ScienceNews
Explores
November 2024

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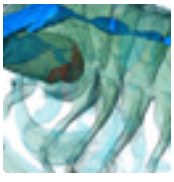

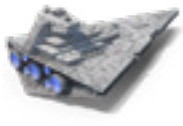

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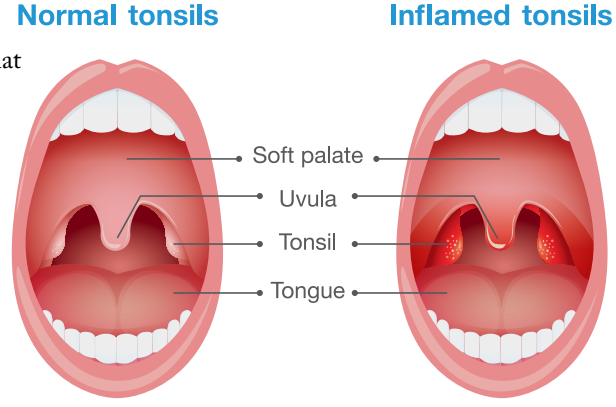
Q How do tonsils work and get inflamed?

— *Kellan S.*

A The tonsils are soft pads of tissue in the throat that block germs from entering the body through the nose or mouth. Tonsils do this by producing germ-killing proteins called antibodies. But tonsils can get infected when they become overwhelmed by germs. These tissues can then become inflamed. This inflammation, called tonsillitis, can make the tonsils swell up, leading to a sore throat. Viruses, such as those behind the common cold and the flu, are a common cause of tonsillitis. But tonsillitis can also be triggered by bacteria, including the germs that cause strep throat.



Q Why can't we feel the world spinning?

— *Dia H.*

A We don't feel the Earth spinning because our planet rotates at a smooth and nearly constant speed. That's about 1,600 kilometers (1,000 miles) per hour at the equator. Everything held by Earth's gravity is also moving at the same rate. And since you're moving at the same speed as the Earth's spin, you don't feel it. It's similar to riding in a car cruising down a flat highway. We can tell we're moving by seeing landmarks pass us, but we don't really feel ourselves moving with the car. We only feel movement when the car swerves, hits a bump or changes speed. Earth doesn't make those kinds of sudden, noticeable changes as it rotates. And while the speed of Earth's rotation does fluctuate, those changes are too small for us to feel.

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SOLAR22/SHUTTERSTOCK

Sarah Zielinski
Editor, *Science News Explores*

CORRECTION

In the October 2024 story "This biologist gets help from the public to track seadragons" (p. 14), the photo credit belongs to John Smith, not Nerida Wilson. We're sorry for the error.

SOCIETY

Common high-school textbooks promote unscientific views on gender

Such faulty teaching could be used to justify prejudice, scientists worry

The biology of sex and gender are more complex than many textbooks suggest.

DEDRAW STUDIO/SHUTTERSTOCK

Major textbooks used by most introductory biology classes in U.S. high schools contain overly simplistic — and misleading — language when describing sex and gender. That's the finding of a new study.

The study authors worry that such faulty teaching may be used to justify sexism or prejudice against certain segments of society.

Brian Donovan is an education researcher at BSCS Science Learning in Colorado Springs. His team analyzed six widely used intro high-school biology textbooks.

The researchers looked for passages that dealt with biological sex and gender. In all, they found 362 paragraphs in genetics chapters that dealt with these topics. In each book, at least some passages erred in how they described sex or gender. The study also found problems with how the books taught about traits linked to genes. The researchers shared their findings in *Science*.

The researchers found that the textbooks tended to focus on so-called "either/or" traits. These are discrete traits that you either have or you don't. But such traits are rare.

Most traits vary across a spectrum. They reflect the impacts of many different genes and how those genes interact with the environment. Height is one example.

Sex can vary across a spectrum, too. Doctors assign sex at birth based on visible genitals. But there are millions of people whose bodies are not strictly male or female. There was no mention of such intersex individuals in any of the books reviewed for the new study.

What's more, gender is different than sex, points out Donovan. While females and males usually have certain chromosomes (XX and XY, respectively), chromosomes and genitals do not set gender. "Gender has to do with our beliefs and ideas about males and females," explains Donovan. What is considered normal behavior and preferences for males, females or nonbinary people varies between cultures. It also can change over time. These expectations — called gender norms — affect how society treats people.

Yet in the new study, none of the paragraphs on such topics described the difference between sex and gender. And if students don't learn the difference, Donovan worries, they may assume gender differences are due to sex. It can also make it harder for students to accept transgender people, whose gender doesn't match the sex they were assigned at birth.

These beliefs also can affect someone's views on gender

equality. Previous research has shown that people who believe men and women have distinct capabilities based on their genes were less likely to support equal pay for women. People with such beliefs also may question whether women should be leaders, says Catherine Riegle-Crumb. She is a sociologist at the University of Texas at Austin and one of the new study's authors.

One way to combat unscientific messaging is to call it out, says Riegle-Crumb. People naturally exhibit a diverse range of traits. Don't try to fit everyone into a few simple boxes. Instead, she suggests, notice both the many traits people share and the ways we differ.

— *Laura Allen*

Read more here.

FOSSILS

Three kids stumble upon rare *T. rex* fossil

Experts say the remains belonged to a teenage dino

It's not every day you come across a dinosaur fossil. But three kids spotted one that could help science better understand the ancient king of beasts.

Brothers Jessin and Liam Fisher and their cousin Kaiden Madsen discovered a rare juvenile *Tyrannosaurus rex* fossil. They found it while roaming around North Dakota's famed Hell Creek formation on July 31, 2022. The young dino they spotted had likely been between 13 and 15 years old when it died.

"I was completely speechless," recalls Kaiden. He was 9 when he and his cousins found the fossil.

The finding could help scientists understand how *T. rex* matured, says Tyler Lyson. He's a paleontologist in Colorado at the Denver Museum of Nature and Science.

Liam, who was 7 at the time, spotted the dino's leg bone while hiking with Kaiden, Jessin and his dad. The family took pictures of the bone and sent them to Lyson. Lyson then organized an expedition to dig up the fossil about a year later.

Lyson and the team found the dinosaur's lower jawbone and a few teeth. That's how they knew it was a *T. rex*.

The team also unearthed a shin bone. It measured 82 centimeters (32 inches). They knew it belonged to a "teen rex" because the shin on an adult *T. rex* is about 112 centimeters (44 inches). Along with the shin and jaw, the team has so far uncovered the skull and some tail bones.

The teen *T. rex* fossils now reside at the Denver Museum of Nature and Science.

— *Skyler Ware*

A rare fossil find turned a hike into a memorable expedition for (left to right) Liam Fisher, Kaiden Madsen and Jessin Fisher.

360 million neurons

Researchers recently calculated that the *T. rex* telencephalon, a part of the forebrain, had between 245 million and 360 million neurons.

The estimate suggests that the dinosaur's forebrain was more similar to a crocodile than a primate — and contradicts a 2023 estimate that the *T. rex* brain may have been similar to that of a baboon.*

* The Anatomical Record, *April 26, 2024*

GIANT SCREEN FILMS

ANIMALS

Hibernating bumblebee queens may survive floods

Experiments show these bees can bounce back from submersion

Most bumblebee queens spend the winter hibernating in a chamber called a hibernaculum (inset) before becoming active in the spring.

N. RAINE

Life for a bumblebee queen isn't always regal, nor cushy. In the spring, she starts to build her colony. But before that, she must survive winter by hibernating alone underground, at risk of floods and other hazards.

Fortunately, these sturdy queens are no divas. Researchers have found that hibernating bumblebee queens can survive being submerged for up to a week.

Bee biologists Sabrina Rondeau and Nigel Raine stumbled on this discovery after a lab accident at the University of Guelph in Canada. They had been studying how hibernating queens respond to pesticide exposures. The refrigerator storing the dormant bees malfunctioned, causing four of the vials housing queens to flood.

"I was very concerned at first," says Rondeau, now at the University of Ottawa. "I thought, of course, they were dead." But when she picked up the queens with forceps, they started wiggling. They were most definitely alive.

Rondeau and Raine decided to run more rigorous tests to see just how waterproof these queens are. They shared their findings in *Biology Letters*.

To begin, the researchers gathered 143 queens of the common eastern bumblebee (*Bombus impatiens*). They placed each bee in a soil-filled vial and stored them at a cold temperature to simulate hibernation. They then added water to the vials. Seventeen queens served as controls; no water was added to their vials.

The flooded queens were kept at cold hibernation temperature for eight hours, 24 hours or one week. After that, these royals were moved to vials with dry soil and kept in the cold for eight weeks more.

This test set-up mimicked possible flooding scenarios that could exist in the real world. Generally, hibernating queens seem to prefer sloped ground and sandy soils — ones unlikely to flood. Even so, it now appears they could weather a storm.

Seventeen of the 21 queens that were submerged for seven days and then resumed hibernation were alive eight weeks later. This survival rate did not differ statistically from the bees that weren't submerged.

The submerged queens were soaking wet when first pulled out of the water, Rondeau says. But the next day, "they are fluffy again, beautiful, like nothing happened," she recalls. "Extremely surprising." — *Darren Incorvaia*

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

Brainy Birds

Parrots can use tools, solve puzzles, speak words and more >>

By **Erin Garcia de Jesús**

MARTIN MECNAROWSKI/SHUTTERSTOCK

Though parrots look very different from us, these birds are providing great insights into human intelligence. Did you know there are nearly 400 different species of parrots? Researchers estimate dozens of parrot species may use tools.

PATRICK WOOD

Bruce the kea is missing his upper beak. This makes the olive-green parrot always look a little surprised. He's not the only one. Scientists are shocked at what he can do in spite of his injury.

Bruce has been missing part of his beak since at least 2012. That's when he was rescued as a young bird. He went to live at the Willowbank Wildlife Reserve in Christchurch, New Zealand.

Bruce's injured beak means he can't forage on his own. Keas, which live in New Zealand's alpine forests, use their long, sharp beaks to rip up plant roots and pry insects out of rotten logs. Nor should Bruce be able to keep his feathers clean — normally the birds preen with their beaks. But Bruce, his keepers noticed, had figured out how to preen using small stones.

First, he selects his tool: pointy pebbles. He rolls them around in his mouth with his tongue until he finds one that he likes. He holds the chosen pebble between his tongue and lower beak. With it, he picks through his feathers.

The behavior was not learned in the wild. When Bruce arrived at Willowbank, he was too young to have learned how to preen. And no other bird in the aviary uses pebbles in this way. "It seems like he just innovated this tool use for himself," says Amalia Bastos. In 2021, she spent time at Willowbank studying keas. She and others reported Bruce's grooming trick in *Scientific Reports*.

Tool use is just one of parrots' many talents. The birds are famous for imitating, and perhaps even understanding, human speech. Some species can solve complex puzzles, such as opening a latched trash bin. Others can practice self-control. Such abilities match those seen in some primates.

These abilities all make the birds seem very intelligent. Defining intelligence is tricky, though, especially across species. Researchers often rely on behaviors that show signs of gaining and using knowledge. Such signs can include planning, problem solving, learning and maneuvering objects. Researchers once thought these features made humans special. But chimpanzees, dolphins and elephants also show these talents. So do parrots and members of the crow family.

Even so, parrots may not be an obvious choice for studying humanlike intelligence. Birds and humans last shared a common ancestor more than 300 million years ago. Parrots' bodies and brains are very different from ours. But studies over the last decade are highlighting the hidden powers of bird brains. Parrots may have a lot to teach us about how humanlike intelligence can emerge

A wide skill set

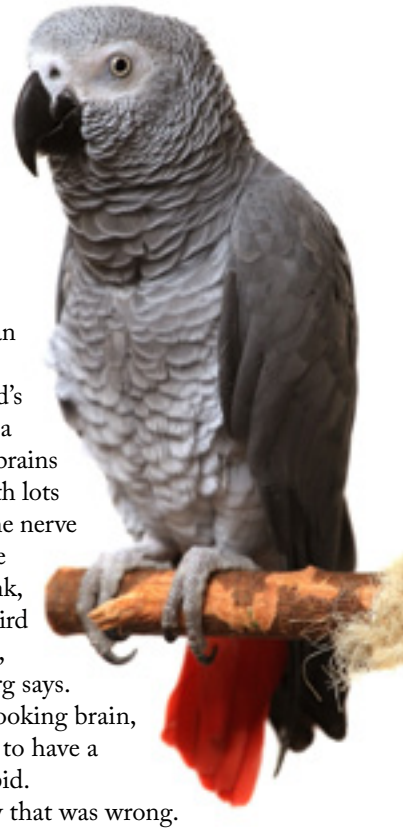
Irene Pepperberg has long suspected this. She studies parrot intelligence at Boston University in Massachusetts.

In the 1970s, Pepperberg started working with Alex, an African gray parrot (*Psittacus erithacus*). When he died in 2007, Alex was famous for his large vocabulary and knowledge of shapes, colors and even math.

Parrots' ability to speak words is their most well-known talent. African grays are especially good at picking up words and speaking clearly, Pepperberg says.

These parrots can repeat up to 600 different words, researchers reported in 2022. Although some parrots simply mimic people, others can be taught to communicate.

African gray parrots can repeat up to 600 different words, researchers have found. Some parrots simply mimic people. Others, though, can be taught to communicate.



Bruce the kea is missing the top half of his beak. To compensate, the New Zealand parrot figured out a way to use pebble tools to help him clean his feathers.

A talking parrot can't tell you what it thinks or why it behaves a certain way, Pepperberg says. But "you can ask them the same types of questions that you ask young children." To test their smarts, Pepperberg might ask her birds to count objects. Other times, they may be tasked with picking the larger of two objects.

Pepperberg's parrots have also learned to make requests. One of her African grays, for example, can ask for time alone by saying, "Wanna go back."

Other clues to birds' thinking come from how they use objects.

Hyacinth macaws crack open nuts using tools. They hold pieces of wood in their beak or foot to keep the food in just the right position. Palm cockatoos craft drumsticks and rock out to attract mates. Goffin's cockatoos can recognize individual tools as being part of a set. Only humans and chimpanzees are known to do this.

Overall, 11 of the nearly 400 parrot species have been documented as using tools in scientific studies. By scouring YouTube videos, Bastos and her team noted tool use by 17 more species. They plotted the 28 known tool-users onto an evolutionary tree. Based on this work, the team estimates that 11 to 17 percent of parrot species may use tools.

The beauty of a bird brain

Studying parrot brains can also offer clues to their impressive smarts. A bird's brain looks nothing like a primate's. Most primate brains have a cerebral cortex with lots of curves and crinkles. The nerve cells packed within those wrinkles help people think, remember and learn. A bird brain, on the other hand, looks smooth, Pepperberg says. Because of this simple-looking brain, it was long thought that to have a bird brain was to be stupid.

But Pepperberg knew that was wrong.

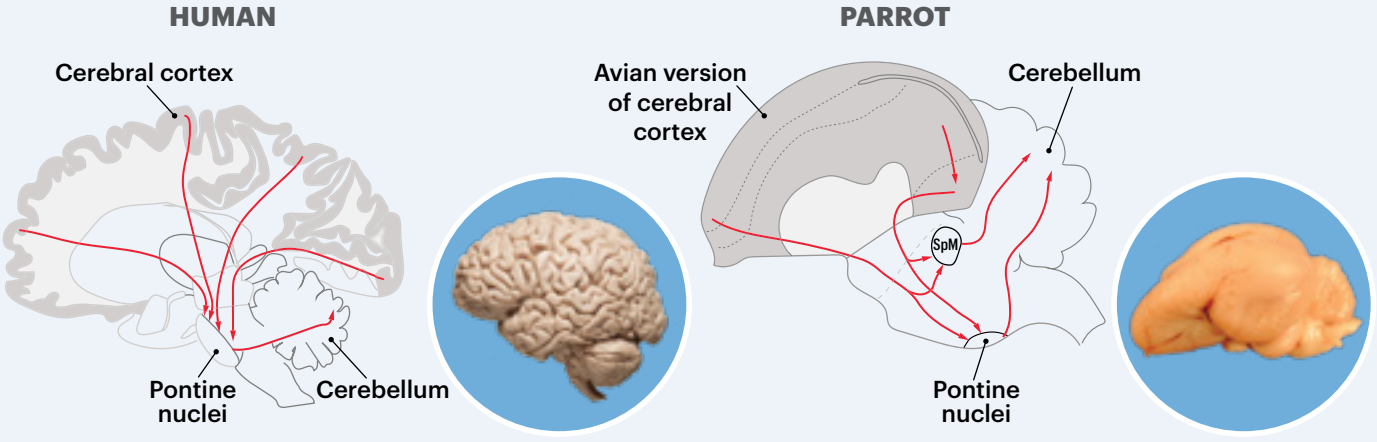
By the early 2000s, scientists had found that parts of a bird's brain work like those that mammals use for learning, planning and other complex behaviors. Despite the smooth look, bird forebrains can hold more nerve cells than those of mammals with the same skull space, says Erich Jarvis. He studies genetics at Rockefeller University in New York City.

This blue-and-yellow macaw is examining a puzzle piece. Scientists can learn about how parrots think from how they use objects.

ROSA JAY, ERIC ISSELEE/SHUTTERSTOCK

INFORMATION HIGHWAY

Though human and parrot brains look different, they may share a brain circuit that coordinates complex skills. Signals from the front of the brain travel to the cerebellum (red arrows) through clusters of neurons called the pontine nuclei. Front regions help with learning, memory and problem-solving. The cerebellum, found at the back of the skull, coordinates movement. Birds have an additional connection that passes through an area called the SpM. This pathway is particularly big in parrots and might help with their brainpower.



Parrot brains are especially densely packed. Some species even have more neurons than such large-brained primates as orangutans and chimpanzees. And the cells may link up in ways not found in other animals, Jarvis says.

In 2018, researchers found a major information highway in parrot brains. The discovered circuit connects the front and back of their brains. And it may play a similar role as one found in human brains, says Cristián Gutiérrez-Ibáñez. At the University of Alberta in Edmonton, Canada, he studies nerve pathways that help animals sense and move.

Through this pathway, front parts of the brain involved in complex behavior send information to the cerebellum. This region at the back of the brain helps with coordination and balance. In people, it also helps with skills like learning how to talk or making tools. Perhaps it could do the same in parrots.

The evolution of intelligence

To figure out how parrots evolved their brainpower, scientists have to go way back in time. Today's birds evolved from a group of small, meat-eating dinosaurs called theropods. About 66 million years ago, an asteroid impact wiped out all non-bird dinosaurs from the planet. Modern birds emerged after this catastrophe.

The asteroid impact triggered rapid changes in the environment. This may have pushed some birds to evolve larger brains quickly, says Daniel Ksepka. At the Bruce Museum in Greenwich, Conn., he studies how birds evolved. His team analyzed skull models of more than 2,000 living bird species, 22 extinct bird species and 12 non-bird dinosaurs. After the asteroid hit, some birds rapidly evolved big brains, they found.

Parrots and members of the crow family have some of the largest brains of any bird. And larger brains relative to body size often suggest intelligence.

The ancestors of parrots probably had large brains that helped them solve problems in their environment. After the asteroid impact, this would have allowed them to outcompete other animals for resources. Birds that learn how to open pinecones with their beaks are more likely to survive than those that wait for berries that might never come, Ksepka says.

Birds of a feather

Today, having a big brain is just one thing humans and parrots have in common. They also both live long lives, mate for life and learn from others how to sing or talk.

A need for complex communication may have paved the way to greater intelligence, says Lucy Aplin. At the University of Zurich in Switzerland and Australian National University in Canberra, Aplin studies animal behavior and evolution. Parrots "have very large, flexible vocal repertoires," she says. "They can learn new vocalizations throughout their lives."

It's unclear — to us — what most parrot calls mean. But some parrots make signature sounds that declare who they are or what groups they belong to, Aplin says.

Parrots live in large, close-knit groups. So a good memory and greater intelligence may help the birds maintain relationships and climb up the social ladder.

Sulphur-crested cockatoos (opposite page) are a common species in Australia, where they live in large groups and sometimes become pests because of their brainy abilities.

CHRIS PARSONS/DIGITALVISION/GETTY IMAGES PLUS; ANDREW IWANIUK/UNIV. OF LETHBRIDGE; DIAGRAMS: C. GUTIÉRREZ-IBÁÑEZ

Sulphur-crested cockatoos, for instance, live in groups of hundreds of individuals. And they can maintain pecking orders that don't seem based solely on appearance or size. That suggests cockatoos may be able to remember other individuals, Aplin says. That would take lots of brainpower. Her team is now using magnetic resonance imaging (MRI) to explore possible links between big brains and parrots' social lives.

Gutiérrez-Ibáñez and his team are focusing instead on what birds' feet can reveal about their smarts. When ancient birds evolved wings, they could no longer use their front limbs to catch food or move objects. Over time, some birds such as parrots and raptors came to use their feet for these tasks. Such "hand-eye" coordination acts as a stepping stone toward intelligence, Gutiérrez-Ibáñez says. His team reported these findings in *Communications Biology*.

Take primates. Monkeys and apes with better motor skills tend to have bigger brains, researchers reported in 2016. Some species use sticks to crack open nuts or pull ants out of anthills. Good motor skills, Gutiérrez-Ibáñez says, probably help explore an item's physical properties. And big brains may help animals figure out new ways to use objects.

Parrot intelligence in the wild

How parrot intelligence plays out in the wild is mostly unknown. What scientists know about parrot smarts largely comes from captivity. Having no predators and plenty of food might allow parrots to learn behaviors they wouldn't in the wild, Pepperberg says.

It's also possible that scientists are just missing out on seeing the brainy feats of wild parrots. "Researching these highly mobile animals is a challenge in the wild," says Rachael Shaw. Shaw studies the behavior of native New Zealand birds at Te Herenga Waka – Victoria University of Wellington.

Alice Auersperg and her team solved that problem by capturing wild Goffin's cockatoos in Indonesia. This biologist studies the evolution of bird intelligence at the University of Veterinary Medicine Vienna in Austria. The researchers placed the captured birds in a field-based aviary. The team then studied how the cockatoos make sets of wooden tools to get seeds out of sea mangos.

Some of the birds made up to three kinds of tools, the team found. Each kind differed in its size, how it was made and its use. Thick, sturdy tools shaped from entire branches helped wedge sea mango seed casings apart. The cockatoos made small and medium-sized tools by stripping bark from branches. Tiny and sharp bark fragments let the birds pierce the seed coating. The cockatoos turned to medium-sized tools to remove the seeds from their casings.

In Singapore, some captive Goffin's cockatoos have escaped into urban areas. The birds soon grew in number. Seeing how these birds adapt in real time is "super exciting," says Theresa Rössler. She works with Auersperg in Vienna.

It's an opportunity to learn how new surroundings might lead to novel problem-solving behaviors. And that, she says, is "evolution in the making."

ERIC ISSELEE/SHUTTERSTOCK; JOANNA WENDEL

Read more about clever cockatoos here:

Cockatoos learn from each other how to open garbage bins

Magic helped this researcher trick birds for science

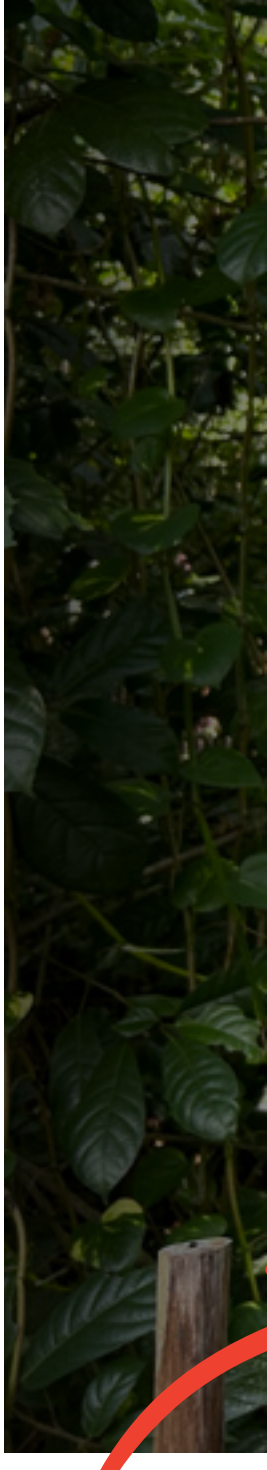
Elias Garcia-Pelegrin investigates how animals perceive their world

Elias Garcia-Pelegrin was looking for a quick magic trick that would capture the attention of people, not birds. He performed magic to help pay for university. And his "fast pass" fit the bill. But he soon realized that this trick could serve another use: in a study of Eurasian jays.

Eurasian jays are clever birds that perform their own tricks when caching, or storing, food for later. To fool thieves, the birds first hold their treat in their bill. They then pretend to store the morsel by slipping it into their throat pouches. These antics resemble a magician's hand tricks, which fool onlookers into believing an object has moved. He wondered how well these feathered magicians would fare against human magic.

In their 2021 study, Garcia-Pelegrin and his team performed three types of hand tricks for humans and jays. While the humans were fooled by all three, the Eurasian jays only fell for one: the fast pass. He suspects it's because, unlike us, the birds don't have expectations about how hands move.

Garcia-Pelegrin is now studying intelligence in hornbills. These dazzling birds rival the smarts of corvids and parrots in some ways, he says. In this interview, Garcia-Pelegrin shares his experiences and advice with *Science News Explores*. (This interview has been edited for content and readability.) — *Aaron Tremper*



Male gentoo penguins offer pebbles to potential mates. If his partner accepts, the two perform a series of synchronized bows.

Q What inspired you to pursue your career?

A I used to work at the Sea Life London aquarium in England. One of my jobs was taking care of the gentoo penguins. They perform this beautiful spectacle every single year. When they are courting, the male takes a pebble to the female and bows to her. If she approves, she'll bow back. They create this dance together through bowing.

It got me thinking. What's the male considering when he chooses a pebble? What's the female thinking when she receives the pebble and bow? This was a completely alien world to me. It's not something that they teach you in psychology courses. I just found it so fascinating that until 20 years ago, the phrase "bird brain" meant someone was stupid. That all changed when we started testing more animals. The more birds we tested, the more we realized this was not the case.

Q How did you get into magic?

A I didn't plan on magic being a part of my science. I started learning coin tricks in high school. I was

To thwart thieves, Eurasian jays pretend to hide food in different spots. Remembering where they actually stashed their treats requires excellent memory.

RAFAL SZOZDA/SHUTTERSTOCK; E. GARCIA-PELEGRIN; RALPH LEE HOPKINS/ALAMY

In high school, Elias Garcia-Pelegrin learned coin tricks to improve his focus. He now performs magic for animals to understand how they see the world.

quite the fidgety kid in class and was diagnosed with hyperactivity. My dad was a medical doctor and taught me coin tricks to help me keep still in class. I became good enough to earn money by performing for others.

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

A I was very bad at school. I had a short attention span, and it was difficult for me to concentrate. I had to repeat a course and didn't get into university when I first applied. I learned that who you are right now doesn't determine who you will be as an adult. If you're passionate about something, then things will align. If you're not finding your place right now, you'll find that in the future for sure.

I think all that matters is that you find something worth doing. If you're passionate about something, just do it. It's a privilege to find something that you love.

COMPUTING'S CLIMATE COSTS

Can scientists curb AI's energy and water use?

By **Kathryn Hulick**

Computing equipment stacked all the way to the ceiling. Thousands of little fans whirring. Colored lights flashing. Sweltering hot aisles alongside cooler lanes. Welcome to a modern data center.

KWARKOT/SHUTTERSTOCK

Every ChatGPT conversation, every Google search, every TikTok video makes its way to you through a place like this.

"You have to go in with a jacket and shorts," says Vijay Gadepally with the Massachusetts Institute of Technology, or MIT. As a computer scientist at MIT's Lincoln Laboratory in Lexington, Mass., he helps run a data center that's located a couple of hours away by car in Holyoke. It focuses on supercomputing. This technology uses many powerful computers to perform complex calculations.

Entering the data center, you walk past a power room where transformers distribute electricity to the supercomputers. You hear "a humming," Gadepally says. It's the sound of the data center chowing down on energy.

Data centers like this are very hungry for electricity, and their appetites are growing. Most are also very thirsty. Cooling their hardworking computers often takes loads of fresh water.

More people than ever before are using applications that rely on supercomputers, says Gadepally. On top of that, he adds, supercomputers are doing more energy-intensive things. Stuff like running ChatGPT. It's an artificial intelligence, or AI, model that can generate code, write text or answer questions.

Just two months after it launched, ChatGPT reached 100 million active users, making it the fastest growing app ever. And, Gadepally adds, energy-hungry AI doesn't just power chatbots. "AI is making its way into everything." Generating one image using an AI model such as Stable Diffusion XL can draw as much energy as fully charging a smartphone. That's the finding of researchers at Carnegie Mellon University in Pittsburgh, Pa. and a collaborative AI platform called Hugging Face.

Meanwhile, the climate crisis is worsening. Since people still burn fossil fuels to produce most of our electricity, a growing demand for energy leads to higher releases of greenhouse gases. That's got some experts looking at how to cut the climate impact of AI. Their goal: to make such increasingly popular AI tools more sustainable.

Bigger isn't always better

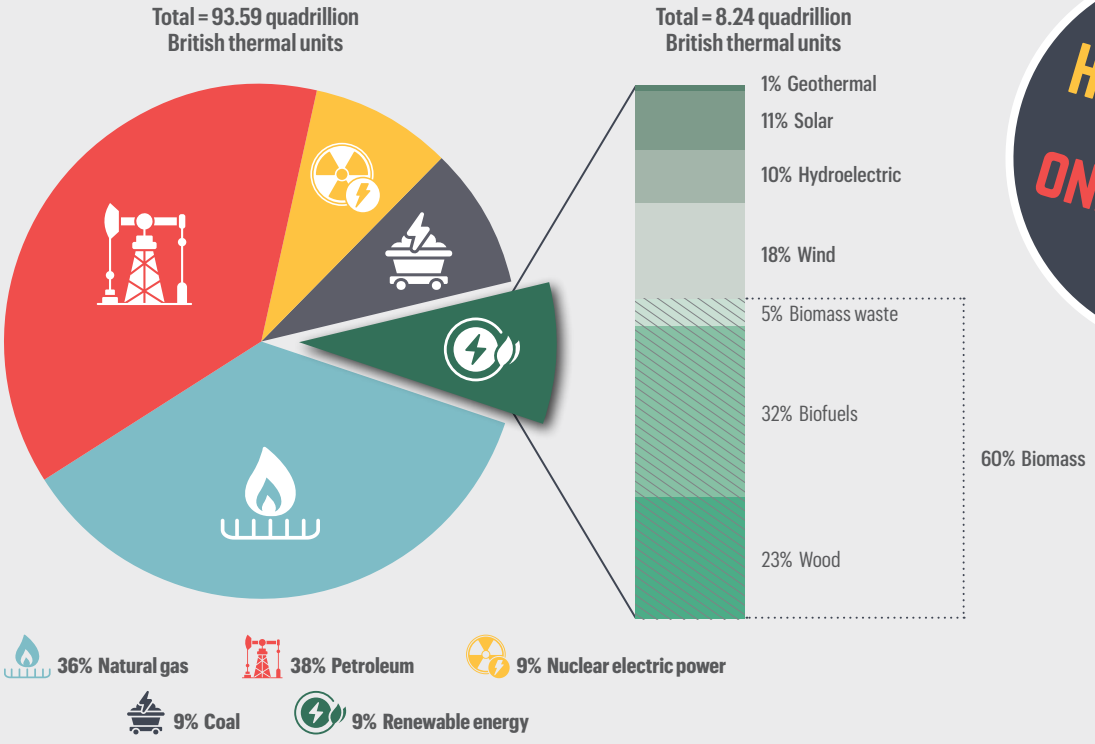
AI's appetite for energy depends on what type of model it is. Many of the ones used in scientific research are quite small. "A lot of the models I've trained take a few hours on a personal computer," says Alex Hernandez-Garcia. This AI expert works as a researcher at Mila, an AI institute in Montreal, Canada. A lean model like that has a teeny-tiny carbon footprint, he says. It may be similar to the power used to keep an incandescent light bulb lit for a few hours.

However, tools like ChatGPT rely on large language models, or LLMs. An LLM is a type of AI based on machine learning. It learns to predict the order of words.

Vijay Gadepally (above) helps manage a group of supercomputers located at the Lincoln Laboratory Supercomputing Center in Holyoke. "A lot of the Massachusetts universities utilize this as their data center," he says. His team has found ways to make their supercomputers devour less energy.

MIT LINCOLN LABORATORY

U.S. primary energy consumption by energy source, 2023



DATA SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION, MONTHLY ENERGY REVIEW, TABLE 1.3 AND 10.1, APRIL 2024, PRELIMINARY DATA
NOTE: SUM OF COMPONENTS MAY NOT EQUAL 100% BECAUSE OF INDEPENDENT ROUNDING.

HOW 'GREEN' IS YOUR ONLINE LIFE? FIND OUT ON PAGE 28

Fossil fuels (coal, petroleum, natural gas) provide much of the energy in the United States (above). AI is an ever-increasing energy hog, but some scientists are working to change that.

As their name implies, LLMs are big. Really big. That's because there is so much language data available to feed them. It takes months and many supercomputers to train them, says Hernandez-Garcia.

In a 2023 paper, his team surveyed the carbon footprints of many AI models. Based on this research, he estimated the climate impact of training the LLM GPT-3. (Updated versions of this model run ChatGPT today.) Its impact might equal some 450 commercial airplane flights between London, England, and New York City, he says. This research also looked at models trained to classify images, detect objects, translate languages and more.

Making any of these models bigger often provides better results. But a large jump in model size usually leads to only a very tiny increase in its ability, notes Hernandez-Garcia. Bigger isn't always better, his team has shown. Models whose use led to the most greenhouse-gas emissions didn't always perform the best, their analysis showed.

In a 2021 paper, Emily M. Bender argued that, in fact, LLMs may be getting too big. Bender is a computational linguist at the University of Washington in Seattle. "AI is a luxury," she says. Therefore, people should think carefully about the ethics of building ever-larger models.

The worst-case scenario

One measure of an AI model's size is the number of parameters it contains. Parameters are what get tweaked as the model learns. The more parameters a model has, the more detail it can learn from data. That often leads to higher accuracy.

GPT-2 — an LLM from 2019 — had 1.5 billion parameters. Just a couple years later, GPT-3.5 was using 175 billion parameters. The free version of ChatGPT runs on that model today. Users who pay for the app get access to GPT-4, an even more advanced LLM. It's said to manipulate an estimated 1.76 trillion parameters!

The free version of ChatGPT that was running in early 2023 consumed about 10 times as much energy per question as a Google search at that time, says Alex de Vries. He's a Ph.D. student in economics at Vrije (Public) University Amsterdam in the Netherlands. He's also the founder of Digiconomist. This company studies the impact of digital trends.

In a 2023 study, de Vries estimated that at the height of ChatGPT's popularity, the app was likely consuming about 564 megawatt hours of electricity per day. That's roughly equal to the daily energy use of about 19,000 U.S. households. So he decided to do a thought experiment: What if every Google search people are doing right now

instead went through an LLM such as ChatGPT? "Google alone would be consuming as much power as Ireland," he realized. (Google has since added AI-generated answers from its model Gemini to many searches — but it has not shared how much energy this may add.)

Will AI tools based on giant, energy-hungry LLMs soon gobble up as much electricity as entire countries? Not overnight.

The good news, de Vries says, is that his thought experiment is "an extreme example." Most tech companies, he notes, can't afford to buy that much energy. Plus, data centers don't have enough supercomputers to support such a huge demand for AI. This type of AI requires special computer chips. Right now, factories can't make those chips fast enough, he says. "That gives us some time to reflect on what we're doing" — and maybe do things differently.

Putting data centers on a diet

Gadepally and his team aren't just reflecting — they're acting. They've found several ways to put their data center on an energy diet.

Not all AI tasks require a humongous energy hog, the Hugging Face study showed. These researchers measured the carbon footprint of tagging movie reviews as either positive or negative. The footprint of tagging 1,000 reviews with a small model, trained only to perform this single task, was around 0.3 gram of carbon dioxide, or CO_2. When the researchers did the same task with big, powerful LLMs, they found emissions of around 10 grams of CO_2 — 30 times as much.

Gadepally's team has developed a new AI model that could help rein in other AI models. Called CLOVER, it figures out what a user is trying to do, then selects only as big a model as that task truly needs.

CLOVER can "mix and match models to best suit the task at hand," says Gadepally. Last year, his team reported that CLOVER can cut the greenhouse-gas emissions of AI use at a data center by more than 75 percent. With those savings, the accuracy of the results that AI models provide drops by only 2 to 4 percent.

Video games provided the idea for another energy-saving trick. "One of our colleagues is a big gamer," notes Gadepally. Many machine-learning models run on what are known as graphics processing units, or GPUs. These computer chips were designed to run visually demanding video games. His colleague found he could put a brake on the power his GPU could draw while playing games. Scientists refer to this tactic as "power capping." Usually, it does not impact the quality of games running on GPUs.

This data center has a very low carbon impact — it runs mainly on renewable energy.

As GPUs work harder, they draw more power — and heat up. If they aren't allowed to draw as much power at once, their work may take a bit longer. But power-capped GPUs aren't wasting energy ramping up and then slowing back down, the way non-capped GPUs do. Plus, power-capped GPUs don't get as hot. That means they also don't need as much cooling.

Gadepally's team tested this with an LLM named BERT. Without power-capping, it took 79 hours to train BERT. With power-capping, training took three hours more. But they saved energy, he says, equal about to what's used in a week by the average U.S. household. That's a big energy savings for a small amount of added time.

Their tests were so successful that they're now using power-capping throughout the data center. "Some people have said we're a bit weird for doing it," says Gadepally. But he hopes others will follow their lead.

Imagining AI differently

The data center where Gadepally's group did all these tests actually has a fairly small carbon footprint. That's because its electricity mainly comes from a nearby hydroelectric dam. This is a water-powered energy source that doesn't release a lot of greenhouse gases into the air. Tech companies can reduce their climate impact by building data centers or scheduling data calculations at places that get most of their power from renewable sources.

However, there's only so much green energy to go around. Using it for AI means not using it for something else.

Engineers built the Lincoln Laboratory Supercomputing Center on the Connecticut River so they could power it with renewable energy. A hydroelectric dam on the river behind the building supplies most of its energy, with the rest coming from wind, solar and nuclear sources.

MIT LINCOLN LABORATORY

These green pipes transfer water — and heat — from a data center to cooling towers (background).

Also, the best places to collect green energy may not be ideal for data centers. In Arizona, a lot of solar and wind farms already feed electricity into the power grid. The state's weather, however, is very hot. Data centers everywhere need to keep their computers from overheating. Most use fresh water to do this.

"Computing needs a tremendous amount of water," points out Shaolei Ren. He's a computer engineer at the University of California, Riverside. Climate change is making fresh water scarcer, especially in places like Arizona. So thirsty data centers built in those areas can become a big problem.

Many experts have called for tech companies to measure and report on their greenhouse-gas emissions and water footprints. That's a great idea. But there's only so much that tech companies can do to cut these impacts while building ever-larger AI models.

Real change starts deeper, with the way society approaches the systems it builds, suggests Priya Donti. Before throwing all available resources into a system, we need to consider that system's sustainability as well as its environmental and social impact. Donti is a computer scientist at MIT in Cambridge, Mass. She also co-founded the organization Climate Change AI. This group looks at ways AI and machine learning can help society reach climate goals.

Right now, says Donti, large tech companies are driving the emergence of ever bigger AI models. But "it doesn't have to be that way," she says.

Researchers are finding creative ways to make smart, useful, greener AI. For example, they can transfer insights between AI models. They also can train using less — but higher-quality — data.

One company, Numenta, is looking to the human brain for inspiration. Designing AI models that are more similar to the brain means "much less math has to be done," explains co-founder Jeff Hawkins. And fewer calculations means a lower demand for energy.

"AI doesn't have to be super, super data-hungry or super, super compute-hungry," says Donti. Instead, we can "imagine AI differently."

JOHN_T/SHUTTERSTOCK; THE MIT PRESS

The computers in a data center generate a lot of heat. Cooling systems often use large amounts of water to transfer heat from the computers to a cooling tower outside.

READ MORE

Power On!

By Jean J. Ryoo and Jane Margolis
Illustrated by Charis JB

Technology can promote practices that hurt marginalized communities. Learn how to help make digital spaces fair for all with this graphic novel.

PHYSICS

Musical bottles

Discover how air volume affects pitch

By Science Buddies

Some musical instruments, such as ocarinas, produce sound with vibrating cavities of air. Such instruments are Helmholtz resonators. The frequency, or pitch, of sound produced by a Helmholtz resonator depends on the volume of air inside its cavity. But what exactly is that relationship? In this experiment, we explore how the volume of air inside a simple Helmholtz resonator, a bottle, affects the pitches of its musical notes.

OBJECTIVE

Determine the relationship between musical note frequency and air volume when blowing over the top of a bottle

EXPERIMENTAL PROCEDURE

1. Pour a little water into a narrow-necked plastic or glass bottle.

2. Touch your lower lip to the edge of the bottle opening, purse your upper lip, then blow gently over the top to make a musical note.

3. Use a chromatic tuner or piano to see what pitch the bottle creates and record the result in a notebook. Also record the volume of open air inside the bottle.

4. Add some water to the bottle, then repeat steps 2–3.

5. Repeat step 4 at least eight more times for a total of at least 10 different water levels — and therefore air volumes — inside the bottle.

6. Repeat steps 1–5 with four more bottles of different shapes and sizes.

7. Graph the results for each bottle, with air volume inside the bottle on the x-axis and pitch of notes on the y-axis. How does pitch change as air volume varies?

Find the full activity, including how to calculate your answers, at snexplores.org/bottlemusic. This activity is brought to you in partnership with Science Buddies.

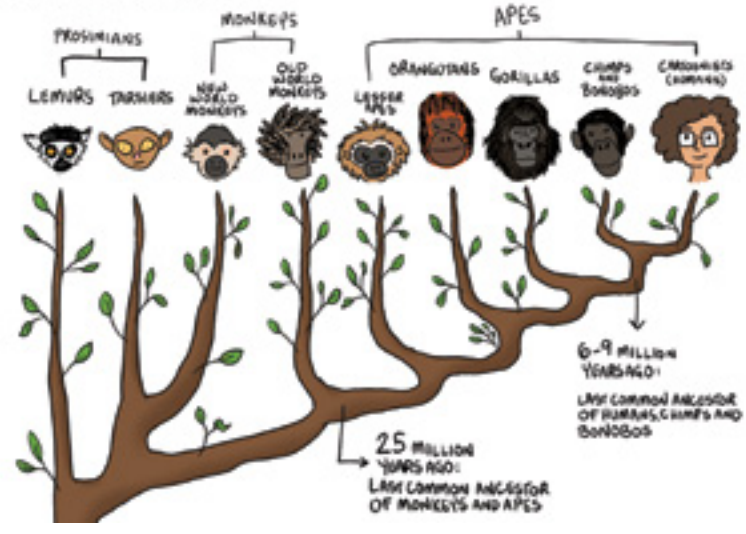
SCIENCE BUDDIES

ABSTRACT/SHUTTERSTOCK

Chimps and Bonobos Have Great Memories for Faces

Written by Maria Temming
Illustrated by JoAnna Wendel

Humans can recognize faces they haven't seen for nearly 50 years. Similarly long-lasting memories in chimps and bonobos suggests we share this trait with our last common ancestor.



HEALTH

Period blood could help diagnose illness

The first diabetes test based on menstrual blood has already been approved

To test for disease, doctors might swab someone's nose, collect their urine or draw blood for analysis. Menstrual blood has not traditionally been used in this way. But it might soon.

In January, the U.S. Food and Drug Administration approved the first health test based on period blood. It's called the Q-Pad. It can be used at home to detect a substance in menstrual blood that can show if someone has diabetes.

Around 1.8 billion people worldwide menstruate. "Why let that go to waste?" says Sara Naseri. She's a cofounder of Qvin, the company that makes the Q-Pad.

Naseri's research has since shown period blood can indeed provide "essential health information," she says. This includes red flags for diabetes. It might also include evidence of other ailments.

PERIOD BLOOD AND THE Q-PAD

Menstrual blood is far more complex than the blood that runs through veins or arteries. It's made of cells and tissue from the thickened lining of a person's uterus. It gets shed when they get their period. As a result, it does contain blood, just like you would get by drawing blood from elsewhere in the body. But it's also full of proteins, hormones and bacteria found only in the uterus.

Naseri, who has trained as a medical doctor, wondered if substances in period blood could be measured like they can be in other blood samples. So she and her colleagues compared menstrual blood with blood drawn from elsewhere in the body. They found that several substances can reliably be measured in period blood. That includes chemical markers of diabetes and inflammation. It also includes hormones that could help track someone's health and diagnose problems.

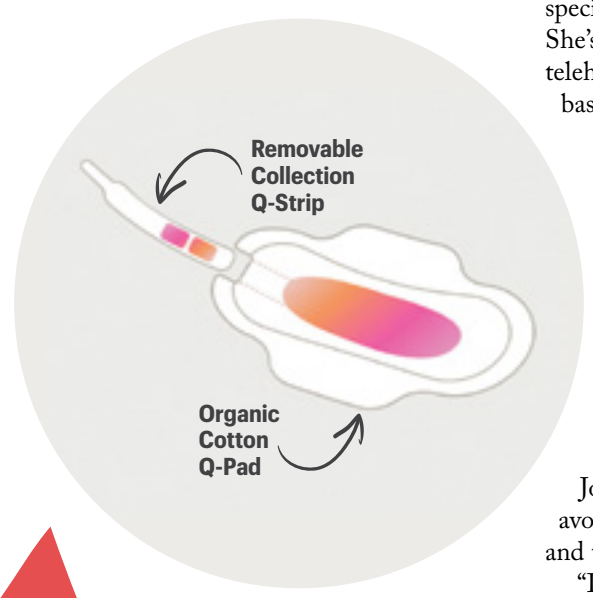
Naseri and her colleagues shared these findings in 2019. Further tests on using menstrual blood to diagnose diabetes led to the creation of the Q-Pad.

The Q-Pad kit comes with two special menstrual pads. These have removable collection strips. A user wears the pads and allows the strips to collect blood during one menstrual cycle. Then both strips are mailed to a lab for testing. The lab runs a hemoglobin A1c test, which reflects a person's average blood sugar levels over the last few months. Based on these data, it's easy to tell if someone has diabetes. The person then gets their results via app or email.

"The reliability is excellent," says Kathleen Jordan. And Q-Pad results match those from typical blood tests. Jordan is a doctor who

Menstrual blood contains a host of proteins, hormones and bacteria as well as, of course, blood. The Q-Pad has a strip that can be removed to test period blood for signs of diabetes.

FAVEBRUSH, OLLY KAVA/SHUTTERSTOCK



specializes in women's health. She's chief medical officer of the telehealth provider Midi Health, based in Menlo Park, Calif.

Diabetes can damage the eyes, kidneys, nervous system and heart. Estimates suggest that nearly 9 million people in the United States have diabetes but don't know it. Many others have heightened blood sugar just below the level where diabetes can be diagnosed, Jordan says. Many risks can be avoided if the disease is caught and treated early.

"I think more people need to get tested, period," Jordan says. The Q-Pad could help.

What's more, many people with diabetes also have PCOS. That's short for polycystic ovary syndrome. This condition causes irregular periods and infertility. By running the A1c test, Q-Pads could help diagnose PCOS as well as diabetes, Jordan says.

OPPORTUNITIES AND OPEN QUESTIONS

For now, testing of period blood has been approved only for diabetes. But Naseri thinks it may have a far greater potential.

Menstrual blood could be used to measure a protein that signals inflammation, she says. Or hormones that offer clues to someone's thyroid health. Or even antibodies that show how your immune system is responding to COVID-19. Doctors already test for all these things in standard blood samples.

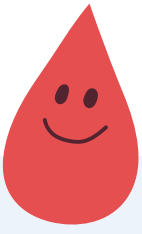
And stuff in period blood that's not found in other blood samples could lead to new types of tests. For instance, researchers have found substances in menstrual blood that are signs of infertility. Or cells in menstrual blood could help diagnose endometriosis. That's a condition where tissue similar to the lining of the uterus starts growing outside the uterus.

But many open questions need answers before period blood can be used for all these tests.

Miriam Santer cofounded theblood, a German company that is testing period blood. "There's not enough basic understanding" of female bodies, she says. That includes "how we're affected by specific diseases, how we react to medication, therapeutics and so on."

Talking about menstruation at all is still taboo for many, Santer adds. That stigma has been a major barrier to studying the basic bodily process. And that, in turn, has slowed progress in providing better health care to people with periods.

— Payal Dhar



What Is Menstruation?

Menstruation is the normal release of blood and tissue from a person's uterus through the cervix and out of the body through their vagina. It is part of a natural, roughly monthly cycle for people with uteruses. This process of shedding uterine tissue is also known as getting your period.

Most people who have uteruses identify as girls or women. But transgender boys and men, as well as nonbinary people with uteruses, can also get periods.

People start getting their periods during puberty. Many begin menstruating between ages 11 and 14. But some start earlier or later. People often stop getting their period around age 50.

People with uteruses menstruate each cycle as a result of their bodies preparing for the possibility of getting pregnant. As part of that process, the lining of the uterus thickens. That way, if one of the person's eggs gets fertilized, it has a cozy place to settle in the uterus. There, it can grow into a fetus throughout pregnancy.

If someone does not get pregnant during a certain cycle, their uterus does not need such a thick lining. The lining breaks down, passes through the cervix and leaves the body through the vagina. This is menstruation. The shed material is known as period blood.

During a person's period, they may bleed for three to seven days. Some people use pads or tampons to collect and dispose of period blood. Others use different menstrual products, such as absorbent period underwear or rubber menstrual cups.

Menstruation can come with a host of side effects. Some people get cramps or back pain during their periods. Others feel bloated or tired. They might even get food cravings or experience mood swings. Such side effects are normal.

But more severe symptoms may signal health issues. Someone may need to talk to their health care provider if their cycle lasts less than 21 or more than 35 days. They may also need medical attention if they bleed longer than seven days. Or if they bleed a lot more or less than usual. Severe cramps, vomiting or bleeding between periods may also be signs that a person needs medical help.

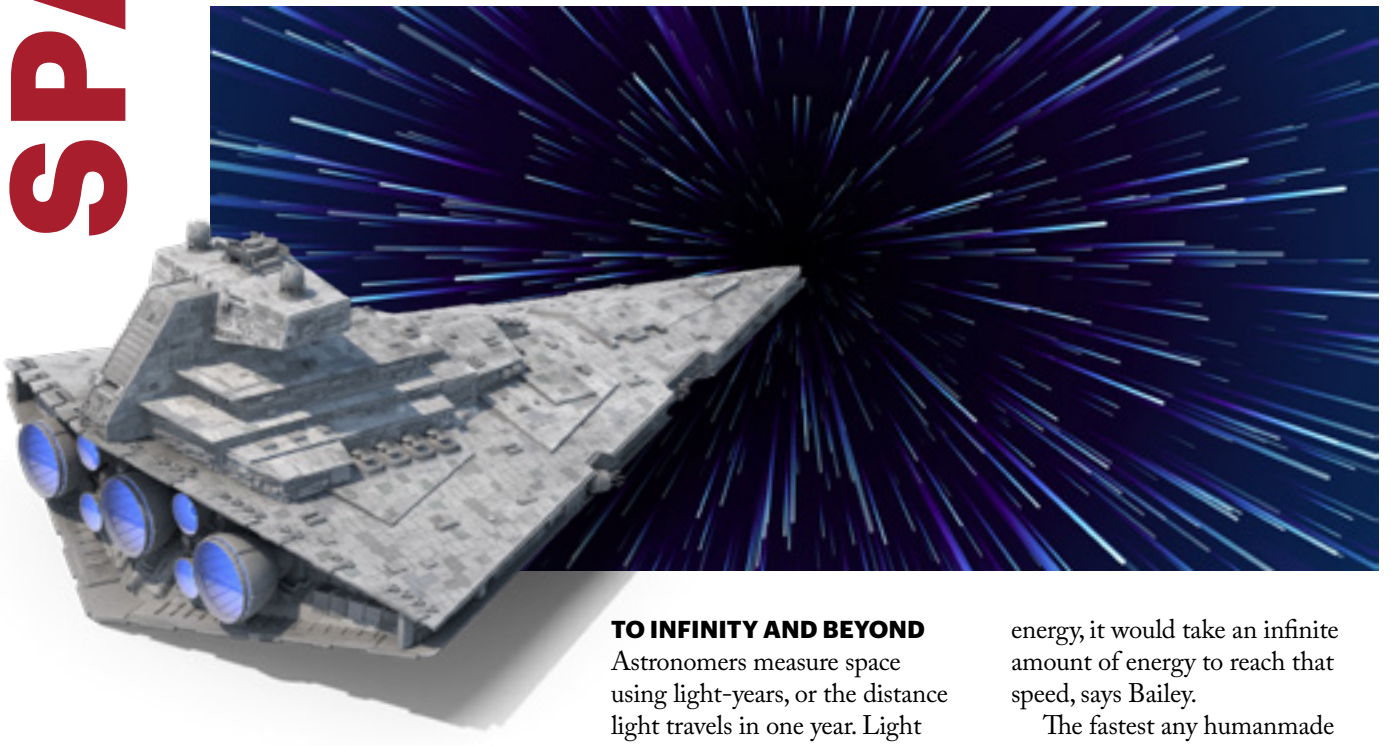
— Maria Temming

OLLY KAVA/SHUTTERSTOCK; QVIN Q-PAD

SPACE

Spacecraft need an extra boost to travel between stars

Experts ponder how future technology might take us to the cosmos



In *Star Wars*, spacecraft move faster than the speed of light. In reality, reaching light speed would require an infinite supply of energy.

YUKHYM TURKIN, SHUTTERSTOCK-PIXELSQUID/SHUTTERSTOCK

In *Star Wars*, pilots enter a dimension — hyperspace — to travel between different worlds. To merge onto this cosmic highway, the ships are equipped with special engines called hyperdrives. Once inside hyperspace, these speedsters zoom faster than light. With a push of a lever, the ships can travel between star systems in a few hours to days.

Science fiction makes space travel look easy. But many of these stories break the laws of physics to get from planet to planet. Off-screen, the technology needed to reach another star system doesn't yet exist. However, emerging propulsion methods could brighten the future of interstellar travel.

TO INFINITY AND BEYOND

Astronomers measure space using light-years, or the distance light travels in one year. Light speeds through interstellar space at around 300,000 kilometers (186,000 miles) per second. Proxima Centauri, the nearest non-sun star to Earth, is 4.24 light-years away.

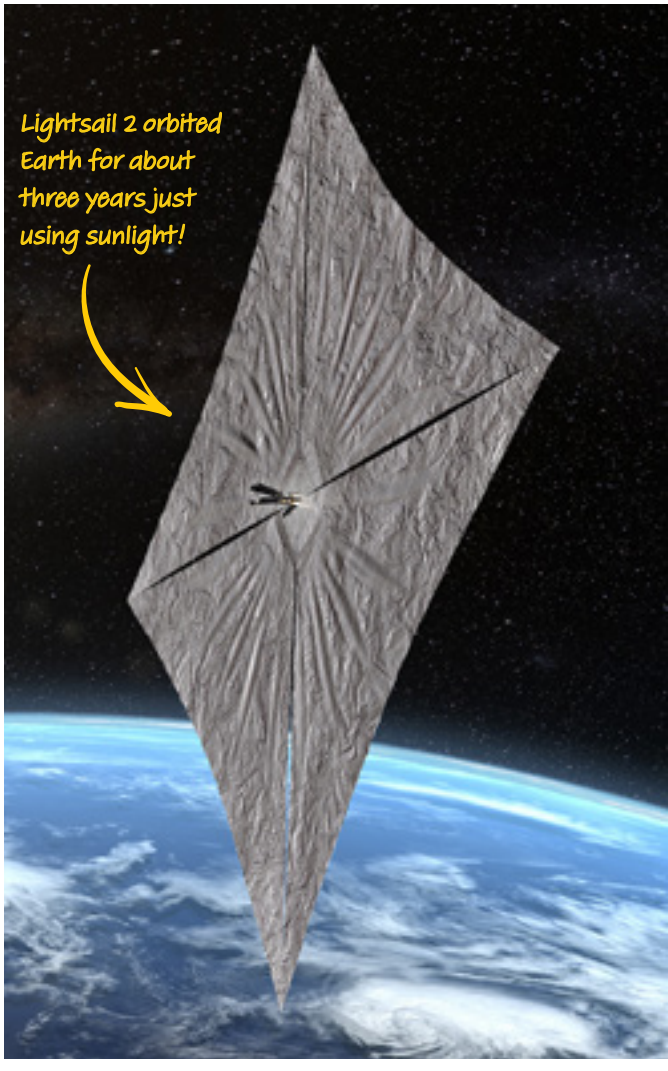
Using something like hyperdrive to travel between star systems would be impossible, says Scott Bailey. An engineer at Virginia Tech in Blacksburg, Bailey designs instruments to study Earth's atmosphere. "That's like driving [a] car right to the mall that's light-years away," says Bailey. "That's not going to happen with any sort of propulsion."

Even reaching light-speed is impossible. That's because, due to the nature of light and energy, it would take an infinite amount of energy to reach that speed, says Bailey.

The fastest any humanmade object has traveled is only about 0.05 percent the speed of light. At this speed, it would take about 7,700 years to reach the exoplanet Proxima Centauri b.

A spacecraft traveling at a tenth of the speed of light could shave down the trip to Proxima Centauri b to a speedy 40 years. Future engineers could use nuclear power to achieve such a speed, says Bailey, but developing that technology could take thousands of years.

Controlled fusion could help, says Cole Miller. Miller is an astronomer at the University of Maryland, College Park. Controlled fusion harnesses energy from combining atomic nuclei to create a steady supply of power.



Researchers have been working on controlled fusion for about 70 years. But these experiments have yet to produce more energy than they consume, Miller notes.

SAIL AWAY

Some vehicles in the *Star Wars* universe rely on "sun jamming" to zip along using solar wind. This "wind" is the constant stream of charged particles produced by stars. These spacecraft have huge sails that catch the solar wind, moving through space like a ship on the sea.

The Planetary Society crowdfunded a small spacecraft, Lightsail 2, that moved in a similar way. Rather than relying on solar wind, though, these solar sails used pressure from sunlight itself.

While light doesn't have mass, it does have momentum. Solar sails intercept sunlight with thin sheets made of polymers and a reflective plastic called Mylar. When speeding photons hit the sail, they bounce off and transfer energy. These small and repeating collisions create a force that can push objects along.

Lightsail 2 launched in 2019 and orbited Earth for about three years before reentering the atmosphere.

But using solar sails to propel a large spacecraft would be tough, says Miller. The thrust produced probably wouldn't be strong enough to carry large ships ferrying humans.

Upscaling solar sails would offer unique benefits, however. Using sunlight would allow a spaceship to accelerate without fuel. And unlike Earthbound objects, spacecraft aren't slowed down by air friction produced by an atmosphere. This would allow any spacecraft to continue gaining speed as long as it's exposed to sunlight.

FINDING THE FORCE

Star Wars makes the cosmos seem like a raceway. But the immense distances separating worlds hinder space travel, even within our solar system.

For now, the longest distance we're looking to transport people is to Mars, says Jarred Young. This engineer studies propulsion systems at the University of Maryland, College Park. Researchers are eyeing new methods that could bring people to and from the Red Planet safely, he says.

One of these is ion engines. These thrusters create force by shooting charged atoms from the back of a spacecraft. *Star Wars*' TIE Fighters wind through space battles with them. But real ion engines work best with straight paths, says Young. "It's essentially point-and-click propulsion."

Ion engines aren't as powerful as the chemical propellants used in rockets. Chemical rockets create thrust by combusting fuel and oxygen-releasing substances called oxidizers.

But chemical rockets only burn for a short time. Ion engines can last months or even years, possibly helping fuel future trips to Mars. These thrusters, though, aren't yet strong enough to propel massive spacecraft that far, Young says.

And for now, reaching new worlds is only possible in fictional galaxies far, far away.

— *Aaron Tremper*

The Parker Solar Probe (top left) is the fastest-moving humanmade object. Its top speed is 635,266 kilometers (394,736 miles) per hour. But the speed of light is still about 1,700 times faster than that!

STEVE GRIBBEN/JOHNS HOPKINS APL/NASA; JOSH SPRADLING/THE PLANETARY SOCIETY

TECHNOLOGY

How 'green' is your online life?

Your digital choices affect your environmental footprint

In today's world, it can feel like our entire lives take place in front of a screen. Whether we're texting friends or laughing at TikToks, our digital devices are always close.

Their proximity can help us feel more connected to friends or family. But they also can physically disconnect us from interacting with people face-to-face. Beyond our mental well-being, these devices also can impact the well-being of our planet.

Every device we plug in or charge up uses electricity. Much of that power comes from burning fuels that add greenhouse gases to the air. As a result, each of our devices leaves a trail of climate-warming gases, usually carbon dioxide, or CO_2.

We won't see those gases. They probably won't even be emitted in our neighborhood. But every text, email, download, scroll or chat will result in a bit more pollution. As millions of other people around the world use their screens every day, too, those little impacts really start to add up.

Not seeing how our online social lives dirty the air or warm the planet won't make those impacts any smaller. In fact, we're unlikely to try to limit those impacts if we can't imagine them — much less tally them.

The answer is not necessarily to give up our devices. Instead, we can learn to use them in more eco-friendly ways. There's no one solution to greening our digital lives. But every small change we make to lower the carbon footprint of our screen use is a step toward slowing the rate of climate change and making our world a better place.

— *Sarah Wells*

The average person sends some 10,000 emails annually, emitting about **3 kilograms (6.6 pounds)** of CO_2

Six ways to make your online activity greener

Use smaller TVs and other devices. Larger devices use more resources to light up all those pixels.

Switch to a less-smart device that isn't streaming video. To stream something, your device must access data held at some big computer center. These centers devote a lot of energy to air conditioning the rooms housing their servers and other hardware. Spending all that energy has an environmental cost.

Stick to text or email. Text-based work produces less carbon pollution than video. That's because video or big image files used in streaming are much larger and more energy-intensive than the simple text of an email.

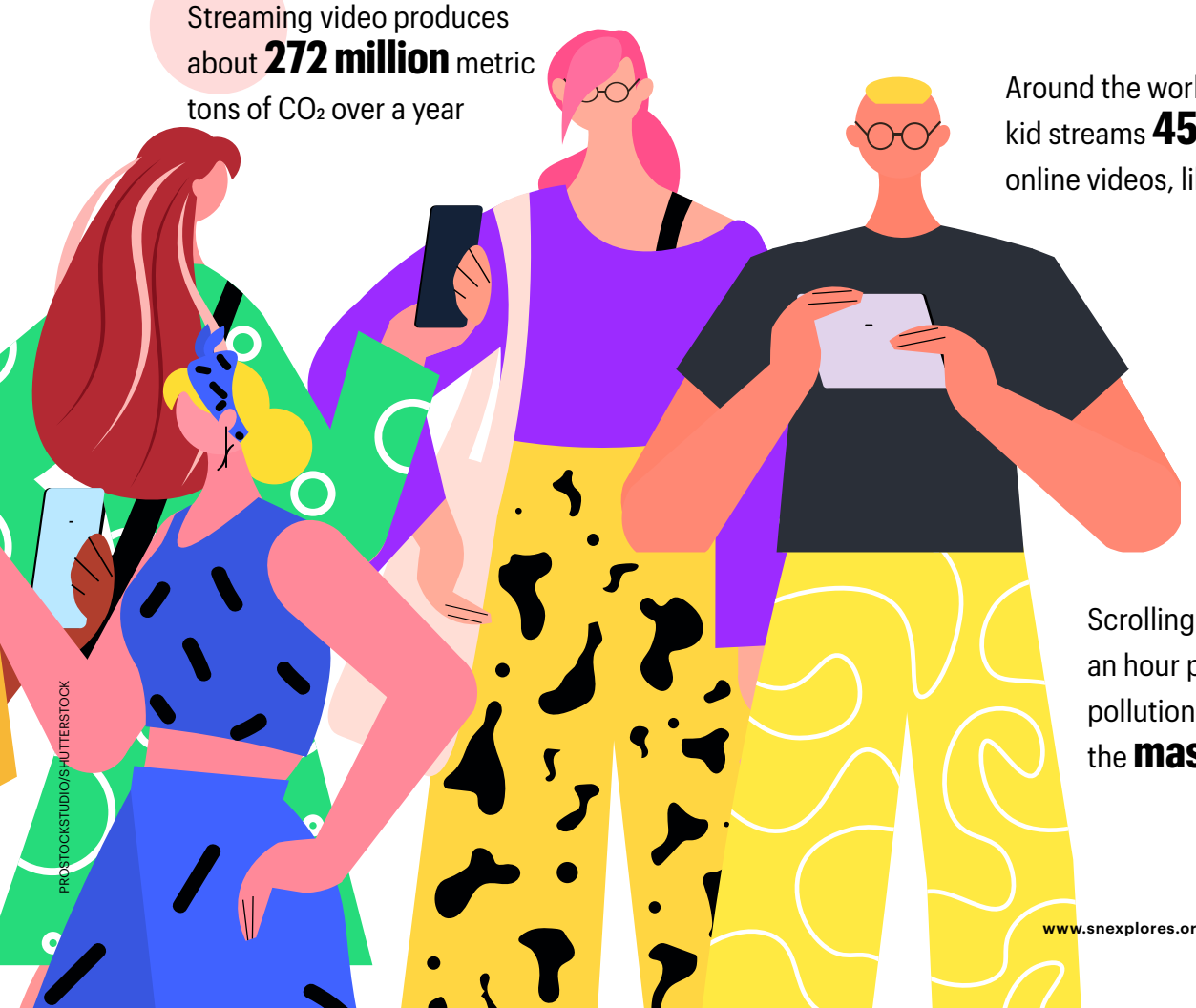
Hold onto your phones and other devices longer. Creating replacement devices generates more carbon emissions. Plastic from discarded devices could take hundreds of years to break down in a landfill. Glass screens may even take millions of years.

Turn off features like auto-play when streaming video. Auto-play algorithms can keep us scrolling longer than we intend to. They also can play videos — using energy — after we've fallen asleep.

Discuss this topic with your family. You can start by bringing it up at family dinner when discussing other climate topics, such as the carbon footprint of dining on meats versus plant-based foods. Then you can decide where screen time fits within your family's priorities.

Streaming video produces about **272 million** metric tons of CO_2 over a year

Around the world, the average kid streams **45 minutes** of online videos, like YouTube, daily



Scrolling TikTok for an hour produces CO_2 pollution equal to about the **mass of a plum**

PROSTOCKSTUDIO/SHUTTERSTOCK

SPACE

Jupiter's Great Red Spot is shrinking

If the storm keeps dwindling, it could someday disappear

Centuries ago, astronomers observed a dark oval nicknamed the Permanent Spot on Jupiter. It was about the same distance from Jupiter's equator as the giant windstorm known as the Great Red Spot seen today. Researchers have wondered whether these spots are the same. Now, a study suggests the spots are distinct — and hints at what could become of the Great Red Spot.

Agustín Sánchez-Lavega and his colleagues dug through historical observations of Jupiter's spots. These records dated back to the 1600s, when Jupiter's observers sketched what they saw through their telescopes. "It was very exciting to see … the observations and drawings that astronomers made with great precision 375 years ago," says Sánchez-Lavega. An astronomer and planetary scientist, he works at the University of the Basque Country in Bilbao, Spain.

The Permanent Spot appeared in observations of Jupiter made from 1665 to 1713. But after that, reports of Jupiter bore no signs of this feature. Then, beginning in 1831, drawings of Jupiter showed a spot resembling the Great Red Spot. At first, it appeared as a clear oval. In later records, it was drawn with a red tint.

Sánchez-Lavega's team also tracked the spots' sizes and shapes from 1665 to 2023. They measured the Permanent Spot from centuries-old drawings. Those data suggested that this spot's length was two to three times smaller than that of the Great Red Spot in 1879. They got the Great Red Spot's size from a photograph taken that year.

It seems that naming the earlier feature the "Permanent Spot" was a bad call. Its absence in the record for 118 years and its small size suggest it may have vanished before the Great Red Spot emerged. The researchers shared their findings in *Geophysical Research Letters*.

The Great Red Spot has been shrinking since it was spotted in the 1800s. It's now about the size of the long-lost Permanent Spot. If the Great Red Spot keeps getting smaller, it could reach a new stable size or even disappear. — *Carolyn Wilke*

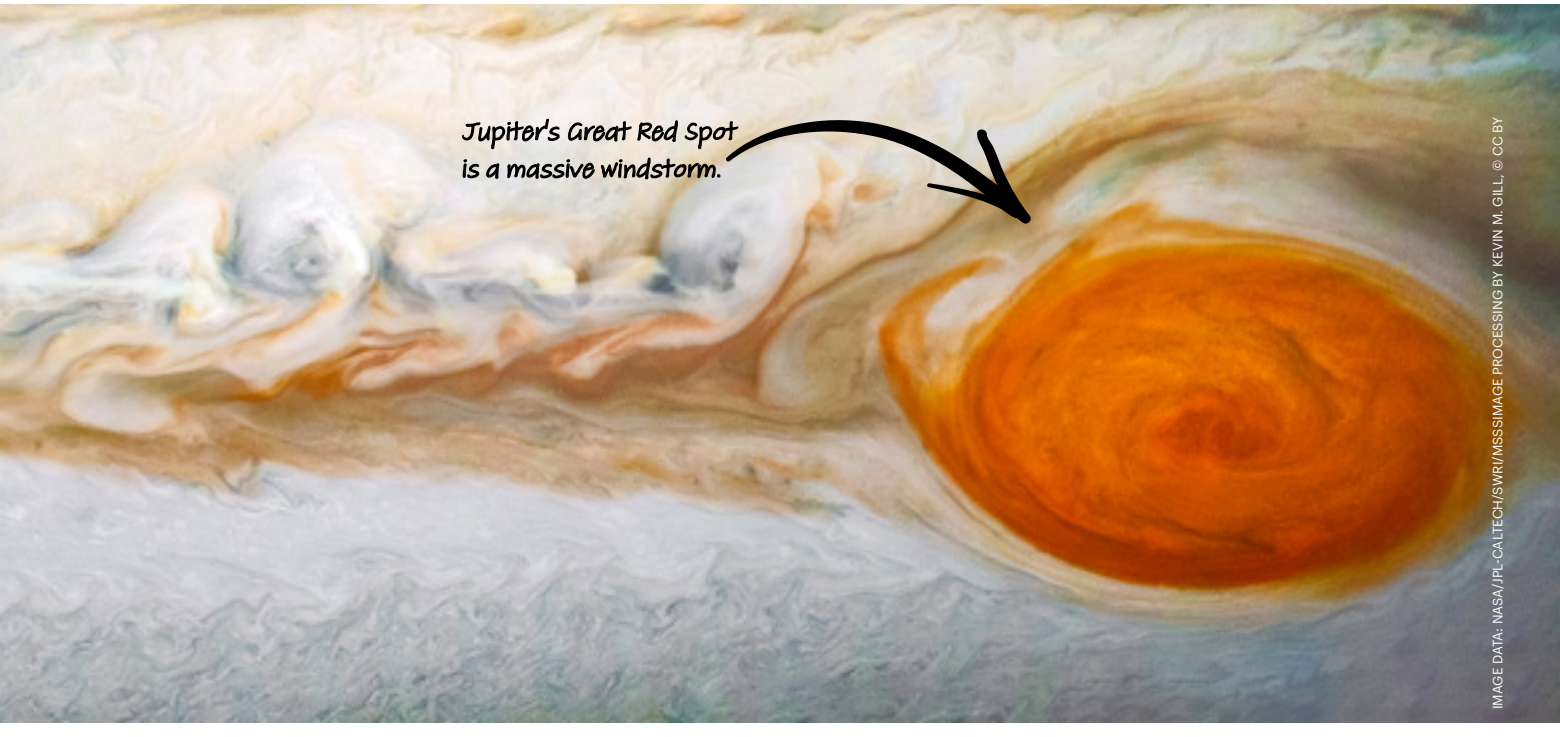
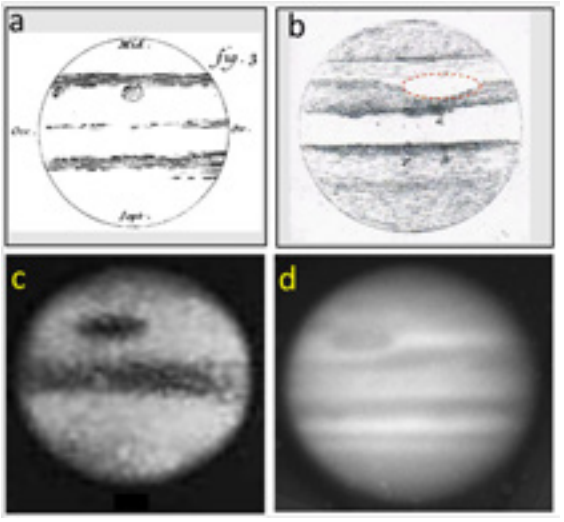


IMAGE DATA: NASA/JPL-CALTECH/SWRI/MSSSIMAGE PROCESSING BY KEVIN M. GILL, © CC BY



Scientists have observed spots on Jupiter for almost 400 years. A drawing by French astronomer Gian Domenico Cassini dates to 1672 (top left) and one by German Samuel Heinrich Schwabe is from 1851 (top right). Andrew Ainslie Common used a telescope to photograph the planet in 1879 (bottom left). A telescope at the Lick Observatory in California captured an image in 1890 (bottom right).

FIGURE A

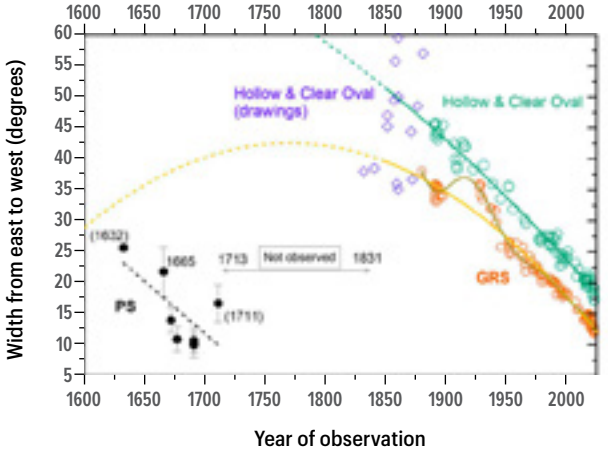
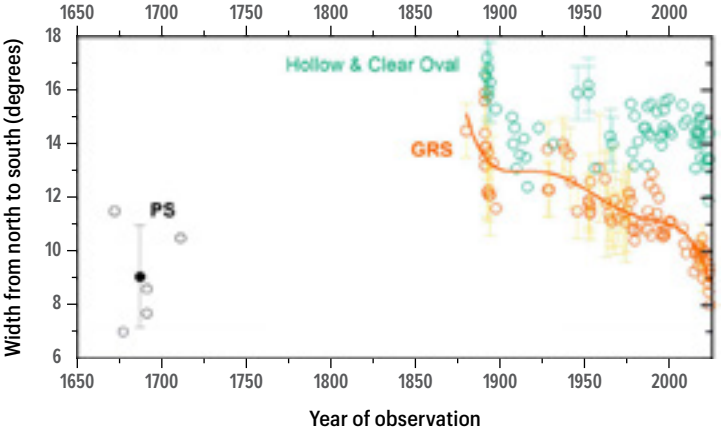


FIGURE B



Sánchez-Lavega and his colleagues took measurements of the Permanent Spot (PS) and the Great Red Spot (GRS) from drawings, photos and other images. The term GRS usually describes just the swirling red oval. This oval is surrounded by a whitish area, called the hollow. But sometimes no red is visible. At those times the whole thing is called the clear oval. These features are on a curved surface, and their length and height can be described in degrees. For instance, a full circle is 360 degrees, and one-quarter of a circle is 90 degrees. Figure A shows how wide the spots are from east to west. Figure B shows how wide the spots are from north to south.

DATA DIVE

1. Look at Figure A. What was the Permanent Spot's width from east to west in 1632? How did its width change in the late 1600s and early 1700s?

2. How wide from east to west was the Great Red Spot in 1875? How wide was it in 2020?

3. Look at Figure B. The black dot gives the average width for the Permanent Spot from north to south. How does this value compare with the individual observations of the spot's width (open circles)?

4. How has the width of the Great Red Spot from north to south changed from 1875 to 2024?

5. Based on the changes to the Great Red Spot's width (from east to west and north to south), what is happening to its overall area?

SÁNCHEZ-LAVEGA ET AL/GEOPHYSICAL RESEARCH LETTERS 2024

ANSWER

Trilobite fossils include soft tissue never seen before

The discovery helps reveal the weird way trilobites ate

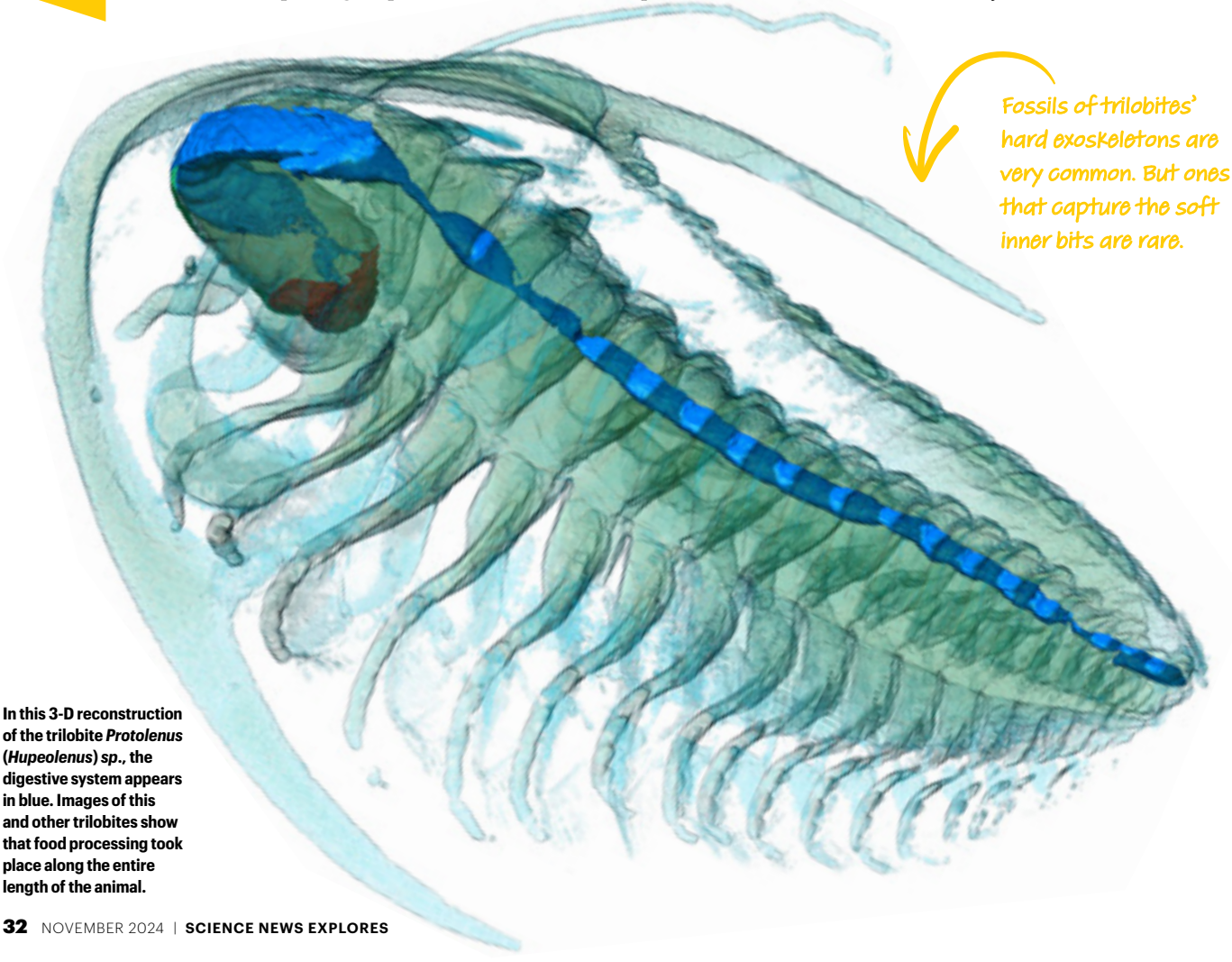
In rocks from Morocco, scientists have unearthed the best-preserved trilobites ever found. Trilobites are arthropods that once lived in the ocean. They died out some 252 million years ago. Fossils of their hard exoskeletons are common. But it's rare to find any trace of trilobite soft tissue, which tends to break down.

Soft tissue parts of trilobites are clearly visible in the new fossils. These include the animals' antennae, legs and digestive system. John Paterson and his colleagues shared the find in *Science*. Paterson is a paleontologist at the University of New England in Armidale, Australia.

The trilobites' soft tissue was likely preserved thanks to a nearby volcano exploding. Superheated ash from the eruption flowed into nearby waters, where it covered the trilobites and entombed them. Crucially, the ash hit water before hardening around the trilobites. Without the water's cooling effects, the hot ash would have burned the critters away.

Such pristine fossils reveal that trilobites had many pairs of legs from their head to their torso, and the animals ate with these limbs. They chewed food along a central groove while passing bits of food toward a tiny mouth.

— *Lucas Van Wyk Joel*



Fossils of trilobites' hard exoskeletons are very common. But ones that capture the soft inner bits are rare.

In this 3-D reconstruction of the trilobite *Protolenus* (*Hupeolenus*) *sp.*, the digestive system appears in blue. Images of this and other trilobites show that food processing took place along the entire length of the animal.

INSIDE THE MIND OF A YOUNG SCIENTIST

A Regeneron International Science and Engineering Fair winner 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? Amelia Hammersley, a finalist at the 2024 Regeneron International Science and Engineering Fair (ISEF) shares her experience.

Q What inspired this project?
A "When I was in sixth grade, my younger sister fell pretty bad, and she hurt her head. She got a concussion," Amelia says. Traumatic brain injuries are usually treated with anti-inflammatory drugs that may have negative side effects. For her research, Amelia combined a natural compound called celastrol with the drug naproxen. She tested the combo on concussed fruit flies.

Q Did you encounter any unexpected obstacles?
A To test the flies' recovery, Amelia put them in tubes with raspberry juice at the top to see if they could climb to the top. "I originally wanted to 3-D print a maze to see how fast the fruit flies could go through it," Amelia says. "But I think I kind of overestimated how quickly I could do that."

Q What resources helped you complete your project?
A "My teacher calls it topic shopping," Amelia says. "I created a list of things I was really passionate about. Then I did a big literature review of over 30 articles and summarized and annotated them. And I found out about this natural compound, celastrol, and I was really interested in the neuropathways that it worked through."

Regeneron International Science and Engineering Fair finalist

Amelia Hammersley

Amelia, 17, set out to find a way to reduce side effects of anti-inflammatory drugs used to treat traumatic brain injuries. She tested a combination of celastrol and naproxen on concussed fruit flies, and she found the combo was just as effective as naproxen alone. Amelia is a senior at Oak Park and River Forest High School in Oak Park, Ill.

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