rooms with views of green spaces. Others didn't. Those who could see nature got better faster. They left the hospital about a day earlier, on average. Those with views of nature also needed less pain medication than those without the view.

In general, "we find that greenness has a higher benefit among urban settings," Pescador Jimenez says. That's especially true of urban neighborhoods where people have less money, she adds. When communities plant street trees or other greenery, people in these areas tend to see a boost in health.

What can you do to reap the benefits of nature? Get out into a park for a walk or to play. Plant a tree, if you can. A tree's canopy of shading leaves "actually helps a ton on those hot summer days," Pescador Jimenez points out. It cools the area, removes air pollutants and lowers the volume on honking cars and sirens.

Can't plant a tree? Try a flowerpot or two on the balcony or windowsill. If that's not an option, indoor houseplants work, too.

"How cool is nature?" Pescador Jimenez notes. It can provide amazing health benefits, just by existing near us. But to keep reaping those benefits, we need to preserve as much green space as we can — taking care of it, so it can take care of us.

READ MORE

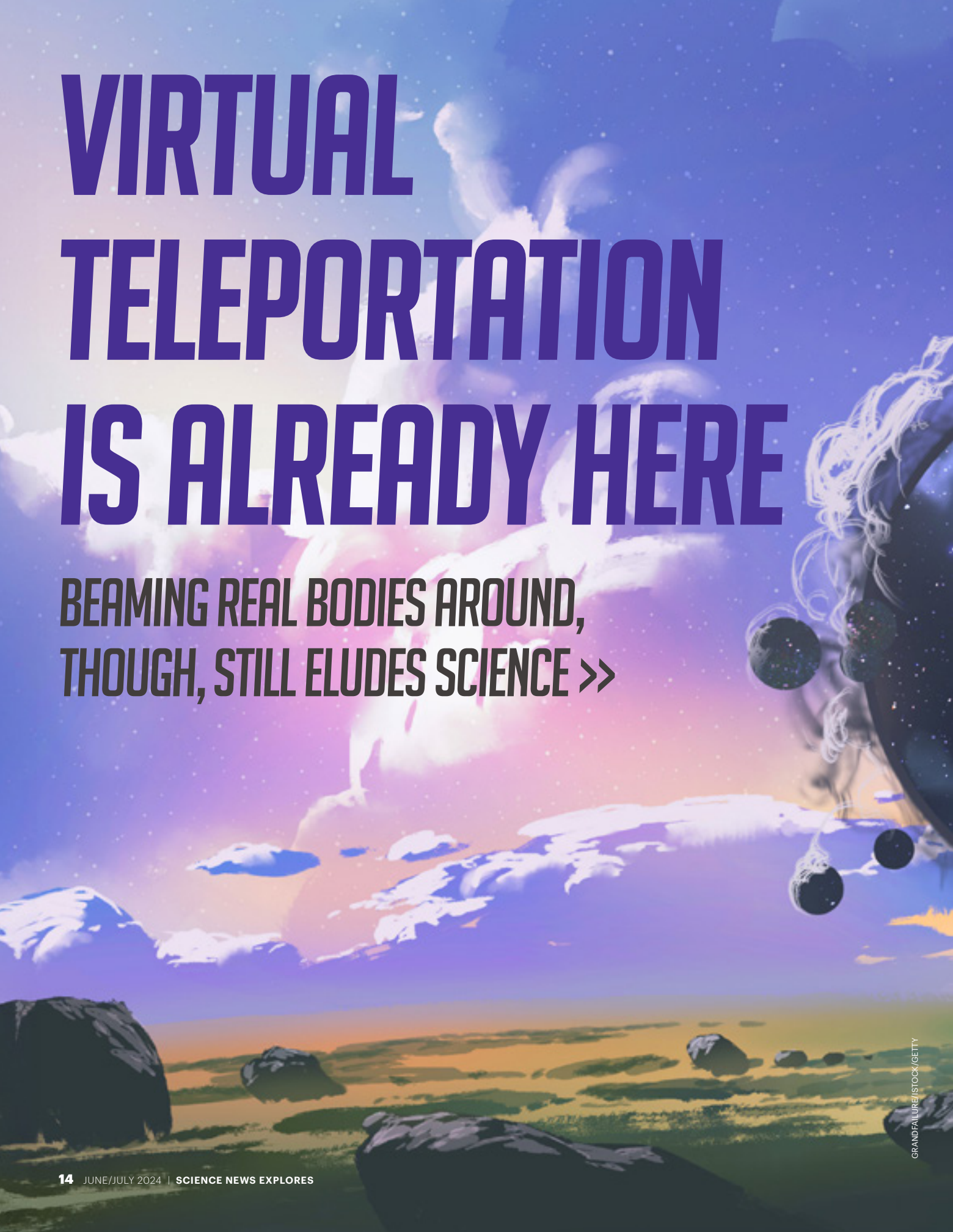
The Language of Plants:
Understanding How Plants Communicate

By Helena Haraštová, illustrated by Darya Beklemesheva

Green spaces are great for our health! Learn about the plants you see outside in this book about how plants communicate, replicate and navigate nature.

VIRTUAL TELEPORTATION IS ALREADY HERE

BEAMING REAL BODIES AROUND, THOUGH, STILL ELUDES SCIENCE >>



GRANDFAILURE/ISTOCK/GETTY

By **Payal Dhar**

Science fiction has inspired plenty of today's technologies. But one that many of us would really like access to remains elusive: teleportation.

It's what the folks in *Star Trek* do, for instance, as they routinely beam themselves to and from distant sites. The process appears to break down people's bodies into energy, then stream them to some destination where they reassemble perfectly.

That type of teleportation is a long way off, scientists say. At least right now, says Paul Weaver, "there's no reason to believe we could do that." You'd need a beam receiver at one site that could "then remotely [re-create a body] in another place." That's still science fiction, says Weaver, who trained in computer science (and claims to be a card-carrying sci-fi nerd).

If, however, we define teleportation as "getting somewhere very quickly," he says, then there are a few ways to do it. One is faster-than-light (FTL) travel. Like *Doctor Who*'s TARDIS, zipping across space and time. Or like the starships of Earth emigrants in *The Ark* (a show that debuted on the SYFY channel in early 2023). The rub: Humans haven't truly managed this yet.

However, Weaver notes, "We do have 3-D printing."

A 3-D printer that is advanced enough, he says, might be able to print a human at some distant destination. Presumably, we could teleport that way. The real challenge, he adds, would be sending the "information" that defines us.

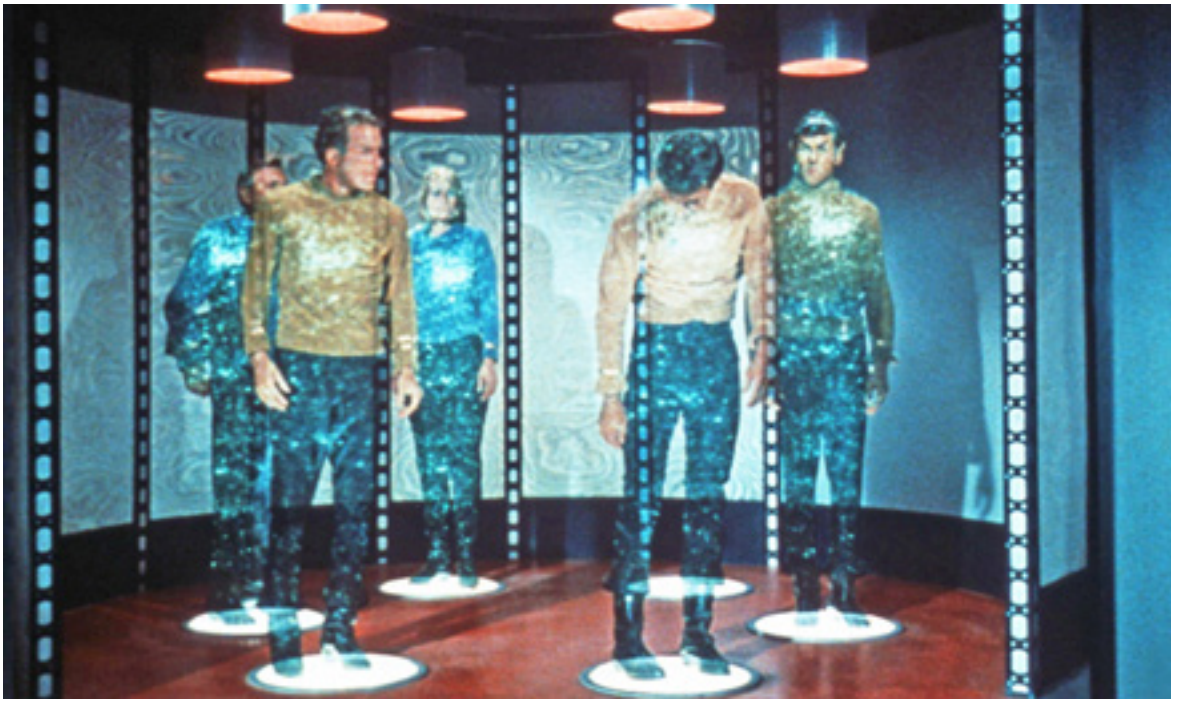
What would that information consist of? How much data would it take to define someone? What bandwidth would we need to transfer those data wirelessly?

In 2012, physics students at the University of Leicester, in England, tried to come up with some numbers. They calculated the time, energy and data needed to teleport someone from Earth to space. At data transfer speeds available 10 years ago, they found, it would have taken at least 4.8 quadrillion years. That's 485 followed by 13 zeroes and is 350,000 times longer than the age of the universe! Even with today's improved data speeds, that type of teleportation remains totally unrealistic.

However, other types of teleportation are quite real. For instance, in 1997, quantum teleportation was demonstrated at the subatomic level. It's related to a phenomenon known as quantum entanglement. (It's something Albert Einstein described as "spooky action at a distance." And for demonstrating its existence, two physicists took home a 2022 Nobel prize.)

In quantum teleportation, two subatomic particles are considered entangled when some aspects of one of those particles depend on aspects of the other — no matter how far apart they are or what may lie between them. To teleport an entire human being, however, is a different matter. It's not just because bodies are much larger. The basic physics also changes dramatically. So that's ruled out for transferring humans.

Fortunately, another type — virtual teleportation — is already here.



In the *Star Trek* franchise, technology can be used to beam people from one location to another, such as from a spaceship to a planet's surface. The process seems to break a person into energy and then reassemble them in a new place. That tech is a long way off. But we can move people around the world virtually now.

ALLSTAR PICTURE LIBRARY LTD/ALAMY

Students at this virtual archeology field school "excavate" in a cave and do lab tests while never leaving their classroom. As one student excavates using a virtual reality headset, their partner performs support tasks in the real world.

Field trip by teleportation

Laura Shackelford works at the University of Illinois in Urbana-Champaign. As a paleoanthropologist, she studies ancient humans. As part of her work, she teaches students how to do excavations. They usually take place at some field school. But in 2017, she started to design something different: virtual excavations.

In one of her sessions, students were "beamed" — virtually — into Mammoth Cave, a national park in Kentucky. Supposedly, a private company discovered natural gas supplies under this site. It now wants to begin mining the gas there by fracking.

Shackelford's students become the archaeologists in charge. Their first task: Study the site's history by excavating it. They must find out if the site has some historic or cultural importance that means it should be left intact.

The students do exactly what they would at a real field school. They learn excavation techniques. They dig up artifacts. They even run lab analyses.

Shackelford's goal is to boost the accessibility of field sites. Field schools tend to be expensive. They also can be quite challenging for people with physical disabilities. Her virtual program gets around those problems. Her students get the experiences they need without having to leave her classroom. From that perspective, she says, "It's been really successful." She's run it twice so far — in 2019 and 2020.

The role of collaboration

Archaeology is very collaborative. To emphasize that, Shackelford's students work in pairs. They take turns donning their team's virtual reality (VR) headset to excavate. At other times they act as the team's support person.

Support partners have a number of tasks. One is to keep teammates wearing the VR headsets from running into objects and their other excavating classmates. "It's partly a matter of safety," Shackelford explains. "I have a room full of students, half of whom are blinded because they're in a virtual [reality] headset."

At a true field site, each pair would be working in a different area of the excavation, Shackelford says. To add that feel for her students, each pair works at a different section of the virtual site. Later, they have to share what they've learned to interpret the data being gathered.

"They can't figure out what the site was used for," she points out, until "they collaborate."

Graduate student Cameron Merrill (top right) worked with Laura Shackelford to create a virtual version of an archeological field site (right). Students can use VR headsets in their classroom to visit the cave, where they learn to set up test pits, dig for artifacts and interpret their finds.

L. SHACKELFORD/UNIV. OF ILL.; CAMERON MERRILL/U. OF ILL.; FRED ZWICKY/UI NEWS BUREAU

In this program, the students will discover that the cave housed a tuberculosis (TB) clinic in the early 1800s. Patients lived there while being treated for the disease.

In the past, TB was a significant problem in the United States. A doctor noticed that caves tended to have clean, dry air. That doctor argued that caves, then, might be good places in which TB patients could recover. In response, some physicians set up clinics in various caves.

"Doctors [later] found that that was a terrible idea," Shackelford says. It proved to be "the exact opposite kind of environment you'd want for TB patients." Her students are now virtually unearthing some of this real TB history. And they're able to take part without the time demands, costs and other challenges of travel and accessing dig sites.

Shackelford hopes to run the program again this year. She also plans to open it to others beyond her own classes. Meanwhile, she's working with her colleagues to improve the course.

For instance, her team wants to make the program accessible to wheelchair users. The researchers are also adding more specialized labs. One lab teaches how to process plant samples. Shackelford is now creating one to study animal remains. Another will focus on dating ancient samples based on the radioactive isotopes in them.

Holoporting into space

What good is teleportation — even the virtual type — if you can't beam people into space? Well, you already can, sort of. In October 2021, NASA beamed one of its medics, Josef Schmid, to the International Space Station (ISS). There, the doctor gave one astronaut a virtual exam.

The space agency used a technique known as holoportation (a mashup of hologram and teleportation). And this term fits: it combines holography with extended reality (XR). To do it, NASA used off-the-shelf hardware.

The headset had an entire holographic computer inside. A motion-sensing camera used advanced sensors to capture high-quality 3-D "models" of the team to be "transported." Those data were then compressed and transmitted live to the ISS. An app called HoloWizard (designed by the software company AEXA) powered the system.

Schmid is a NASA flight surgeon. Being a medical doctor, he takes care of astronauts and

At the University of Illinois Urbana-Champaign, Laura Shackelford (left), David Huang (center) and Cameron Merrill (right) are now working to improve their virtual excavation program based on feedback from users. One priority is to make the program accessible to wheelchair users.

FRED ZWICKY/UI NEWS BUREAU

In the Star Wars universe, Jedi masters could show up to meetings as holograms. Their virtual representations could join conversations as if they were actually in the room.

their families. But for his visit to the ISS, he never left Earth. NASA projected him up there as a 3-D hologram. It also did this for other members of the team, such as AEXA's chief, Fernando De La Peña Llaca. The astronauts could see the virtual visitors and interact with them in real time.

"We knew we were connected when the crew member [wearing the headset] said, 'Whoa!'" recalls Schmid. "We were floating in front of him … as if we were there."

But Schmid and the others remained firmly on the ground. A portion of the space station appeared to be floating in front of each of them. It was "like I was looking into a portal into [the ISS]," Schmid recalls.

The imagery wasn't perfect. There were pixelation issues. And sometimes the linkup turned wobbly. But for Schmid, it felt like a glimpse into the future.

While "on" the ISS, he demonstrated a cranial nerve exam. It's something he might perform with a patient in his office. He also showed the crew how to do a knee exam. Then he proceeded to virtually shake the hand of astronaut Thomas Pesquet. (This was the first ever Earth–space handshake, but it's unlikely to be the last.)

Next time, Schmid hopes NASA will use two motion-capture cameras. That way, people in both places — on Earth and in space — can be "present" in each other's spaces as holograms. He also would like to experience a VR setting in which "you look around — behind you, above you and below you — and you're in the space station." He looks forward to such house calls. Or in this case, maybe they'd be "space calls"?

EUROPEAN SPACE AGENCY ASTRONAUT THOMAS PESQUET (CC BY-SA 3.0 IGO); PICTURELUX/THE HOLLYWOOD ARCHIVE/ALAMY

NASA flight surgeon Josef Schmid gives a Vulcan "live long and prosper" space greeting on October 8, 2021. It was part of his holoported visit to the International Space Station, where he did a medical exam on an astronaut.

One day, holoportation might be used for private medical and psychiatric visits with astronauts. It might also allow NASA to host dignitaries at the space station. Schmid can even imagine astronauts dining with their families — virtually. "Really," he says, "the sky is no longer the limit."

Beyond teleportation

XR is not a new technology. Neither is holography. Engineers are just finding newer ways to use them. XR for virtual teleportation has, in fact, been around for a while. During the pandemic travel limitations of 2020 and 2021, the tourism industry tapped into XR to offer virtual tours. Some companies now use it for factory visits, tours of sports stadiums and more. Others are working on ways to let people work together in an immersive, virtual environment (such as site visits and meetings).

As NASA has shown, holoportation has great potential for 3-D telemedicine. The space agency can even imagine true extraterrestrial use, such as for future missions to deep space.

But there are also plenty of potential uses here on Earth. People could holoport to safely visit extreme environments, such as Antarctica during its months of frigid darkness. Doctors might also use it to "visit" patients on offshore oil rigs or at military bases on the frontlines of conflict.

But to physically teleport someone from one place to another? "As far as we know," Weaver says, "right now there doesn't really exist any technology that can scale up to transport an entire human being."

This computer scientist is making virtual reality safer

Niall Williams creates new algorithms to help people walk more naturally through virtual worlds

Virtual reality headsets aren't without their risks. Users can bump into walls, furniture or even other people. Niall Williams is looking to fix that. This computer scientist makes programs that keep people safer while using VR. He works at the University of Maryland in College Park.

Williams works with redirected walking. This technique nudges users along a path in the real world by subtly changing their virtual display. Developers can tweak how VR programs represent traveling distance, says Williams. For example, algorithms can make two feet of walking in the real world cover more virtual ground. This lets users walk naturally while exploring large digital spaces.

Fast or large adjustments can leave users disoriented and queasy, though. Redirected walking also works best in areas with fewer obstacles. To help, Williams designed a program that calculates a safer path for users. It avoids both physical and virtual obstacles. "We kind of play tricks on people to get them to walk around safely," says Williams.

His algorithms stopped more collisions than other redirected walking programs. By using slower changes, they also lower the odds of motion sickness. Williams is exploring other ways to use natural walking in virtual spaces, he says. In this interview, Williams shares his experiences and advice with *Science News Explores*. (This interview has been edited for content and readability.) — *Aaron Tremper*

Q What inspired you to pursue your career?

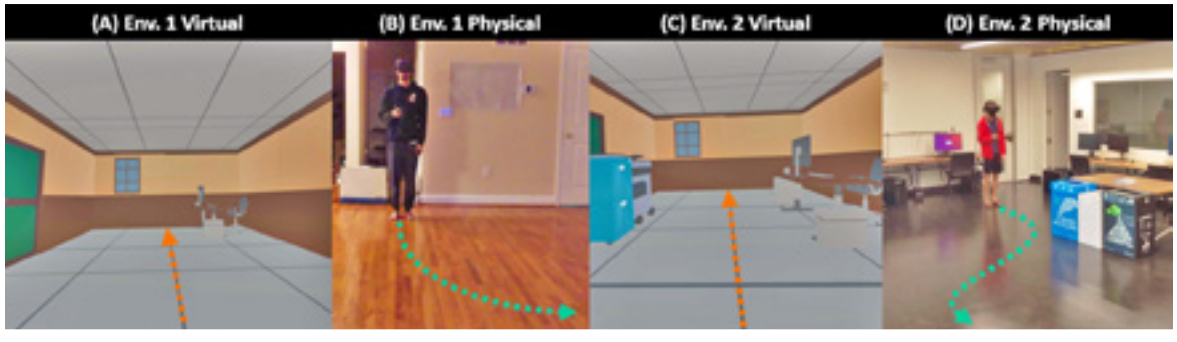
A I wanted to study biology, but I wasn't good at chemistry. I liked programming and got some experience in high school. So I decided to do a computer science degree. After a few years, I learned about computer graphics. It's a combination of all of my interests. I also really enjoy video games, animations and art.

Q How did you get to where you are today?

A There are a lot of Ph.D. students in my lab that work on different things. In our lab meetings, the students studying robotics would discuss problems they were working on. I saw this interesting intersection between robotic navigation and virtual reality (VR) locomotion. Robot navigation is getting from one point in the environment to another point without getting stuck. Sort of like how your Roomba knows where to go in the room to figure out where it needs to clean.

A big problem in VR locomotion is that you're seeing a virtual environment through the headset, but you're physically located in a different environment. If you want to reach some destination in the virtual world, your path to that destination is likely blocked by some physical objects. I realized that I could probably sort of combine the two fields after talking with my lab mates. This might help people avoid objects when they're in VR.

N. WILLIAMS



Niall Williams (top) tested his algorithm in different physical and virtual scenarios. In one test, the virtual environment was larger than the physical space available (bottom left). The program guided the user along a curved route in the physical world to compensate. In another test, the program had to navigate a straight virtual path while avoiding real-life objects placed in front of the user (bottom right).

Q What piece of advice do you wish you'd been given when you were younger?

A I wish someone told me earlier on that a Ph.D. can be fun. Becoming a scientist should be fun, and it often is. Sure, it'll be difficult and you'll have to work hard, but you get paid to study whatever you think is interesting. Your only real responsibility is to think deeply about that problem or topic and try to contribute some new piece of knowledge. It's a unique experience that is not the same as just doing more school.

I also wish someone told me early on that being a scientist is a real career path. Scientists are not just fictional characters in movies. We're real.

CHEMISTRY

A battery that makes cents

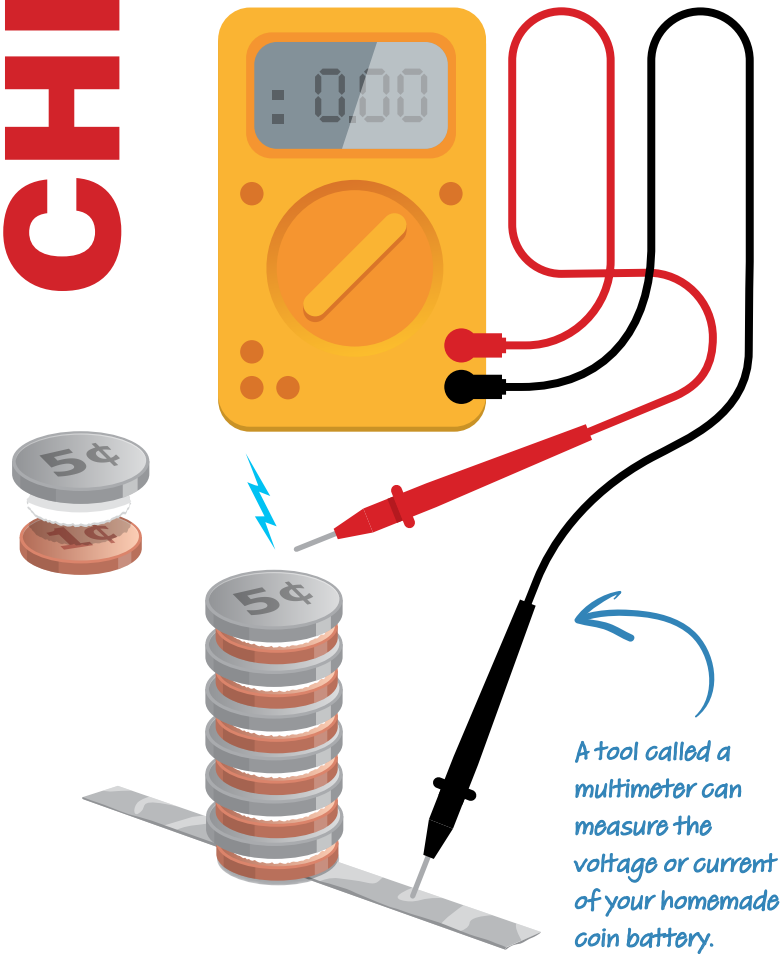
Build and test your own coin-based battery

By Science Buddies

In a type of battery known as a "voltaic pile," charged particles move from one metal to another through an electrolyte. That movement of charge creates an electric current that can power other devices. Let's make voltaic piles using a vinegar-based electrolyte sandwiched between different coins. Then we can see how adding more coin-electrolyte sandwiches to the pile affects the battery's electrical output.

OBJECTIVE

Test how the number of coins in a "voltaic pile" affects the battery's output



EXPERIMENTAL PROCEDURE

1. Mix ¼ cup of vinegar with 1 tablespoon of salt.

2. Cut a strip of aluminum foil 2 by 8 centimeters (0.8 by 3.1 inch). Fold it lengthwise three times.

3. Cut a paper towel into circles slightly smaller than a penny, and soak each one in the salt-vinegar mix.

4. Put a penny atop the foil strip, cover the penny with a paper-towel circle and top that with a nickel.

5. Place another penny atop the stack, cover it with a paper-towel circle and top it with a nickel.

6. Touch one probe of a multimeter to the foil strip. Touch the other to the coin pile's top nickel. This will let you measure the voltage and current produced by the pile.

7. Record those values and the number of coins in the pile in a notebook.

8. Repeat steps 5–7 and create two graphs: one that plots voltage against number of coins in the stack, another that plots current against number of coins.

9. How do voltage and current change when you add more coins?

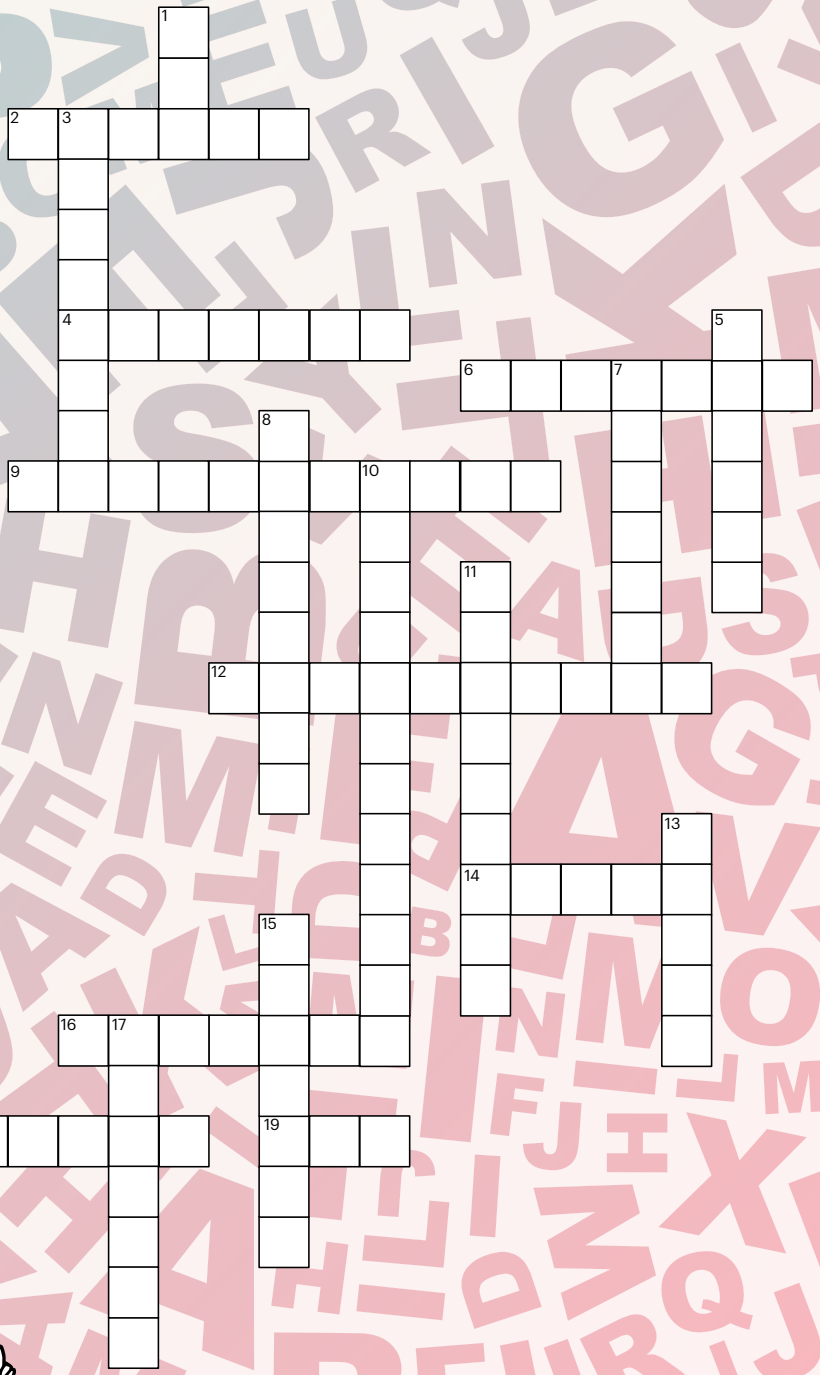
Find the full activity, including how to analyze your data, at snexplores.org/coinbattery. This activity is brought to you in partnership with Science Buddies.

SCIENCE BUDDIES

ILLUSTRATION BY STEVE MCCRACKEN

Crossword

If you're having trouble figuring out the answers to the clues below, make sure you read all the stories in this issue. Check your work by following the QR code at the bottom of the page.



BEKUL NIS/SHUTTERSTOCK

ACROSS

2. A portable computer that contains billions of transistors

4. The pigment color in a blueberry's waxy coat

6. This type of teleportation has been achieved at very tiny scales

9. These types of notes will help you retain more information

12. These cause air bubbles in a stream of water to make sound

14. A new species of hedgehog was found in this country

16. Reddish glows above thunderstorms that may resemble carrots

18. A dry, shrub-filled area that's prone to wildfires

19. A shortened version of "electroencephalogram"

DOWN

1. A lightning strike that zips upwards from a cloud instead of down

3. A brain region associated with stress and fear

5. A spinning dead star that flashes like a lighthouse

7. This type of star is the left-behind corpse of a giant star

8. Along with fiber and fat, these are a third part of poop solids

10. A disease nicknamed "TB"

11. Students on a virtual field trip to a cave can dig these up

13. A type of wood used in a new type of transistor

15. A voltaic pile is one example of this type of device

17. A mythical fiery bird

TECH

Balsa wood transistors could lead to 'greener' electronics

Chemical treatment can turn this wood into a building block of electrical circuits

A new approach to making "green" electronics could come from a tree.

A team in Europe has invented a transistor made from balsa wood. Wood-based electronics could require fewer mined materials than today's devices. And they could result in less climate-polluting gases.

Transistors play a critical role in computers and other electronics. They act like tiny switches to control the flow of electricity. Engineers use them to process and store data.

Transistors are usually made of silicon. Producing silicon can release large amounts of pollutants. One, carbon dioxide, causes climate warming. And nitrogen oxide gases can harm people's lungs and worsen asthma. Turning this silicon into devices then relies on fluorinated gases. These are thousands of times more potent at warming the climate than CO_2.

A wood transistor would need no silicon at all. And it opens up new ideas for possible uses. Physicist Daniel Simon calls it "a big deal." He works at Linköping University in Sweden, where the new device was made. But he wasn't part of that team.

Maybe future electronic devices could be made in living plants, Simon says. "Imagine peeling away some bark from a living tree," he says, "and stamping electronic circuits into the living wood."

Wood doesn't conduct electricity when it's dry, notes Van Chinh "Robert" Tran. A graduate student at Linköping University in Sweden, he led the design of the new transistor. So first the team had to alter wood to allow electricity to flow through it.

There are at least two ways to do this, says Guido Panzarasa. He's a materials scientist at ETH Zürich, in Switzerland. You could treat the surface of wood in a way to turn it into a better electrical conductor. He's working on devices that use this process.

A second approach uses the structure of the wood to support conducting materials. That's the idea behind the new Linköping transistor.

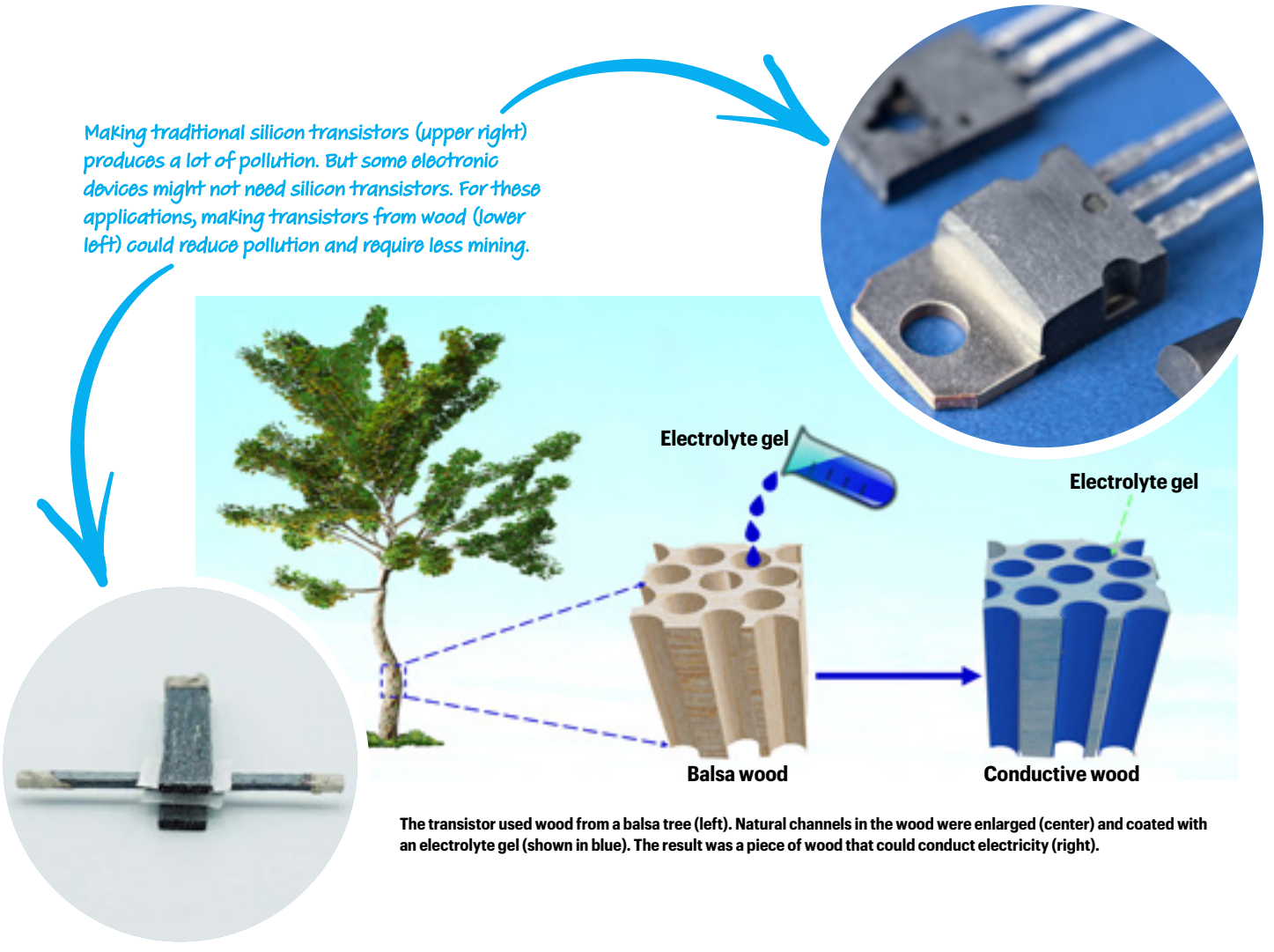
Wood is porous and full of channels. Water flows through these channels as a tree grows. But when they dry, those channels empty out. Tran's group suspected those channels could be useful — especially if they were a bit larger.

Lignin is the material in cell walls that helps plants stand tall. Using heat and chemicals, the Linköping group removed lignin. That opened more space in those channels. Then, the team coated the insides of those hollowed-out channels with a material that conducts electricity.

One day, wood might become the basis of a new type of green electronics. Devices could be made from — or even inside of — trees.

MISHA KAMINSKY/E+/GETTY

Making traditional silicon transistors (upper right) produces a lot of pollution. But some electronic devices might not need silicon transistors. For these applications, making transistors from wood (lower left) could reduce pollution and require less mining.



The transistor used wood from a balsa tree (left). Natural channels in the wood were enlarged (center) and coated with an electrolyte gel (shown in blue). The result was a piece of wood that could conduct electricity (right).

HOW IT PERFORMED

The team built a transistor with three small pieces of the treated wood. Each was one millimeter (0.04 inch) thick and 30 millimeters (1.2 inches) long. Two pieces were five millimeters (0.2 inch) wide, and the third was two millimeters (0.08 inch) wide. The narrower piece was sandwiched crosswise between the other two to make the shape of a lower-case letter t.

This device worked like an electrical switch. The top and bottom pieces acted like a gate.

The channels of the middle piece were filled with a gel called an electrolyte. Charged ions flowing through this electrolyte created a current. But when a voltage was applied between the top and bottom pieces, it changed the conductivity of the channel in the middle. It basically turned the ion flow "off."

By turning the voltage on and off, the researchers could control the flow of current through the middle piece.

The team tested balsa, pine and ash wood. Balsa conducted electricity three times as well as either of the other two. This may be because it is less dense than other woods, with large channels.

This result shows a "proof of concept" — that the idea can work, even if the wood-based device is not yet ready to put into today's electronics.

Today's laptops may hold billions of transistors. For all of these to fit, they must be tiny — only a little wider than a strand of DNA. The wood transistor is big enough to see and hold. And it can withstand only a low voltage. (Voltage is like an electric pressure that pushes electrons along.)

Such a transistor still might prove useful for electronics that require little voltage, says Isak Engquist. He's a physicist and engineer who led the Linköping team.

Engquist's team next wants to improve the device so it can handle more voltage. They're also looking to find the right application.

That might be an environmental sensor, Tran says. Or maybe a tree-based battery. Wood-based devices could let the researchers dream big. "We have even discussed growing the transistor inside the tree," Tran says. How's that for the ultimate in green electronics?

— *Stephen Ornes*

LIFE

Phoenixes aren't the only creatures to survive the flames

Fires can kill all living things, but some creatures do like it hot

The phoenix has reached the end of its life. With a loud cry, this beautiful crimson bird bursts into flame. A few minutes later, from a pile of hot ash, a baby bird pokes out its tiny head. The phoenix has burned, but it is born anew.

This is a myth found in ancient Greek and Egyptian stories. Now, references to the phoenix can be found across fiction, from *Harry Potter* to the anime *One Piece*. There are no real phoenixes hiding anywhere. But science has revealed that some living things can take quite a bit of heat. And like a phoenix, a few are even born from the ashes.

Tardigrades are reputed to be one of the world's toughest critters. After all, these hardy little animals can survive the vacuum of space. But a warm day at the beach might be a challenge. Used to cool, damp moss, tardigrades begin to die at temperatures between 29° and 37° Celsius (84° and 99° Fahrenheit). When times get tough, tardigrades can enter a state of suspended animation called "tun." But even then, they can't take more than an hour at 83 °C (180 °F).

And while that's hot, it's not as hot as fire. Even the coolest flame starts at 600 °C (1,110 °F). No living thing can take that kind of heat, says Robert Kelly. He is a chemical engineer and microbiologist at North Carolina State University in Raleigh.

When something is on fire, the carbon in the chemicals in that item combines with oxygen to form carbon monoxide and dioxide. This is combustion. Because carbon is found in every living thing on Earth, nothing living can survive burning. "Not without protective gear," Kelly says.

But some living things can survive high temperatures. Kelly studies hyperthermophiles.

Some weevils (opposite page) can survive temperatures above 50° Celsius (120° Fahrenheit). And while they can't survive a direct flame like a phoenix (right), the bugs have a survival strategy for an oncoming fire. Some species lay eggs inside plants that can beat the heat. When the fires fade, the weevil eggs hatch — like a phoenix from the ashes.

These single-celled life forms live in places like hot springs or deep-sea vents. Some are bacteria. But the toughest, hottest of all are members of the archaea — one of the three domains of life.

Not all archaea love the heat, but the ones Kelly studies do. The upper limit for these heat-hardy cells is 120 °C (250 °F) — well above the boiling point of water. If a person were to step into the hot springs where they live, Kelly says, "your skin will basically just fall off your bones." At temperatures that high, he explains, meat — including human muscle — cooks instantly.

That heat offers challenges to the archaea, Kelly notes. Proteins — important complex molecules in cells — begin to fall apart. Kelly and his colleagues have found thousands of tiny relationships between molecules that help hold the cells together as temperatures soar. "Nature has a lot of very subtle things they do to stabilize a protein," he says.

SURVIVING A FIRE

A phoenix might be able to use some of those tiny chemical reactions to keep its proteins together. But a whole bird — even just a baby — is a lot larger than a single cell. Luckily, some animals have learned to survive heat — even as their world burns.

In South Africa, tiny beetles called weevils live in the fynbos — a dry, shrub-filled area that's prone to wildfires. Marion Javal was on a hike there with her friends in 2018 and crossed an area that recently had burned — and she got inspired. Javal is an entomologist — someone who studies insects — at the Institute of Research for Development in Montpellier, France.

In the burned area, "we saw a bunch of very tiny weevils walking on the floor. But, like, very, very small insects that are not really able to fly," she says. "So we started wondering how and why they were [t]here." Weevils that were able to fly would be able to escape a burn. But insects that can't fly are stuck, she says. Insects are ectothermic — their bodies are the same temperature as the air around them. As the air heats up during a wildfire, they do too. How did the tiny, flightless bugs survive the burn?

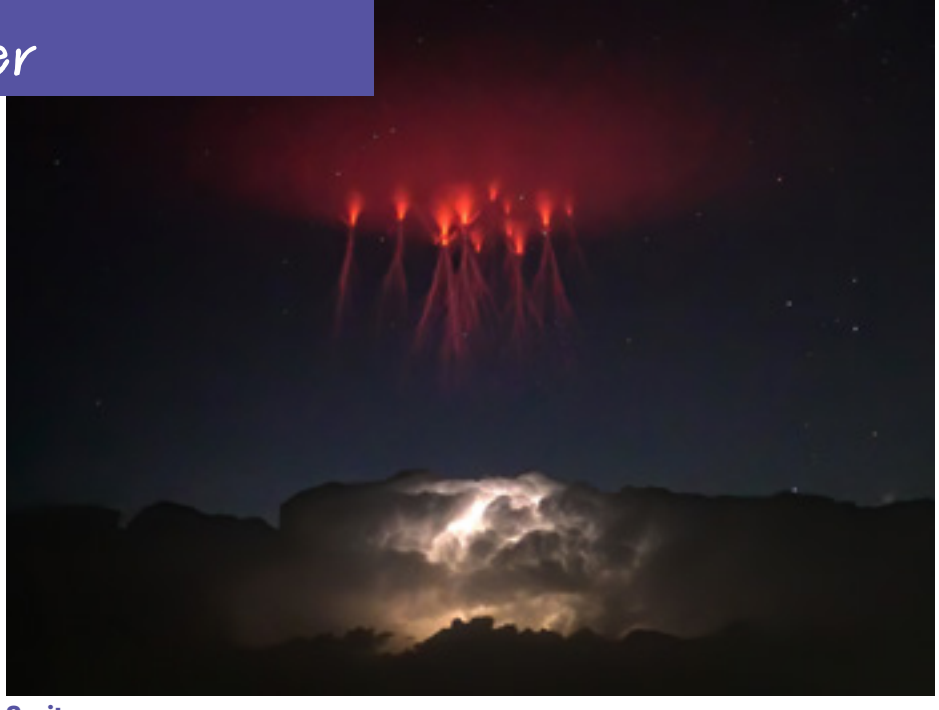
Javal and her colleagues collected weevils from the area and tested how much heat they could take. One species, *Ocladius costiger,* could survive up to 52.6 °C (127 °F). Another, *Cryptolarynx variabilis,* lived up to 53.4 °C (128 °F). "It was quite unexpected to try to find such high temperature for these very tiny weevils that we had in the study," Javal says. The scientists published their results in the journal *Ecological Entomology* in 2022.

The beetles might have some adaptations in their cells to help them survive, Javal notes. Some adult beetles also can dig down into the soil to flee the flames. And some species, she notes, lay eggs inside plants with tough, woody exteriors. Those plants can survive the heat of summer as well as any fires intact, protecting the eggs inside. And then, when the fires die away, the weevil eggs hatch — like a phoenix from the ashes.

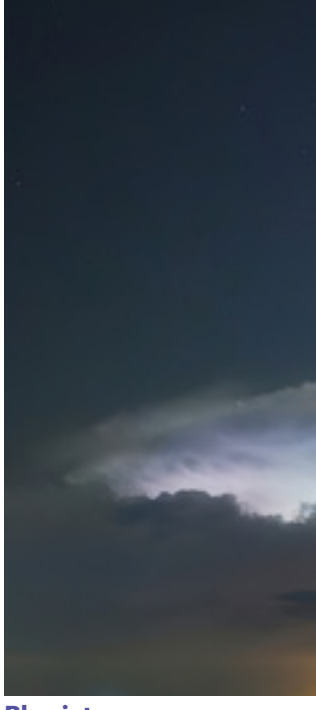
— *Bethany Brookshire*

KLYAKSUN/SHUTTERSTOCK; RÉMI ALLIO (REMIALLIO.GITHUB.IO/)

EARTH



Sprites



Blue jets

The weird lights known as sprites, jets and ELVES

A variety of 'transient luminous events' flash in the skies above intense thunderstorms

Photographer Paul Smith recalls the first time he captured a sprite. He was shocked.

It was the summer of 2017. Smith had gone out to California's Mojave Desert to photograph a meteor shower. While driving, "I thought I saw sprites out of the corner of my eye," he says. "Just flashes on the horizon."

These sprites were no fairytale creatures. They're jagged, blood-red glows that sometimes appear above powerful thunderstorms.

While setting up to view the meteors, Smith aimed one camera at the distant storm — on the chance there really were sprites there. "After about an hour, I caught this one sprite," he says. Its glow was just a crimson smear on his camera. "But once I saw it, I immediately knew what it was. And I was just in complete and utter disbelief."

Since then, Smith has tried to capture as many sprites as he can. "They're like snowflakes," he says. "No two are the same."

Based in Edmond, Okla., Smith has now documented thousands of sprites. He's also caught more than a hundred blue jets, dozens of green flashes called ghosts and several ELVES. All are types of mysterious, fleeting lights that flicker in the skies above large storms. Together, they're known as transient luminous events — TLEs, for short.

"The tops of thunderstorms are really active," says Steven Cummer. He's an electrical engineer who studies TLEs at Duke University in Durham, N.C. "There's a lot of stuff going on there. But it's hard to see."

At least, it's hard to see from the ground beneath a storm. But photos taken by citizen scientists like Smith, as well as data collected by airplanes and the International Space Station, have unveiled details about these strange lights that lurk above strong storms.

Such energetic events can alter the chemical and electrical properties of the air around them. And that, in turn, may affect how radio signals travel through the air. TLEs might even play a role in Earth's climate. That's why scientists want to better understand the role of these phenomena in their atmospheric environment. Such research might also help explain curious lights seen flickering above storms on other planets.

— *Maria Temming*

The most well-known transient luminous events are red electric discharges called sprites, upward lightning bolts called blue jets and rings of light called ELVES.

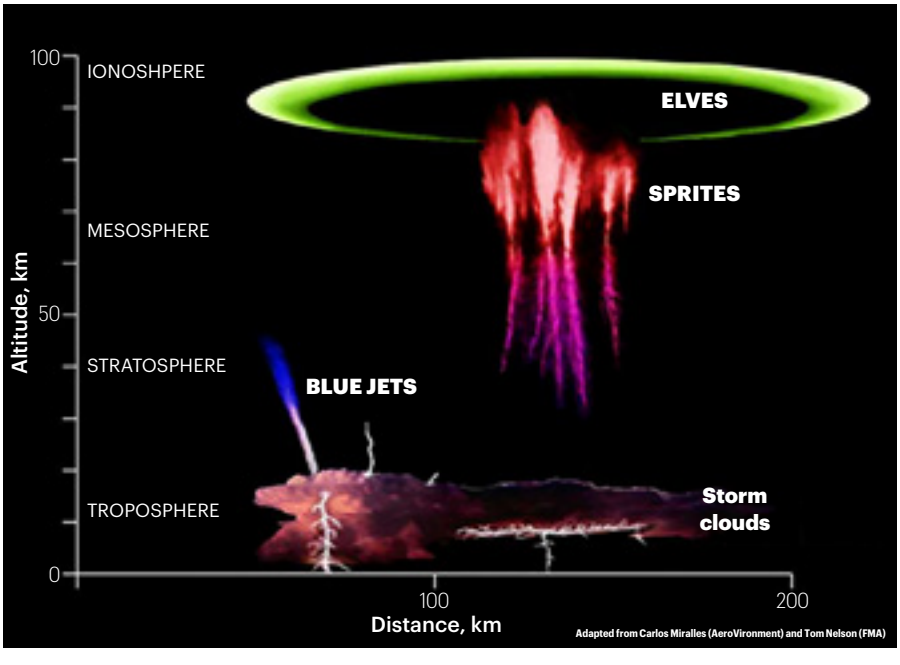
SPRITES, BLUE JETS: PAUL SMITH; ELVES: DTU SPACE, DANIEL SCHMELLING/MOUNT VISUAL

ELVES

Sprites are mostly reddish, but their lower edges can be tinged with blue. And they can sport both diffuse plumes and brighter tendrils of light. Sometimes, their structures are said to resemble carrots or jellyfish. Sprites are triggered by intense lightning strikes that create huge electric fields in the atmosphere. High above the clouds, that electric field can energize nitrogen in the air to glow red. A single sprite can stretch from some 40 kilometers to 80 kilometers (25 to 50 miles) off the ground.

Blue jets are basically just lightning strikes that zip upward from their clouds, rather than down. In the stratosphere, their electricity excites nitrogen to glow blue, giving the jets their signature hue. Jets typically reach from cloud tops — around 15 kilometers (9 miles) high to some 40 to 50 kilometers (25 to 30 miles) high. Small jets that stretch just a few kilometers above their clouds are known as "blue starters." More powerful — and rare — versions reach altitudes of about 80 kilometers (50 miles) and are aptly known as "gigantic jets."

ELVES is an acronym. It's short for "emission of light and very low frequency perturbations due to electromagnetic pulse sources." ELVES appear as fast-expanding rings of light, triggered by intense lightning strikes, around 100 kilometers (60 miles) off the ground. They can grow to be hundreds of kilometers wide and vanish in less than a thousandth of a second.



This diagram shows how high in the atmosphere different types of TLEs are. Blue jets shoot straight out of storm clouds, generally reaching around 50 kilometers (30 miles). Gigantic jets can reach higher. Sprites and ELVES, meanwhile, are electrical phenomena triggered by lightning strikes that appear at much higher altitudes and away from the storm clouds that spawned them.

NOAA

Watch videos of blue jets and sprites here!

SPACE

A recently spotted space object is puzzling scientists

The curious entity's mass lies between that of a black hole and a neutron star

A mystery object has been spotted in our galaxy. The puzzling entity could be a very heavy neutron star — the left-behind corpse of a giant star. Or maybe it's one of the lightest black holes ever observed.

The MeerKAT Radio Telescope in South Africa spotted the unidentified object circling a rapidly spinning dead star called a pulsar. The observatory was monitoring pulsars in a star cluster 40,000 light years from Earth.

Like cosmic lighthouses, these spinning pulsars shoot out powerful beams of light. Some pulsars' beams flash by Earth as regularly as the ticking of a precise clock. But if the flashes don't arrive quite when expected, researchers can tell that another object in space is messing with the pulsar's motion. They can use the timing of the light flashes to work out the other object's mass.

The flashes of a pulsar called PSR J0514–4002E revealed an invisible companion. The object weighs 2.1 to 2.7 times the mass of the sun. That might make it too heavy to be a neutron star. But it would also be lightweight for a black hole. Scientists suspect that once a neutron star gets to be about two to three times the mass of the sun, it collapses and forms a black hole. But no one knows at what mass this occurs. So astronomers can't be entirely sure of the space object's identity.

Researchers shared these findings in *Science*. The team hopes to unveil the object's identity as it continues to track the pulsar's flashes. This may shed light on other similar space oddities, too.

— *Carolyn Wilke*

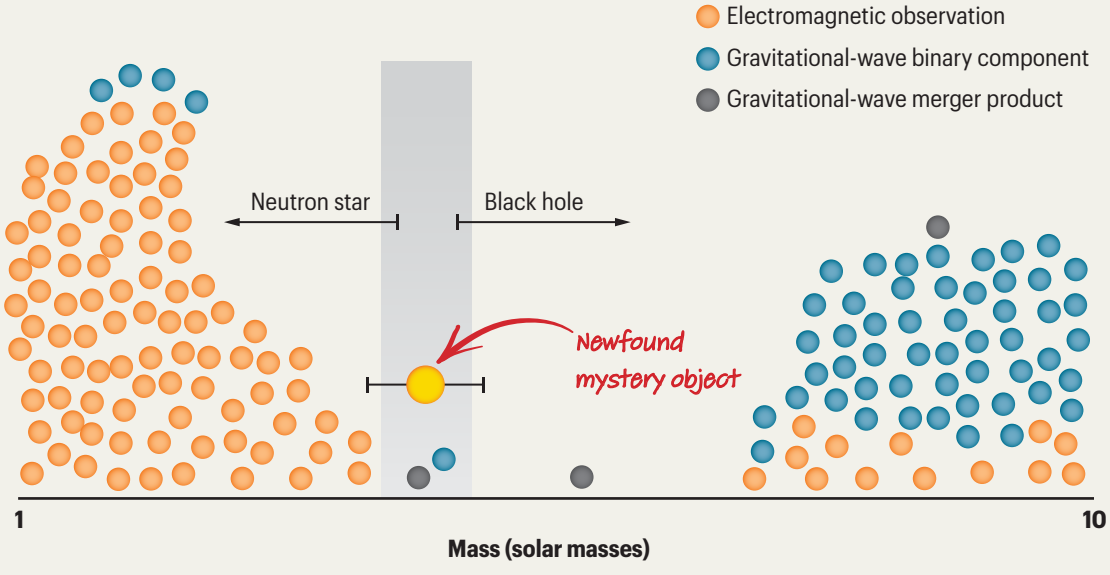
A mystery object spotted orbiting a dead star might be a very lightweight black hole (illustrated), a very heavy neutron star or something else.

DANIËLLE FUTSELAAR/ARTSOURCE.NL

The MeerKAT Radio Telescope is an array of 64 linked radio dishes (one pictured) in South Africa.

Mysterious Mass

Scientists have studied many neutron stars and black holes. These observations have included electromagnetic events (orange points). Such studies capture light to learn about space objects. Other observations are based on ripples in spacetime, or gravitational waves (blue and dark gray). Neutron stars have lower masses (left of gray bar). Black holes have higher masses (right of gray bar). The newfound mystery object (large yellow dot in the grey region) falls between typical neutron star masses and black hole masses.



SARAO; M. FISHBACH/*SCIENCE* 2024

DATA DIVE

1. Look at the x-axis of the graph. What does it mean to describe an object's mass by "solar masses"?

2. What type of observation is most common for neutron stars? What kind is most common for black holes?

3. The data points on the left are neutron stars. Look at how their masses are clustered. Roughly, what is their average mass?

4. The data points on the right are black holes. Look at how their masses are clustered. Roughly, what is their average mass?

5. Find the new mystery object on the graph. How does its mass compare with that of neutron stars? How does it compare with the masses of black holes?

ANSWER

Meet the eastern forest hedgehog

This new hedgehog species is small, dark and adorable

The eastern forest hedgehog is a small, spiky mammal that lives in eastern China. Researchers first scooped one up in the province of Anhui in 2018. Originally, they thought the critter was a Hugh's hedgehog (*Mesechinus hughi*). But that species is typically found some 1,000 kilometers (600 miles) west of Anhui. Plus, DNA from the Anhui specimen didn't quite match that of hedgehogs found farther west.

Intrigued, scientists collected six more hedgehogs from around Anhui and the neighboring province Zhejiang. The animals' physical appearance and DNA confirmed the newly found hedgehogs were unique. Their official name is *Mesechinus orientalis*. The total number of known hedgehog species is now 19. Kai He and his colleagues shared their discovery in *ZooKeys*. He studies small mammals at Guangzhou University in China.

The eastern forest hedgehog is about as long as a pencil and weighs about as much as a can of soda. The black-tipped prickles on the animals' backs are just 1.8 to 2 centimeters (0.7 to 0.8 inch) long. That's about half a centimeter shorter than the spines on Hugh's hedgehogs.

Finding a new *Mesechinus* species in eastern China has expanded the known range of hedgehogs. And knowing what small mammals live where is key to guiding efforts to conserve these wild species, He says.

— *Maria Temming*

At first, the eastern forest hedgehog (pictured) was mistaken for a lookalike relative. But its teeth, skull shape and DNA confirmed it as a new species.

Z. SHI *ET AL*/*ZOOKEYS* 2023

INSIDE THE MIND OF A YOUNG SCIENTIST

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

Science competitions can be fun and rewarding. But what goes on in the mind of one of these young scientists? David Lu Cao, a finalist at the 2024 Regeneron Science Talent Search, shares his advice and experience.

Q What inspired your project?

A "I was really interested in astronomy itself, [and] the origins of life and panspermia in general," David says. Panspermia is the idea that life exists throughout the universe and can be transmitted through space. "I was just naturally interested, because this is one of the unsolved mysteries of humanity."

Q What challenges did you face?

A "The origins of life and, even more so, panspermia is controversial," David says. "It's speculative, so you've got people with a lot of different opinions." In January, he attended the American Astronomical Society conference in New Orleans, La. At the conference, scientists present their research to an audience. People can ask questions or give feedback. There, David learned it is important to listen to new perspectives and criticism. "You've got to realize that that's good. Initially it's kind of like, 'Oh, shoot. Oh, no. I did something bad, or I didn't incorporate something.' But I've realized that's actually really good for my research."

Q Any advice for science project newbies?

A "If you want to try to address these big ideas head-on, [you] have to be able to find a way to have ... good scientific integrity, good scientific practice," David says. "That's something that's very important."

Regeneron Science Talent Search Finalist

David Lu Cao

David, 18, investigated the origins of life on Earth. He was inspired by the 2017 discovery of 'Oumuamua, the first interstellar object confirmed in our solar system. In theory, microorganisms could hitch a ride across the universe on such extraterrestrial objects, like comets or asteroids. David estimated 'Oumuamua's mass to determine how large similar objects must be to shelter microbes from harsh conditions in space. David attends Thomas Jefferson High School for Science and Technology in Alexandria, Va.

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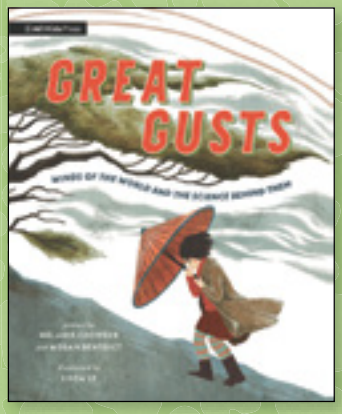

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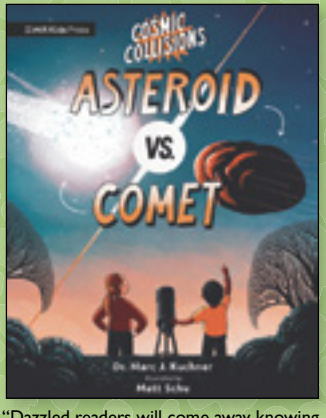

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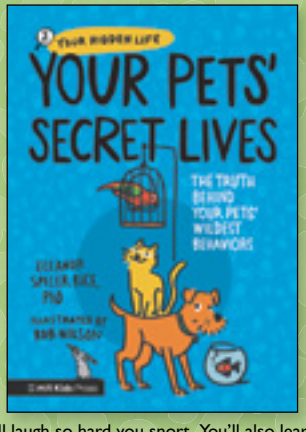

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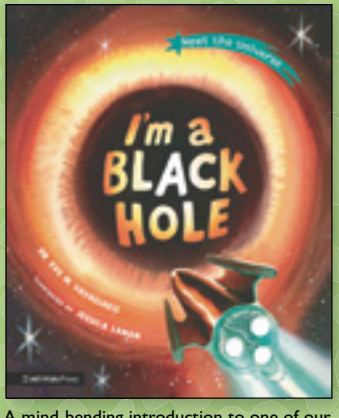

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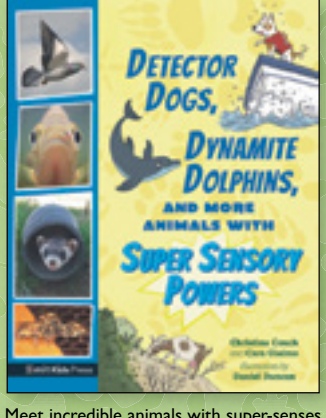

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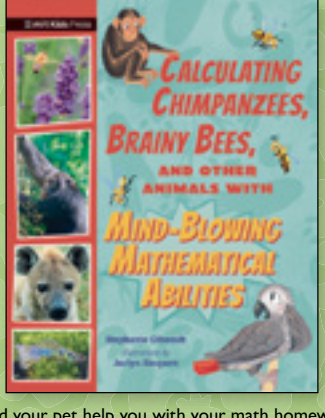

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