ScienceNews Explores

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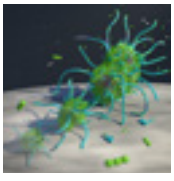

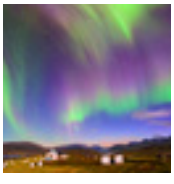

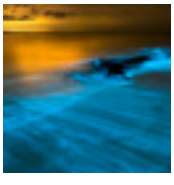

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Q How did birds develop such bright colors?

— Abby K.

A The structure of bird feathers makes them ideal for displaying bright colors, says Klara Norden. She researches bird feathers at Princeton University in New Jersey. Feathers are wider and more flexible than mammal hair, which has allowed them to evolve into different shapes and displays. "It's a more flexible canvas for the color to be put on than hair," Norden says. Some bird feathers, like those of a red male cardinal or pink flamingo, get their pigments from the food birds eat. The shimmery blue of peacock feathers, meanwhile, arises from the way light reflects off those feathers' unique structure. Birds may have evolved such eye-catching colors because, unlike some other animals, they have superb color vision. And this adaptation may have been around since at least the time of birds' ancestors — a group of meat-eating dinosaurs called theropods. "That makes it more likely that you would evolve showy colors, because you can see them," Norden says, "and [birds have] had really good color vision for a long time in evolutionary history."

PHOTOMASTER/SHUTTERSTOCK

Q How can you get skin cancer from the sun?

— Emily Z.

A Most skin cancers are caused by exposure to ultraviolet radiation from the sun. Ultraviolet radiation is a type of light that humans cannot see, but it can reach deep into the layers of our skin. Too much ultraviolet light can damage DNA in skin-producing cells. It can also impair genes that fix damaged DNA. Over time, these genetic changes, or mutations, build up and allow skin cells to grow out of control. This uncontrolled growth is the condition known as cancer, and it can be deadly if it spreads to other parts of the body.

Q I heard black holes are invisible. So how were we able to get a picture of one?

— Izzie B.

A You heard right! A black hole *is* invisible, but material surrounding it is not. A glowing disk of gas and other debris, called an accretion disk, swirls into a black hole. In pictures of black holes that have been taken by the Event Horizon Telescope, this accretion disk shines bright against the dark silhouette of the otherwise invisible black hole.

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Sarah Zielinski
Editor, *Science News Explores*

SPACE

A mysterious double aurora was caught on film

The red and green glows might be related

Alan Dyer was outside his home in Strathmore, Canada, when the dancing Northern Lights caught his attention. He grabbed his camera and started filming. "I knew I had something interesting," says Dyer, a photographer who also writes about astronomy. His footage turned out to be the most complete record yet of a rarely seen phenomenon: a special kind of red-and-green double aurora.

Now physicists have studied those images to learn what may have triggered the unusual light show.

At first glance, the double aurora looks like a floating slice of watermelon. The rind — a shimmery green aurora — is well-understood: It's caused when the solar wind energizes protons trapped within Earth's magnetic field. Those protons rain down, bumping into electrons and atoms in their path. That's what gives the green glow — called a proton aurora — its name.

The fruity-looking red strip is more mystifying. Scientists have known about these "stable auroral red arcs" for decades. But there's no agreement on how they form. One idea is that Earth's magnetic field can heat up certain areas of the atmosphere. That heat could knock particles around, like in proton rain.

Researchers had seen these two types of auroras occur together before. But it was always mysterious, says Toshi Nishimura. He's a space physicist at Boston University. "Scientists didn't have a good idea of why they could be together."

Nishimura and his team looked at satellite observations along with the images captured by Dyer and other amateur astronomers. The two phenomena might be related, they concluded. The key is the thin rays in the red aurora. Those mark the paths of electrons falling through the Earth's magnetic field.

That means electron rain appears to trigger the red aurora, just as proton rain triggers the green one. Both get powered by the solar wind. But the electrons carry less energy than the protons, so they make for a more reddish color. The team reported its findings in *JGR: Space Physics*.

Electron rain might not be the only way to produce the stable red arcs, though, says Brian Harding. He's a space physicist at the University of California, Berkeley. He says the results show that what's going on is more complicated than researchers had thought.

That's important because auroras can warp GPS and radio signals. If scientists want to forecast space weather like they do normal weather, they need to understand these red glows, Harding explains. "You want to make sure that you can predict stuff like this."

— *Asa Stahl*

Photos of a double aurora (red and green lights) are revealing what's behind these rare light shows.

ANIMALS

Armored dinos may have used tail clubs to bash each other

A fossil's broken spikes suggest fights, not *T. rex* bites

Armored dinosaurs with huge, bony knobs on the ends of their tails likely pummeled each other. That's what new fossil findings suggest.

Many of these dinosaurs — known as ankylosaurids — sported heavy clubs on their tails. Such weapons are like natural sledgehammers, notes Victoria Arbour. A paleontologist in Victoria, Canada, she works at the Royal British Columbia Museum. Some clubs may have been as big as a microwave oven.

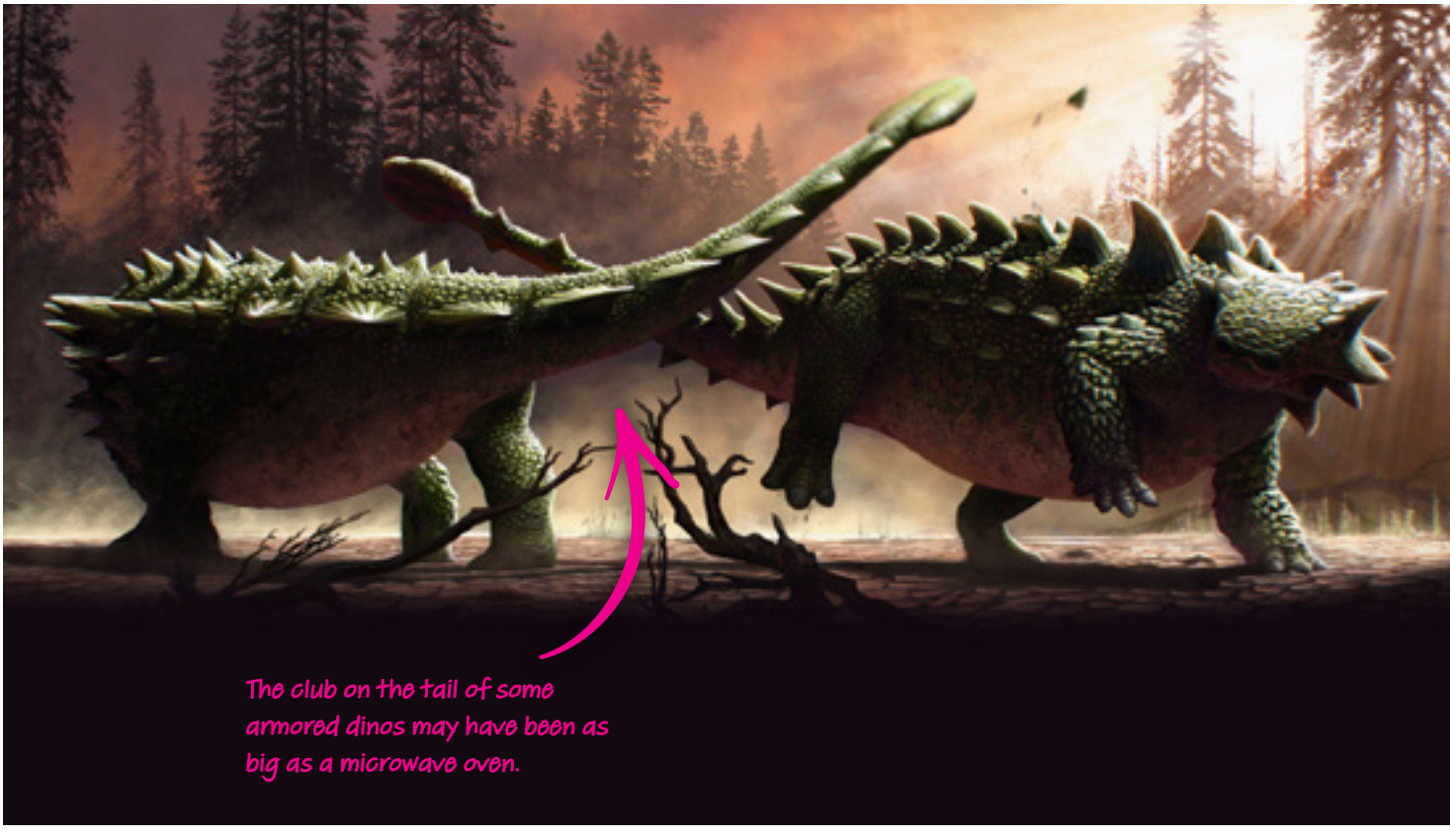
Scientists and artists have long thought the clubs were mainly to defend against predators, Arbour says. But a team she was on found other clues to the contrary.

They were working on a fossil skeleton of an armored dinosaur called *Zuul crurivastator*. As the team chipped away more rock, they found five broken pieces of spiky armor on the dino's sides. Those damaged spikes were clustered on the abdomen, near the dino's hips. If a large meat-eating predator had made these injuries, says Arbour, they'd likely be spread more randomly. There might also have been bite and scratch marks.

Instead, the injuries are more consistent with repeated clubbing. The team shared its findings in *Biology Letters*.

It's possible that tank-like ankylosaurs battled each other for mates, food or territory. This would have been sparring, much as male deer and giraffes do today.

That tail might have been useful defense in a pinch, too. Arbour says, "Having a tail club you can swing around at the ankles of a two-legged predator is a pretty effective weapon."
— *Jake Buehler*



The club on the tail of some armored dinos may have been as big as a microwave oven.

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LIFE

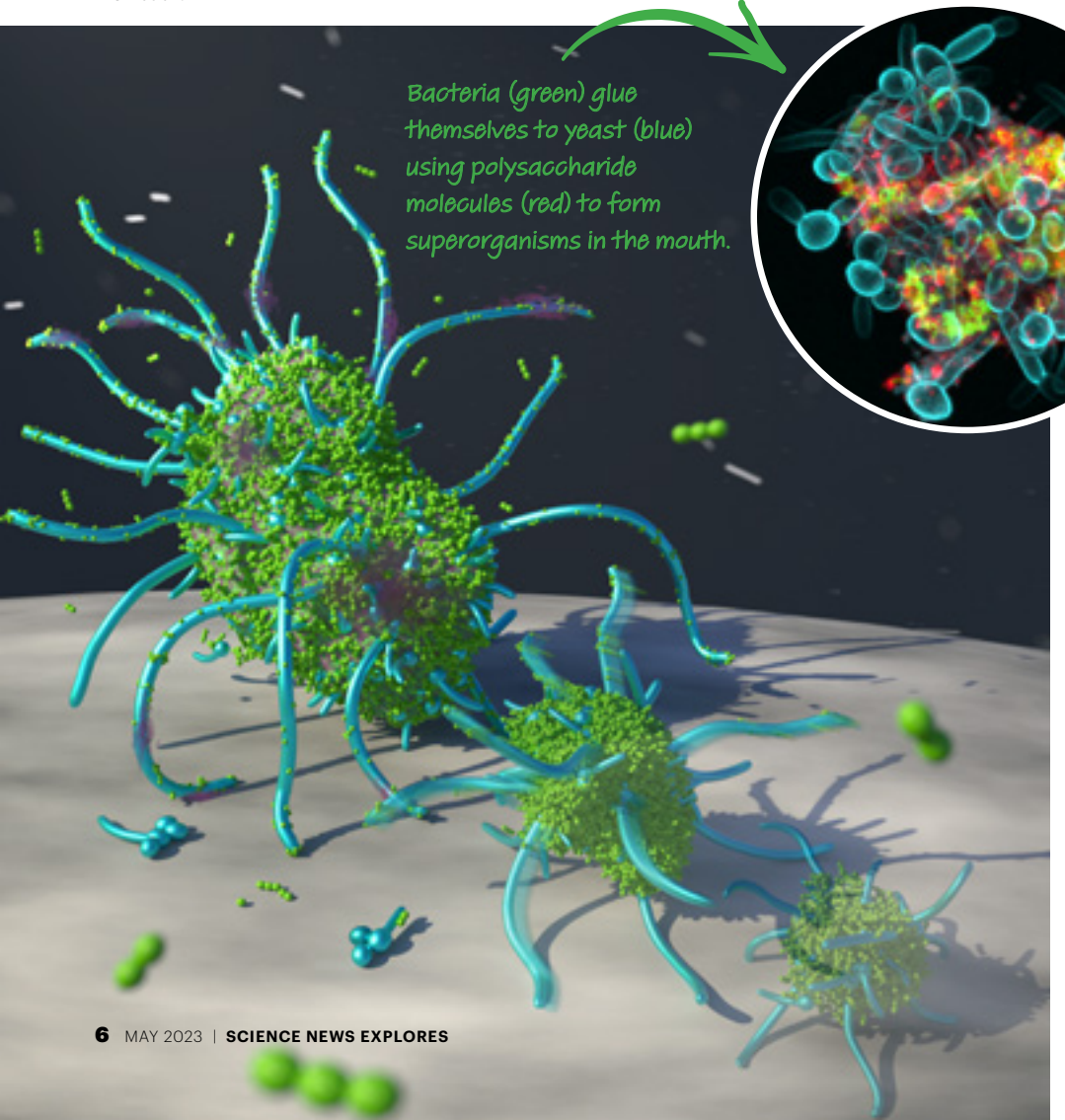
Mouth-crawling superbugs cause severe cavities

Bacteria and fungi team up to crawl across teeth

As the superbug grows, it begins to move. Fungal hyphae (in blue) propel the bacteria (in green) along a tooth's surface in a leaping-like motion.

You know eating sweets can lead to cavities. Tooth decay is caused by sugar-loving microbes that live in the mouth. A new study may have you reaching for your toothbrush: Some mouth microbes can team up into superbugs that crawl across your teeth to cause widespread damage.

Cavities form when dental plaques coat teeth and release acid that breaks down a tooth's hard enamel covering. Many types of microbes form dental plaques, says Hyun (Michel) Koo. He is a dentist and microbiologist at the University of Pennsylvania in Philadelphia. But young children with severe tooth decay have a particular type. These are made up of the bacterium *Streptococcus mutans* and the fungus *Candida albicans*, a type of yeast.



Bacteria (green) glue themselves to yeast (blue) using polysaccharide molecules (red) to form superorganisms in the mouth.

ZHI REN/UNIVERSITY OF PENNSYLVANIA

Koo and his team studied dental plaque and saliva samples from 44 toddlers: 14 with healthy teeth and 30 with severe tooth decay. The healthy children's mouths had bacteria but no yeast. Children with lots of cavities had both types of microbes.

When the bacteria and yeast got together, they developed superspreading powers. Clusters of bacteria glommed on to the yeast. And the yeast grew long hyphae that extended like legs from their centers. The hyphae even worked like legs. They stretched out, lifted the clump of bacteria — the "body" of the superorganism — and moved the whole thing in the direction the hyphae had grown.

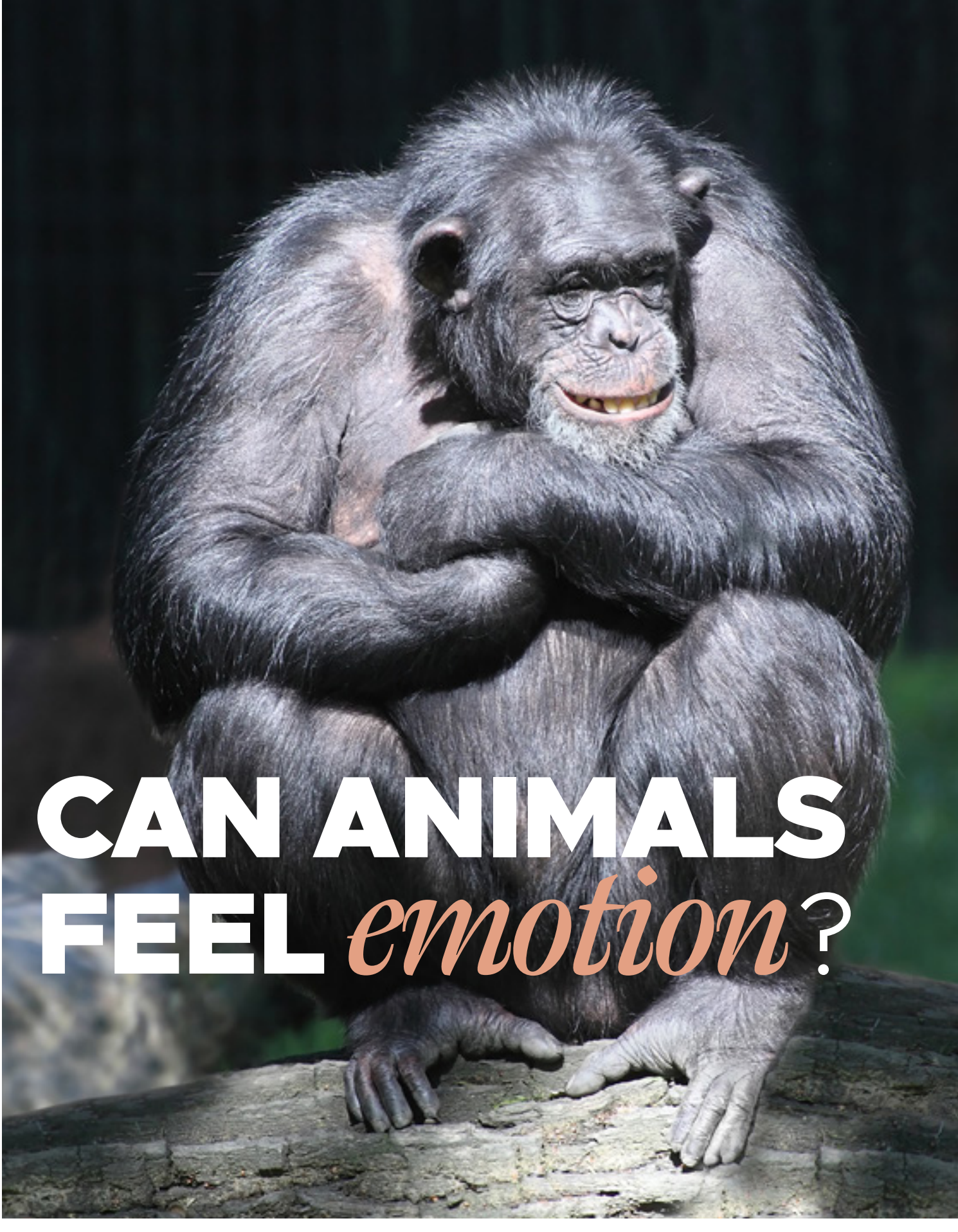
At the same time, the bacteria in the clump continued to multiply. This allowed the superbugs to quickly cover the tooth's surface. Then the clumps started eroding the enamel underneath. The team described these superbugs in *Proceedings of the National Academy of Sciences*.

The superbugs were super tough, too. "They are stickier, harder to kill and more difficult to remove when united," says Knut Drescher. He's a biophysicist at the University of Basel in Switzerland who analyzed the study's images.

Sugar helped the superbugs grow faster, the team found. So in addition to regular brushing, limiting sweets is key to preventing cavities.

— *Alison Pearce Stevens*

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



CAN ANIMALS FEEL *emotion*?

By **Alla Katsnelson**

Researchers are finding ways to tease out what animals experience >>

KLETR/SHUTTERSTOCK

A dog senses a nearby stranger and gives a protective bark. A haughty cat slinks by, ignoring everyone. A cow chews its cud and moos in contentment. At least, that's how we may interpret their actions. We take our own experiences to understand and relate to the animals around us — using our imagination to fill in any gaps along the way.

But such assumptions are often wrong.

Take horse play. Many people assume these animals roughhouse for fun. But in the wild, adult horses rarely play. When captive horses play, it isn't necessarily good, says Martine Hausberger. She's an animal scientist with the French National Center for Scientific Research (or CNRS). Her lab is at the University of Rennes.

Hausberger raises horses on her farm in Brittany, France. About 30 years ago, she noticed that people who keep horses often misjudge cues about the animals' behavior. That inspired her to study horse welfare.

Adult horses that play have often been restrained, she found. Play seems to relieve the stress from that restriction. "When they have the opportunity, they may exhibit play. And at that precise moment they may be happier," she says. But "animals that are feeling well all the time don't need this to get rid of the stress."

Scientists who study animal behavior and welfare are coming to understand how many creatures experience the world. "In the last decade or two, people have gotten bolder and more creative in terms of asking what animals' emotional states are," explains Georgia Mason. She studies animal behavior and welfare at the University of Guelph in Ontario, Canada. There she is director of the Campbell Center for Animal Welfare.

Researchers like Mason are getting insight into a wide range of animals. For instance, recent studies hint that picking up a mouse by its tail can ruin its day. Meanwhile, an unexpected sugar treat may boost a bee's mood. Crayfish might feel anxiety. Ferrets can get bored. Octopuses — and perhaps fish — can feel pain.

Knowing all this could begin to change how we treat animals.

Yet studying what animals feel and experience is a challenge, notes Charlotte Burn. This animal-welfare scientist works at the Royal Veterinary College in Hatfield, England. People can try to learn how animals feel based on clues from their bodies and their behaviors. But feelings are personal. "So doing science about this is a bit strange," Burn says. "You have to get comfortable with the fact that your key thing is unknowable."

MASTER1305/SHUTTERSTOCK

People often use an animal's posture and actions to judge whether it is feeling calm or anxious.

Horse sense

To study horse welfare, Hausberger decided not to focus on fleeting emotions such as if they are happy or sad. For her research, she instead wanted to look at a horse's overall emotional health — meaning how good or bad it feels in the long run.

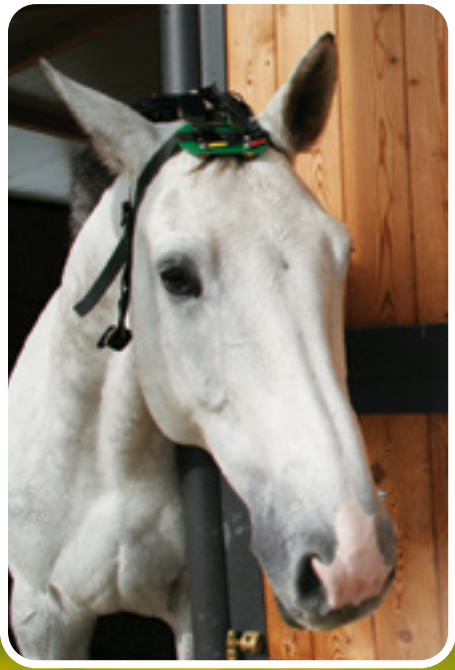
To measure how content a horse is, people often look at its posture or the position of its ears. They might also consider how attentive the horse is to what's going on around it. Appetite and its immunity can shed light on a horse's overall wellness. And certain chemicals in its blood can point to persistent stress.

Recently, Hausberger was part of a team that tested a more direct measure of horse well-being. They looked at brainwaves. To do this, the scientists built a simple, portable device worn as a headset. It provides "a sort of summary of brain activity," she says. Five electrodes on a horse's forehead eavesdrop on its brainwaves. The results offered a snapshot of the horses' secret inner lives. Hausberger's team shared what it found in *Applied Animal Behaviour Science*.

Horses that roamed with their herd, grazing outdoors at will, had more theta brainwaves. In people, theta waves seem to reflect a calm well-being. By contrast, animals that lived in solo stalls had little contact with other horses. These horses had more gamma brainwaves. Some studies in people have linked gamma waves to anxiety and stress.

Another way to study animal feelings is based on human psychology. Scientists can look for parallels in how people and other animals process their experiences. That could offer clues to what animals feel.

Why do scientists think this could work? Well, researchers already use rodents, fish, primates and other animals to better understand humans. These animal models can help them study and develop drugs for mental illnesses. So, the opposite should also work, says Michael Mendl. Scientists should be able to use what they know about feelings in people to study those in other animals. Mendl is an animal-welfare scientist at the University of Bristol in England.



A team is gauging horses' well-being using a headset that measures brain waves.

CÉLINE ROCHAIS; VOLODYMYR BURDIAK/SHUTTERSTOCK

Mood matters

Mendl has focused on one well-known feature of human psychology: affect. This term describes someone's overall mental state. Affect can be positive or negative. Good or bad experiences can often shape someone's affect. And affect can then shape how people see the world, biasing their thoughts and decisions.

Mendl and his colleagues tried to find out if the same was true for rats. They tested whether experiences that might influence a rat's affect would change its decisions. They performed an experiment that suggested this was the case. And researchers have done similar tests on affect in at least 22 species. Those included other mammals, birds and insects.

There's an important limit to this research, however. Its results only suggest whether an animal feels good or bad about some experience, Mendl explains. It does not prove something more basic: whether the animal can have subjective experiences. And by subjective, he means ones that are personal and colored by their own inner lives. This would be in contrast to responses they have to external events or stimuli — responses that all members of their species would likely share.

This type of study assumes that animals are sentient — or aware of their own feelings and experiences. If they aren't, then studying animals' well-being wouldn't make sense, says Mason at Guelph. "But none of the measures we use can assess or check that assumption," she says. And the reason, she adds: "We simply don't yet know how to assess sentience."

Searching for emotional life

Some animal experiences may vary by species. Take animals that live in groups, such as sheep. For them, Mason says, isolation "probably induces a form of terror that … humans can't imagine." Or think of creatures such as homing pigeons that can sense magnetic fields. For them, being put in a strong magnetic field "may be very upsetting in a way that we don't have a name for," she explains.

But many other feelings could be shared. For example, lots of evidence suggests that the stress of captivity can cause symptoms of depression in animals.

What about boredom? Mason and her colleagues proposed a way to tell the difference between depressed animals and bored ones. A depressed animal loses interest in its surroundings, they reasoned. A bored animal might be drawn to both good and bad experiences — anything to break the monotony.

Pain is another experience that animals share. Pain has two aspects, notes Matthew Leach. He studies animal behavior and welfare at Newcastle University in England. One part of pain is physical. It simply reflects when pain receptors in the body turn on. Animals respond to it as a reflex or due to a basic learned response. No conscious awareness is needed.

The other part of pain is emotional. And this part is trickier to measure. The reason is that it shows up in more complex behaviors. For instance, mice prefer a temperature up to 10 degrees Celsius (18 degrees Fahrenheit) warmer than they find in most research labs. So, the rodents build intricate nests in their cages to stay cozy. But when in pain or distress, the animals' nest-building abilities fall apart.

Facial expressions are a more direct way to assess pain or other distress in animals, Leach says. His group and others have identified a range of expressions in more than a dozen species, from mice to horses. With less than 30 minutes of training, people can learn to spot the twisted grimace of pain on animals' faces, Leach says.

And their faces can reveal much more than pain. Artificial-intelligence systems have helped identify a whole range of emotions in videos of mice. They've spotted pleasure, disgust and fear. Those feelings are visible in the tilt of a mouse's ears or a curl of its nose. "We're still very much in the infancy of understanding what facial expressions are telling us," Leach says.

The seafood industry may need new welfare rules if crabs, lobsters or other invertebrates can feel pain.

Researchers can often use an animal's behavior to tell if it is in pain. But recognizing pain in animals that are very different from us is hard, says Leach. Take octopuses. With their three-lobed brains, they are "as far from a vertebrate as you could possibly ever get," he says. So octopuses may experience things quite differently.

Neuroscientist Robyn Crook has explored that. She works at San Francisco State University in California. Her team's results show that octopuses probably feel pain and hint at emotional awareness in octopuses, Crook says. But not everyone agrees. "It is very difficult," she admits, "to produce convincing evidence of [this] in an animal that's very unlike us."

A matter of ethics

From an ethical point of view, treating octopuses as if they feel pain "is wise and humane," Mason says. But researchers are still figuring out where to draw the line for different animals.

That question prompted scientists in the United Kingdom to survey research on animal sentience. They reviewed all the evidence they could find on cephalopods (octopuses and related animals) and crustaceans (shellfish such as shrimp). This involved looking at studies on their brains and behavior. The researchers also looked at common practices in the seafood industry.

The group had a checklist of things that could qualify an animal as sentient. One was whether its nervous system could combine different types of sensory information. Another was the complexity of an animal's pain-sensing system.

This research showed that certain invertebrates such as crabs, lobsters and octopuses should be considered sentient. Although it's impossible to be sure, it appears they might be able to experience pain and suffering. So "the body of evidence is starting to make us think [such animals] deserve the benefit of the doubt," Burn says.

In light of that, animal-welfare laws may need to start protecting these creatures. In fact, updates to U.K. animal-welfare laws may make it illegal to boil lobsters alive. The new rules could require swifter, less painful methods to kill the animals.

There is still much to learn about animals' emotional states — and on a more basic level, sentience. But that research could help us take better care of the animals who share our planet. It also could give us a new perspective on how much of our inner life is shared across the animal kingdom.

A painful shot led octopuses to avoid a spot they once liked, hinting that the animals can make emotional associations.

It's easy to misjudge cues about how animals feel, especially in species that are very different than us.

PENGUINS: ONDREJ PROSICKY/SHUTTERSTOCK; SHEEP: BARONB/SHUTTERSTOCK; CRAB: ALAN TRAVERS/GETTY; OCTOPUS: PAN DEMIN/SHUTTERSTOCK

MYSTERY SOLVED

Forensic scientists are gaining an edge on crime >>

Samantha Hayek is asleep when the call comes in. There's been a crime. Someone needs to collect evidence of what happened. Hayek is a forensic specialist with the Sioux Falls Police Department in South Dakota. "We'll respond to all different kinds of stuff," she says, "whether it's a death investigation, burglary or vehicle accident." Sometimes, it's a suspicious event, such as a death that turns out to be due to a health problem. In this case, two people had been shooting at each other through a crowd.

By **Alison Pearce Stevens**

MICROGEN/SHUTTERSTOCK

When Hayek arrives, the people have gone. The crime scene spans nearly two blocks. It takes her eight hours of painstaking work to document the evidence left behind.

She takes photos of the area, then finds and flags each piece of evidence. This includes 34 spent shell casings (what's left after a gun fires a bullet). Cups and cans litter the ground. A blood trail leads away from the scene. Hayek takes more photos to show where she found each item. Then she swabs the blood, bags the shell casings and other items, and heads back to the lab.

Forensic scientists such as Hayek do the important work of figuring out what happened during a crime. The evidence they collect and analyze helps police detectives piece together a picture of the scene. Recent advances in forensic science are making this process easier. New tools, for instance, can help recover vanished fingerprints. Others can identify people from really small samples of tissue.

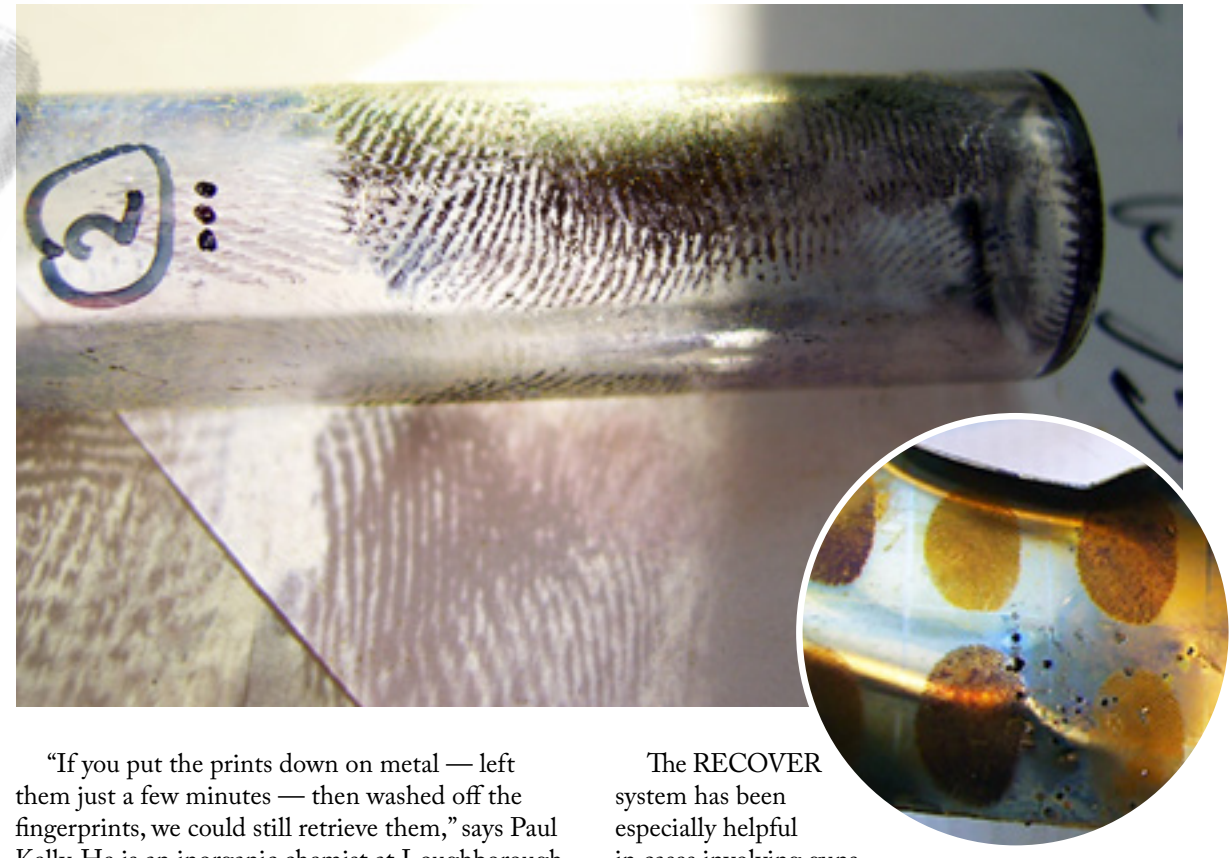
Seeing the invisible

Fingerprints are among the most used — and useful — pieces of forensic evidence. That's because they're unique to each individual. Forensic scientists "dust" for fingerprints by applying to a surface a powder that binds to fatty acids and amino acids left behind by a finger's touch. An analyst then compares the print with others in a national database. Anyone fingerprinted in the past should be in the system. If one of those people has now left prints at the scene, the analyst will know who it was.

Because fingerprints are such a good source of identification, criminals sometimes try to remove them. They might wipe down everything they touched. They may even go so far as to clean surfaces with bleach or some other chemical. Once that's happened, typical fingerprinting methods no longer work. But a new system called RECOVER can find those prints — even when they're gone from view.

Forensic scientists collect evidence to aid all sorts of investigations, from suspicious deaths to vehicle accidents. Here, forensic specialist Samantha Hayek, in South Dakota, shows how she documents a crime scene.

JACKIE WYNIA/S.HAYEK/SIOUX FALLS CRIME LAB



These fingerprints led to the development of a new way to make hidden prints reappear.

P. KELLY/LOUGHBOROUGH UNIVERSITY

The accidental discovery of these fingerprints on the outside of a vial (above) led Paul Kelly and his lab team to develop the RECOVER system. The system revealed prints on a piece of metal (inset) that had been buried, hammered, burned and left in a pond for a week.

"If you put the prints down on metal — left them just a few minutes — then washed off the fingerprints, we could still retrieve them," says Paul Kelly. He is an inorganic chemist at Loughborough University in Leicestershire, England. He and his students created the first version of RECOVER. It uses a chemical vapor to expose a fingerprint.

If you touch a piece of metal, "the components of the fingerprint will corrode the metal surface," Kelly says. It's incredibly minor — not enough to see once the visible print is removed. But it's there.

"We did a demonstration where we washed [the print] off almost immediately," he says. And another where they soaked the metal in bleach for a week. In one extreme case, his team buried the metal for a week (twice), ran it over with a car and threw it in a pond for another week. But when they exposed each of the metal pieces to the vapor, every loop and swirl of the fingerprints appeared as an intense blue. The molecules in the vapor had linked to each other and to the corroded metal.

One of Kelly's former students now oversees RECOVER at a company called Foster + Freeman. The company designs, makes and sells the system to forensics labs around the world. The tool is so powerful it's been used to solve cold cases — long-unsolved ones.

In 2021, Florida detectives arrested a man after his prints were found on old evidence. At the time of the crime, in 1983, those fingerprints had not been visible. But the new system now turned them up, despite the evidence having been in storage for 38 years.

The RECOVER system has been especially helpful in cases involving guns. In the past, Hayek has had to choose between swabbing casings to collect DNA or dusting them for fingerprints. Swabbing destroys the fingerprint pattern — but not the corrosion underneath. With the RECOVER system, she now can collect DNA and send the casing to the lab to check for prints.

Solving mysteries

Not all forensics involves a crime. Roy and Suzie Ferguson work for Tennessee Special Response Team A in Sevierville. They help find the bodies of people who have gone missing. Sometimes it's the result of a crime. Other times, they help search for people after major disasters, such as wildfires or a building collapse.

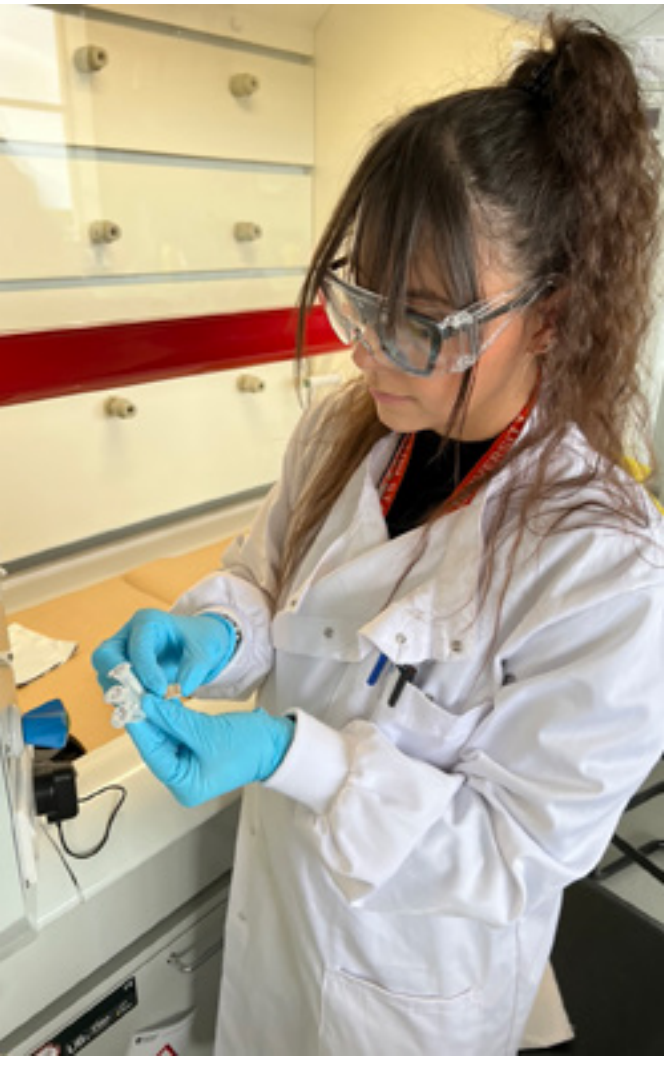
In November 2016, a number of people died in a Tennessee wildfire in Great Smoky Mountains National Park. One man had been at home talking on the phone with his wife when the signal cut out. She didn't know if he had escaped the inferno. When she got to their home, she found it had burned to its foundation. The fire had been so hot, the metal wheels on the cars parked out front had melted. No signs of her missing husband remained.

The search and rescue team brought in several K-9 detection dogs. Each of them signaled the presence of human tissue. Authorities then found an extremely small amount of what could be human remains. It "was later identified as the missing individual," Roy Ferguson recalls.

When forensic specialists find a body — or even a small piece of tissue — they have a mystery to solve. What happened to the person? More importantly: Who were they?

Answering both requires knowing the person's age at death and how long ago they died. It also helps to know the color of their hair, eyes and skin. Sometimes scientists won't have much to work with. They might have only a skeleton or a bit of blood or body tissue. But recent work by Noemi Procopio is helping to provide some of that important information from just a small sample of bone.

Procopio works at the University of Central Lancashire in Preston, England. A biotechnologist, she runs its Forens-OMICS lab. "My main field of research is in bones," she says. Her primary focus has been the study of proteins. That's because proteins last a long time. Even where there's no DNA, some proteins may have survived.



One of Roy Ferguson's search and rescue dogs, Apache, traverses a wooded area in search of a missing person.

Procopio's research has found that proteins change in ways that can help gauge both age at death and time since death. "There's a connection," Procopio says, between the breakdown of specific proteins in bones and time since death. As proteins break down, they release individual amino acids. Amino acids are the building blocks of proteins. Those amino acids also undergo changes with time. Some morph faster than others. These changes can be used as a clock to figure out how much time has passed since someone died, Procopio finds.

Changes in the amounts of specific proteins also can help estimate how old the deceased was when they died.

Procopio recently expanded her research beyond proteins. Her lab now studies smaller protein breakdown products, called metabolites, as well as DNA and lipids (fats).

"It's all connected," she says. "If you approach the problem from multiple angles, you may reach a better final model" to help estimate time since death and age at death.

"We can do all this fancy science starting from a super-small sample," Procopio says. "We carve some lines in the bone. And [in] the process of carving these lines, we generate powder. It's all we need to do all these analyses." It takes just 25 milligrams of powdered bone — about the weight of a small, downy feather — to study the proteins. Another 25 is enough to look for metabolites. About 100 milligrams will allow her group to study the DNA.

The system is still in the early research stages. But Procopio hopes she and her colleagues will develop kits within the next five years that forensic specialists can use in their labs.

Noemi Procopio (left) holds a small piece of bone (between her right thumb and index finger) and three tubes containing dust collected from the bone. Analysis of the bone dust can help pin down the time of death and age of the victim.

N. PROCOPIO; R. FERGUSON

The HIrisPlex-S system can help narrow down eye, hair and skin color from the equivalent of just six cells' worth of DNA.

S.WALSH/IUPUI; CHICAGO REVIEW PRESS

Jump-starting a search

When faced with a body and no clues about who the person might be, analysts can hit a dead end. They need to search databases on missing persons. Knowing someone's age and when they died helps. Even better to narrow the search: Look only for people with blue eyes, for example, or those with black hair.

In the long-running TV show *Bones*, which ended in 2017, researchers frequently used fancy equipment to reconstruct a skeleton's face. This equipment magically gave that face the correct eye, skin and hair color, which made a match fairly quick and easy. But it wasn't until the last few years that it's finally become possible to start narrowing down such physical traits from small samples of DNA.

"We each have pieces of our DNA that code for certain aspects of our appearance," notes Susan Walsh. She's a forensic geneticist at Indiana University–Purdue University in Indianapolis. Walsh and her team have identified 41 genes that affect eye, hair and skin color. Within those genes are variations. Some lead to blue, brown or intermediate eye color. Others to blond, brown, black or red hair. Still others to the range of skin tones found in populations around the world. Some genes affect two or three of these traits.

Using that information, Walsh's team has created what it calls the HIrisPlex-S system. This free online tool allows forensic specialists to input their DNA data. The system then calculates the probability that the unknown person has a particular eye, hair and skin color. This can narrow the search among missing persons, making it easier to identify a body.

The HIrisPlex-S system also works to analyze blood or DNA found at a crime scene. The forensics team might extract DNA and compare it with the national DNA database. But often "people who do these crimes have not been arrested before," Walsh notes. "So there is no match." Running HIrisPlex-S can help focus the investigation. It can tell detectives to interview people with a specific set of physical characteristics, so they don't waste time chasing down fruitless leads. That can be useful when witnesses report seeing very different people at the scene.

Keep in mind, Walsh says, this system isn't perfect. It's accurate at predicting all three coloring traits about three-quarters of the time. It works best at predicting black or red hair, blue or brown eyes, and pale versus very dark skin. "It will make mistakes," she says. Especially if someone's at the border of a color category: hazel or green eyes, for instance. Or pale skin that tans easily. Even someone whose hair has darkened with age. But it has been successfully used to guide investigations in Europe and the United States. And it gets answers from just six cells' worth of DNA.

Advances in forensics are ongoing, and these researchers are excited about what's in store. With the new tools, says Walsh, "You can make a difference in using science. And you can help people."

Hayek agrees. "It's not glamorous and it's not happy. But it's so rewarding. By using these careful and methodical techniques of forensic processing, we're able to provide answers" where none might have been possible even a few years ago.

Read More

Forensics for Kids
—by Melissa Ross

Did you know scientists can use insects to tell when a person died? Find out more about the science behind solving crimes with this activity-filled book.

This scientist is taking crime science out of the lab

Kelly Knight uses her past struggles and passion for forensics to inspire her students

Like many students, Kelly Knight loved science but wondered if she would ever use things like the periodic table after graduating. In her 11th-grade anatomy class, though, there was an activity centered around analyzing blood in a crime scene scenario. It was the first time Knight saw science being put into action. And it introduced her to the world of forensics. "Nowadays, forensics is very popular," says Knight. "But there was no *CSI* when I was in high school."

Knight's journey wasn't an easy one. Imposter syndrome and academic struggles during college made achieving her dream a challenge. Through hard work and with help from a mentor, Knight found a career in forensics. She has analyzed samples in a crime lab as a forensic DNA analyst. And she trained forensic scientists at the Maryland State Police's Forensic Science Division.

She now teaches courses in forensic science at George Mason University in Fairfax, Va., where she is working on a Ph.D. She also spends her time teaching the public about forensics. In this interview, she shares her experiences and advice with *Science News Explores*. (This interview has been edited for content and readability.) — *Aaron Tremper*

K. KNIGHT

Kelly Knight (above in her laboratory) teaches courses in forensic science. As part of her work, she has retrieved DNA from bone (inset). And she even led a group of colleagues and students, while pregnant, to search for evidence at a crime scene from a famous kidnapping (left).

Q How do you get your best ideas?

A Sometimes when you're too close to the project or you've spent too much time on it, you get this tunnel vision. I always get my best ideas once I've taken a step away from it or in the middle of the night. I also get some of my best ideas from my students. They're a really huge source of inspiration. And I'm always surprised by the things that they find and the connections they make.

Q What's one of your biggest failures? And how did you get past that?

A Earning my undergraduate degree was the hardest four years of my life. My grades were really struggling toward the end. That was for a lot of reasons. For example, I was the only Black person in my entire chemistry program, and I never had any faculty who looked like me. Because of that, I struggled feeling like I belonged in chemistry and often felt isolated. When I did reach out for help, I felt like I was dismissed. And that made me stop reaching out for help.

I try to remind myself that students are not always their grades. Just because someone is getting a low grade in a class doesn't mean they're not smart or they don't have potential. There are some really smart people who struggled through some of their classes.

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

A I wish someone had encouraged me to advocate for myself more and not be so afraid to reach out for help. I also wish that someone had told me that asking for help is not a sign of weakness.

I also think that when it comes to different STEM careers, it's important to try different things. This will expose you to a world of possibilities that you didn't even know existed. You don't have to be a doctor or a biologist or a chemist. There are all of these different things within STEM. Some of them may really interest you and you may be really good at one. Don't limit yourself to just the things you see on the surface.

HUMANS

Are fingerprint patterns inherited?

Let's find out if these unique features are random or genetic

By Science Buddies

Each person's fingerprints are unique and last a lifetime. But are fingerprint patterns random? Or do people inherit those features from their parents? If fingerprint patterns are inherited, then pairs of siblings should be more likely to have similar fingerprints than pairs of unrelated people. In this experiment, we'll investigate whether that's true.

OBJECTIVE

Collect, categorize and compare the fingerprints of siblings versus unrelated pairs of individuals to determine if fingerprint patterns are inherited.

BERNATSKII IURII/SHUTTERSTOCK; NEW AFRICA/SHUTTERSTOCK

EXPERIMENTAL PROCEDURE

1. Find at least 15 pairs of siblings and 15 pairs of unrelated people.

2. To collect each print, rub a pencil on a piece of paper until a square about 3 centimeters (1 inch) across is completely gray.

3. Use a moist towelette to clean the person's right index finger. Dry the finger with a paper towel.

4. Press the right index fingertip against the penciled-in piece of paper. Then, press the grey fingertip to the sticky side of a piece of clear tape.

5. Cut off the piece of tape with the fingerprint and stick it to a white piece of paper.

6. Examine each fingerprint and characterize it as a whorl, arch or loop pattern. Use a magnifying glass if you have one. Record your observations in a lab notebook.

7. Calculate the percentages of sibling pairs and unrelated pairs whose fingerprint patterns match.

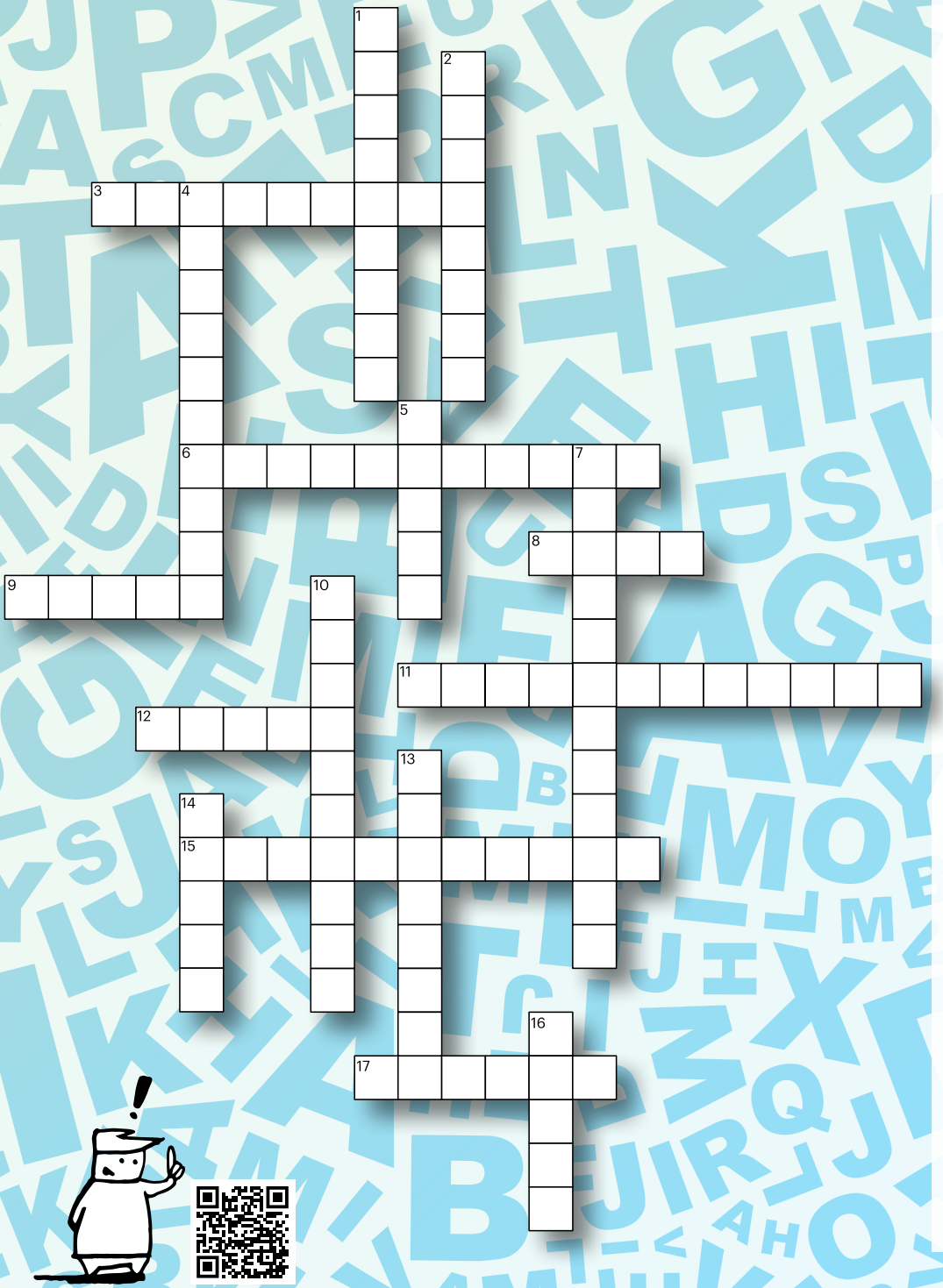
8. Graph your data in a pie or bar chart. Are matching fingerprint patterns more common among sibling pairs or unrelated pairs?

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

SCIENCE BUDDIES

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

3 Invisible object surrounded by a glowing disk

6 Octopuses and related animals

8 How forensic scientists find fingerprints

9 What mice build in cages to stay cozy

11 Found on hands, these patterns might be inherited

12 This type of pollution is causing problems in the dark ocean

15 A state similar to sleep that helps some animals endure winter

17 Free-flying robots

DOWN

1 Fictional substance that freezes a living thing in suspended animation

2 Common shrimplike creatures found in many ocean food webs

4 The building blocks of proteins

5 Single-celled microbes found in the ocean

7 A rarely seen light show in the sky

10 Caused by sugar-loving microbes in your mouth

13 An extinct reptile and relative of modern birds

14 Fluffy animal that lives in a herd

16 Teams up with bacteria in the mouth to cause trouble

TECHNOLOGY

It's a drone! It's a — printer?

Insect-inspired flying printers could build in hard-to-reach spots

Drones already fly and spy. Now, they can build too. For the first time, free-flying robots have 3-D printed structures. A pair of drones working together made a tower as tall as many pro basketball players. Engineers demonstrated this new method of 3-D printing in the lab. They shared their success in *Nature*.

Mirko Kovac, who co-led the research, says that animal builders inspired him. "Wasps are amazing," he says. "Bees are incredible." These insects work together in swarms to make nests much larger than themselves.

A larger BuilDrone and a smaller ScanDrone worked together to build a tower about 2 meters (6.5 feet) tall. A flying printer (inset) squirts out streams of a cement-like material.

IMPERIAL COLLEGE LONDON, UNIVERSITY COLLEGE LONDON, UNIVERSITY OF BATH; SARAH LEVER PHOTOGRAPHY, AUTONOMOUS MANUFACTURING LAB/UCL

Kovac is a roboticist at Imperial College London in England. He also works at Swiss Federal Laboratories for Materials Science and Technology in Dübendorf. His co-leader on this project was architect Robert Stuart-Smith of the University of Pennsylvania in Philadelphia and University College London in England.

To print that basketball-player-sized tower, a BuilDrone carried expanding foam. This material rapidly expands and hardens when sprayed. As the drone flew in a slow circle, it sprayed the foam downward to form layers. When it ran out of material, it flew away so a person could reload more foam or replace the drone's batteries.

This type of foam tends to thicken unevenly. So while BuilDrone was reloading, a second, smaller drone surveyed the work. It was called ScanDrone. It looked for places where the last layer was too thin or thick. Then it created a plan for the next layer to help even things out. This kept the tower straight and sturdy.

The foam tower was cool, but the team wasn't done. In a second demo, BuilDrones and ScanDrones worked together to make a cylinder about the size and shape of a large round cake. This structure was impressive because the drones laid down a cement-like material very accurately, to within millimeters.

The cement-like material was special, too. Researchers at the University of Bath in England crafted it specially for the project. It had to be light enough for the drones to carry. It had to be soft enough for the drones to squirt it out easily. Yet it also had to harden quickly into a strong layer, Kovac said. The drones laid down this

material in a twisting path that made the structure even stronger.

The researchers also did several virtual demonstrations. In one, real drones flew the paths they would take to build a dome but didn't print any material. Other computer simulations showed how teams of as many as 15 drones might work together to build different kinds of structures.

"Nobody had really done this before," says Rahul Panat. He is a mechanical engineer and 3-D printing expert at Carnegie Mellon University in Pittsburgh, Pa., who was not involved in the research.

This was "an impressive demonstration," says Andrea Tagliabue, who also wasn't involved in the research. As a graduate student in robotics at the Massachusetts Institute of Technology in Cambridge, Tagliabue works on control systems for drones. However, he notes that the researchers still have challenges left to solve before 3-D printing drones are useful in the real world.

Because these drones were building inside a lab, they didn't have to contend with wind or other outdoor disturbances. Also, cameras placed around the room could help track the drones' positions and send them along the correct paths. Outdoors, the drones would have to navigate without this extra help, says Tagliabue. He also notes that the more drones there are, the more computation is needed to keep them all coordinated. If that computation takes too long, the drones can't get the instructions they need in real time.

With work, these problems can be solved. Kovac is already planning to do tests outdoors. He also plans to build more complex structures. And he plans to make it so the drones can recharge and reload automatically.

If construction drones could work together like wasps or bees, they could construct buildings or make repairs in places that are tough for human crews and heavy machinery to reach. That may include disaster areas, the tops of tall buildings or even other planets, Kovac says. "There's a lot of interest in building on Mars with robots."
— *Kathryn Hulick*

YUSUF FURKAN KAYA/AERIAL ROBOTICS LABORATORY/IMPERIAL COLLEGE LONDON AND MATERIALS AND TECHNOLOGY CENTRE OF ROBOTICS, SWISS FEDERAL LABORATORIES OF MATERIAL SCIENCE AND TECHNOLOGY (EMPA)

In the future, teams of drones might build structures on Mars (illustrated). Not on the moon, though. The moon lacks the air drones need to push against to fly.

LIFE

Could humans hibernate through space travel?

Suspended animation may one day be possible for astronauts

A teenager boards a spaceship, encloses herself in a coffinlike chamber and falls asleep. Her body is frozen for a trip to a planet several light-years from Earth. A few years later she wakes up, still the same age.

This ability to put life on pause while asleep is called "suspended animation." It's a staple of science fiction. There's Captain America, for instance, who survived nearly 70 years frozen in ice. And *The Mandalorian*'s main character freezes his bounties using a fictional substance called carbonite. All of these stories have something in common. People enter an unconscious state in which they can survive for a long time.

Nothing like this is yet possible in the real world, at least for humans. But some animals and birds have their own forms of suspended animation: hibernation. This might hold some lessons for how astronauts of the future could hibernate for long space flights. But for really long journeys, a deep freeze might be the best option.

BEYOND SLEEP

"I think this is realistic," says Katharine Grabek. She's a biologist who co-founded a company called Fauna Bio based in Emeryville, Calif. "I think it would be done by … making ourselves as similar as we can to a hibernator."

Hibernation may look like a deep form of sleep, but it's not sleep. As an animal hibernates, it chills its body and slows its heart rate and breathing. Metabolism also slows. To do this, an animal must turn on and off certain genes when they hibernate. Those genes do things like control whether an animal burns sugars or fats for fuel. Other genes are involved in keeping muscles strong.

Humans have many of these same genes. We don't use them to hibernate. But turning some of these genes on or off might allow humans to do something similar to hibernation, Grabek says. Her company studies these genes and looks for drugs that can control them.

John Bradford suggests that people might hibernate like bears. Bradford is the chief executive officer of SpaceWorks, a company in Atlanta, Ga. Black bears cut their metabolism by 75 percent when they hibernate. But their bodies stay somewhat warm. Normal body temperature for a black bear is 37.7° Celsius to 38.3° C (100° Fahrenheit to 101° F). During hibernation, their body temperature stays above 31° C (88° F).

Hibernating humans might have to lower their body temperature only a few degrees. "We can probably keep someone in this state very safely for about two weeks," Bradford says.

If people are like bears, hibernation may help keep bones and muscles strong. That is important in space. Bones and

Han Solo was famously frozen in a substance called carbonite.

HAN SOLO: SYLVIROB1/SHUTTERSTOCK; HIBERNATION PODS: HENNING DALHOFF/SCIENCE PHOTO LIBRARY

muscles tend to break down in low gravity. Hibernation could cut the amount of food, water and oxygen that crews need. And it could save people from the inevitable boredom of long trips in space.

THE DEEP FREEZE

But hibernation may not be enough to get people through decades-long trips. That's because most animals come out of hibernation after a few months, Grabek says.

Making people colder might slow their metabolism even more than regular hibernation. But what if you went really cold? Like frozen? Wood frogs in the Arctic freeze solid for the winter. They thaw out again in spring. Could they be a model for humans wanting to travel the stars?

Shannon Tessier studies the effects of extremely low temperatures on organisms. She is looking for a way to freeze human organs for transplants. She works at Massachusetts General Hospital and Harvard Medical School in Boston.

Freezing is usually bad for organs, she says. That's because ice crystals can rip open cells. Wood frogs can stand freezing because they have ways of preventing ice crystals from forming.

Tessier and her colleagues, though, worked out a way to supercool human livers to freezing temperatures without ice crystals forming. The supercooled livers could be stored for about 15 hours longer than most organs stored on ice, the team reported in *Nature Protocols*. But Tessier doesn't yet know if the thawed liver will work if transplanted into a person.

Plus, freezing may not be enough for long-term space travel, she says. Wood frogs can only stay frozen for a few months. Traveling to another solar system would take many years.

In true suspended animation, all metabolism in the body would stop. One way to make that happen is flash freezing to –140° C (–220° F). The ultralow temperature turns tissues to glass.

Human embryos are stored this way by quickly freezing in liquid nitrogen. "We haven't achieved that with a whole human organ," Tessier notes. And you couldn't dunk a whole person in a vat of liquid nitrogen. It would kill them. "We don't have the science … to do that in a way that is not damaging," she says. But maybe someday humans on Earth will find our own carbonite for safe flash freezing. Then, we might be able to travel as frozen cargo to a galaxy far, far away.

— *Tina Hesman Saey*

In fictional depcitions of suspended animation, people travel through space in a frozen state, waking up only after they have reached their destination.

EARTH

How auroras light up the sky

These dazzling displays trace back to particles from the sun

Green auroras glow when oxygen atoms in the atmosphere get excited by high-energy particles.

JUAN CARLOS CASADO (STARRYEARTH.COM)/SCIENCE PHOTO LIBRARY

Some of the most awesome sights in the night sky are the auroras, or northern and southern lights. These dazzling light shows appear as rippling curtains, bright arcs and diffuse glows. Most glimmer green, but some shine red, blue or purple.

Such breathtaking displays trace back to a stream of charged particles that continually flows out from the sun, known as the solar wind. Earth's magnetic field deflects most of the solar wind away from the planet. But that magnetic field snags some particles in the gale. These high-energy charged particles travel along the magnetic field lines toward Earth's poles. There, the particles plunge into the atmosphere, smashing into oxygen and nitrogen atoms.

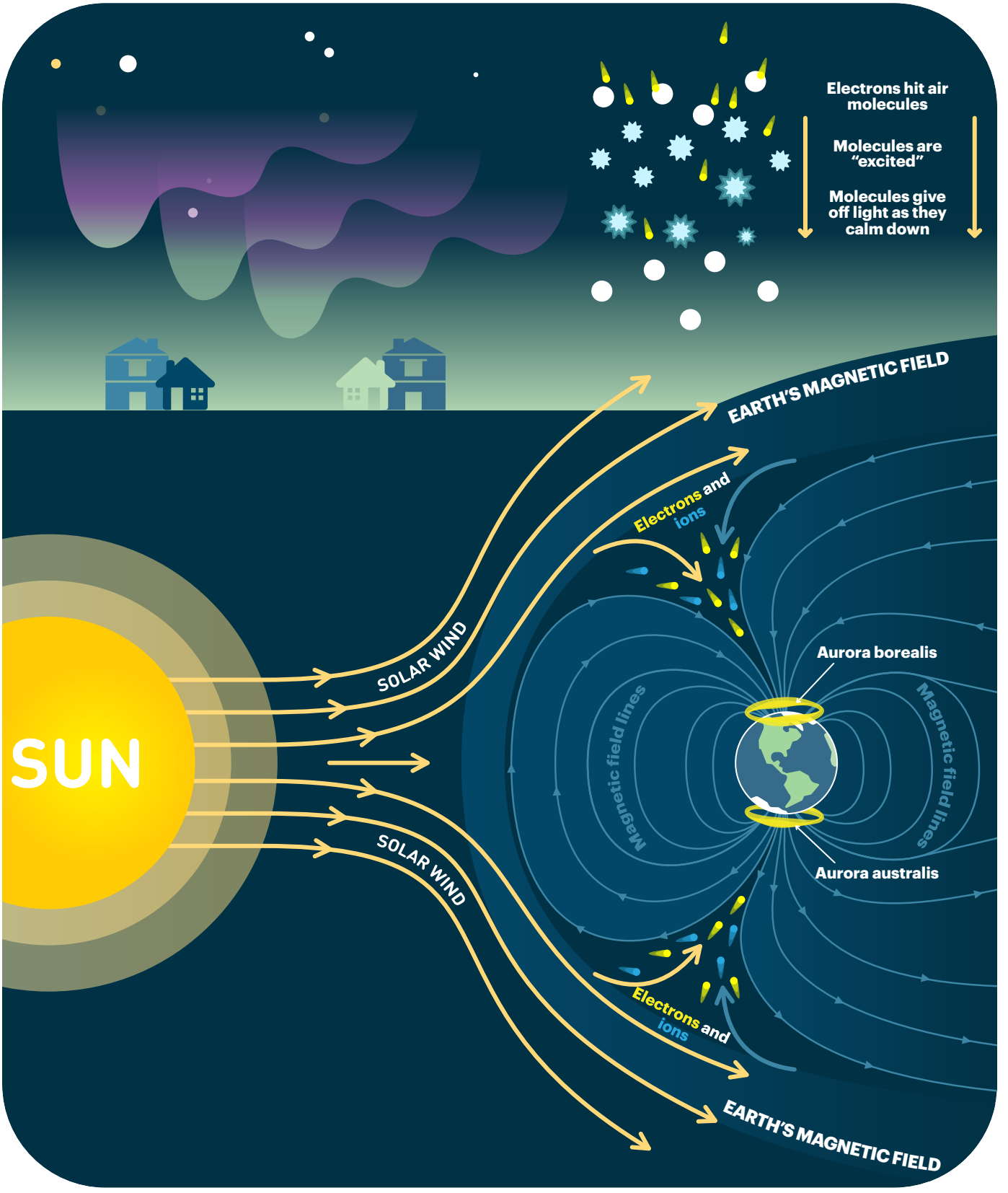
Those collisions excite the oxygen and nitrogen. That is, they give the atoms a little extra energy. But excited atoms are not stable. They quickly relax into a non-excited state. In the process, the atoms release energy in the form of light particles, or photons. These photons make up the auroras.

An aurora's color depends on the energy of the incoming charged particles. Low-energy particles can't dive very deep into the atmosphere. They excite oxygen atoms at high altitudes. Those oxygen atoms glow red. More energetic particles slam into oxygen at lower altitudes. Due to the incoming particles' higher energy, they cause oxygen atoms to emit higher-frequency light. The aurora appears green.

The most energetic particles plunge deepest into the atmosphere. There, nitrogen atoms outnumber oxygen atoms. Cascading particles cause the nitrogen to give off even higher-frequency blue or purple light.

Auroras dance across the sky near Earth's poles. The northern lights, or aurora borealis, are most reliably visible to skywatchers in Alaska and Canada. The aurora borealis also shimmers above Greenland, Iceland and Norway. The southern lights, or aurora australis, can be seen over Tasmania, New Zealand and Antarctica.

— *Maria Temming*



VECTORMINE/ADOBE

MICROBES

Blue-glowing algae light up new devices

The microbes shine when gently pushed or pulled

With a touch or a tug, a new type of device glows, thanks to algae that light up the sea.

Shengqiang Cai remembers the first time he saw such luminous waves from a beach in San Diego, Calif. "It's just gorgeous," he says. "It's a blue light, and you can see it in the dark night." A mechanical engineer and materials scientist, Cai works at the University of California, San Diego.

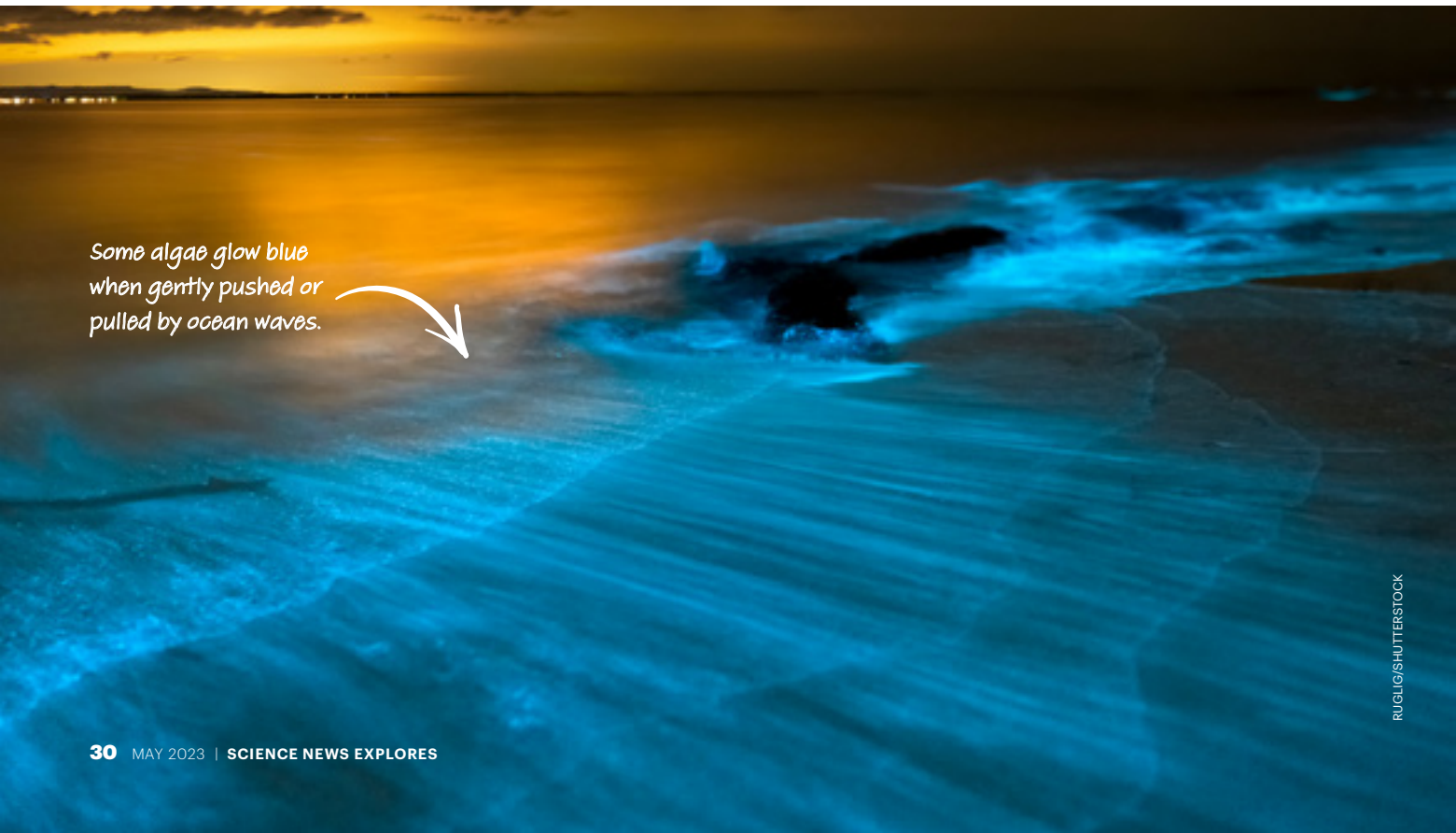
Cai learned that the light was created by single-celled algae (*Pyrocystis lunula*). The microbes glow when they encounter forces from ocean waves. No one knows why. But that mysterious ability sparked a thought for Cai. "The algae are just like a smart material," he says. That is, they respond to something outside of them in a way that might be useful.

There aren't many materials that light up because of a force — especially one as gentle as waves lapping a beach, Cai says. Materials with this rare property might be good for gathering environmental data, such as wind speeds. They could also be used to build robots that explore dark places, such as the deep ocean.

To see if glowing algae could be turned into a useful material, Cai's team grew some in the lab. They injected the algae into a soft, transparent plastic. Then, they stretched the device to see how brightly the algae would shine under different forces. Cai and his colleagues shared these findings in *Nature Communications*.

The team also made a tiny robot full of glowing algae. The robot had four legs arranged in the shape of an X. The end of each leg held a magnet. Another magnet could be used to steer the bot. The bot glowed for 29 days in the lab until the end of the experiment. This raises prospects that the algae-based material could remain useful for at least a few weeks.

— *Carolyn Wilke*

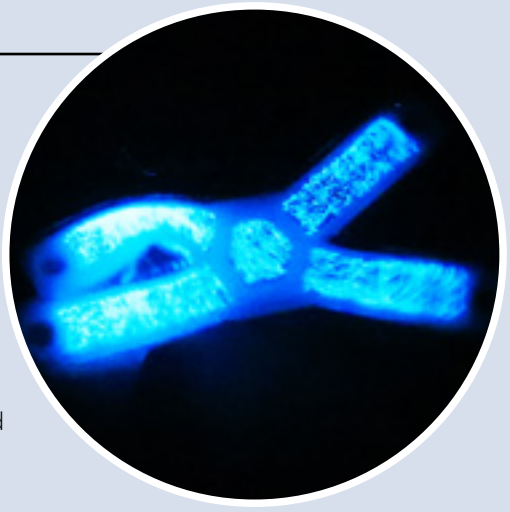


Some algae glow blue when gently pushed or pulled by ocean waves.

RUGLIG/SHUTTERSTOCK

MEASURING BLUE LIGHT

Researchers injected algae at different concentrations into plastic devices. Then, they took pictures to measure how much blue light the single-celled microbes gave off (Figure A). The scientists stretched the devices so they were 50 percent longer than they were originally (Figure B). The team measured how brightly the devices glowed when stretched at different speeds, or strain rate. Finally, the researchers stretched all the devices at the same speed (Figure C). This time, the scientists varied the maximum strain, or how far they stretched each device. Maximum strain is measured as the length of the stretched device compared with its original length.



Robots made with glowing algae could explore dark places, such as the deep sea.

FIGURE A

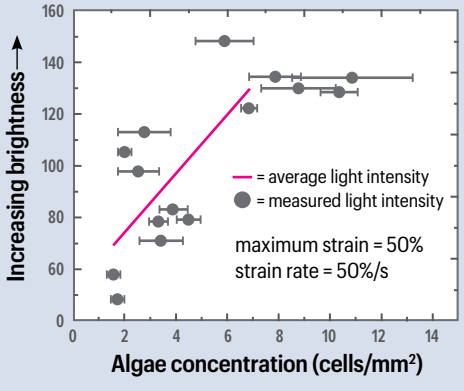


FIGURE B

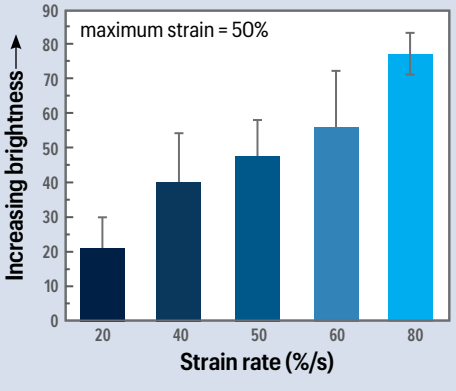
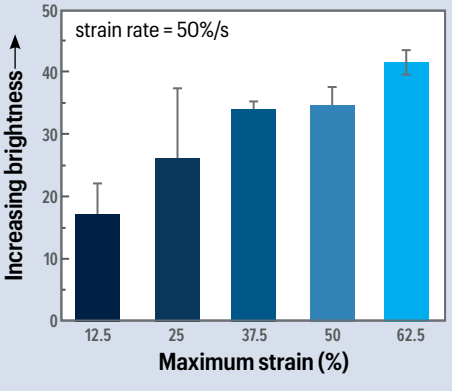


FIGURE C



DATA DIVE

1. Look at Figure A. How does light intensity change with increasing cell concentration?

2. The researchers' camera wasn't able to capture light well when it was brighter than a certain intensity. At what cell concentration does light intensity stop changing?

3. What might these data look like if the camera was able to capture more light?

4. Look at Figure B. What's the range, or spread of values, for light intensity on this graph?

5. How does light intensity change with strain rate?

6. Look at Figure C. How does the light intensity change with the length the devices are pulled to?

7. How might the researchers modify their devices to get a brighter glow?

8. What are some ways to use an object that glows when touched or pulled?

ANSWER

Night lights make even the seas bright

Light pollution can disturb ocean dwellers

Not even the sea is safe from the glare of humans' light at night. The first global atlas of underwater ocean light pollution shows large chunks of the sea lit up in the dark. That risks confusing or disrupting the behaviors of sea life.

Coastal cities cast haloes of light that stretch over the ocean. So do offshore oil rigs and other structures. Tim Smyth led a research team to assess where in the water this glow is strongest. Smyth is a marine biogeochemist at Plymouth Marine Laboratory on the southern coast of England. The team described its findings in *Elementa: Science of the Anthropocene*.

Light pollution is strongest in the top meter (about three feet) of the water, the team found. Here, artificial light can be intense enough to confuse copepods. These common shrimplike creatures are a key part of many ocean food webs. Nearly 2 million square kilometers (770,000 square miles) of ocean get such intense night light. That's an area roughly the size of Mexico.

Farther down, the light gets weaker. But even 20 meters (65 feet) deep, it's still bright enough to bother copepods across 840,000 square kilometers (325,000 square miles) of ocean.

— *Carolyn Gramling*

The glow of coastal cities, wind farms, and offshore oil and gas rigs are seen near the United Kingdom (landmass at left) and Norway (upper right). This light can disturb sea creatures, such as copepods.

JOSHUA STEVENS, T.J. SMYTH *ET AL/ELEMENTA: SCIENCE OF THE ANTHROPOCENE* 2021

INSIDE THE MIND OF A YOUNG SCIENTIST

A finalist of Regeneron Science Talent Search — Society for Science's most prestigious competition — answers three questions about science

Science competitions can be fun and rewarding. But what goes on in the mind of one of these young scientists? Regeneron Science Talent Search (STS) 2023 finalist Ariella Blackman shares some of her science inspiration and advice.

Q What inspired your project?
A For my entire life, I've been super passionate about human spaceflight. I am an aspiring future astronaut. For this project, in particular, I learned about the MOXIE experiment, which is on the Mars Perseverance rover, and it is converting carbon dioxide in the Martian atmosphere into oxygen. I really wanted to do something that would have similar implications, and so that led me to doing plant growth using Martian resources.

Q What was the most challenging part?
A A lot of times, students who have science research programs through their schools will work very closely with one specific mentor and sometimes work in their lab. I didn't fully have that. It meant I had to go and either find an existing journal article that had done a similar study or start sending out emails to random people who I hadn't talked to before, trying to get them to answer my questions, and that was definitely a challenge. But on the other hand, I think it really helped me learn a ton.

Q What advice do you have for other kids working independently?
A Don't be afraid to put yourself out there and just keep sending emails and keep asking questions and eventually someone will write back and someone will be helpful and it will work out. I really learned a ton about just how friendly the scientific community is. Seeing how collaborative this community is makes me really excited moving forward.

Finalist

Ariella Blackman

Inspired by the MOXIE experiment, Ariella, 18, explored how Martian soil might be altered to grow plants on the Red Planet. Those plants could generate oxygen, which is severely lacking in the Martian atmosphere. Oxygen could not only allow astronauts to breathe on Mars but also fuel a rocket returning them to Earth. Ariella attends Harrison High School in New York.

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