ScienceNews Explores
AUGUST 2026

COULD A STORM LAST FOREVER?
P26

REEF RENOVATORS

Parrotfish break down and rebuild coral reefs – one bite at a time

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Science News Explores (USPS 25676, ISSN: 2831-9966) is published monthly except in January and July by Society for Science, Inc, 1776 Massachusetts Ave. NW, Washington, DC 20036. Periodicals Postage Paid at Washington, DC, and additional mailing offices. POSTMASTER: Send address changes to Science News Explores, PO Box 292933, Ketting, OH 45429. Subscriptions cost $29.95 (international rate $54.95 includes extra shipping charges). Single copies are $7.99 plus $1.01 shipping and handling (or for international, $5.01 shipping and handling).

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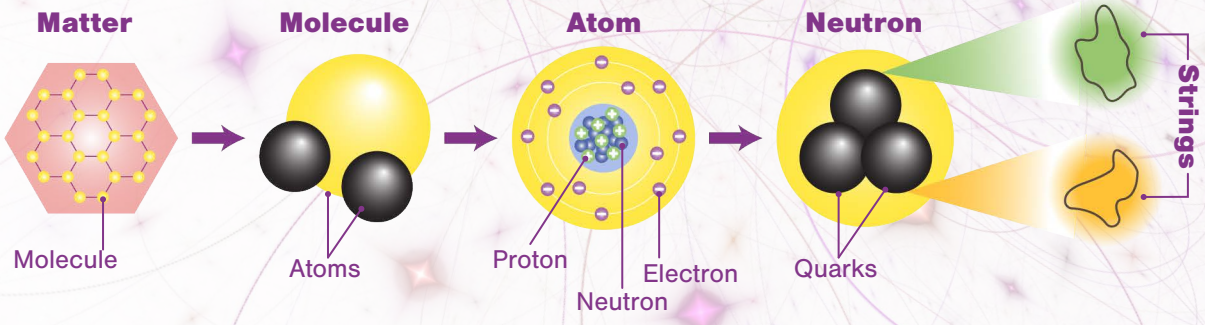
Q What is string theory?

— Raina D.

A Scientists have traditionally thought of the particles that make up our universe as tiny points. But string theory proposes that particles are instead tiny, vibrating loops of string, says Marika Taylor. She's a theoretical physicist at the University of Birmingham in England. "Different vibrations of the string give you different particles," she explains. These include the particles that make up matter, such as electrons. And they would include particles that underpin various forces, such as gravity and electromagnetism. In this way, string theory could explain all the properties and interactions of all the stuff in the universe. Thus, string theory might be a long-sought "theory of everything." But no one yet knows if this theory is correct. "We don't really have ways at the moment to look so deeply into a particle like an electron or a proton that we can see the string structure," Taylor says. But physicists hope that future technology may offer ways to test string theory.



Q Why do additives make food taste so good?

— Faith Y.

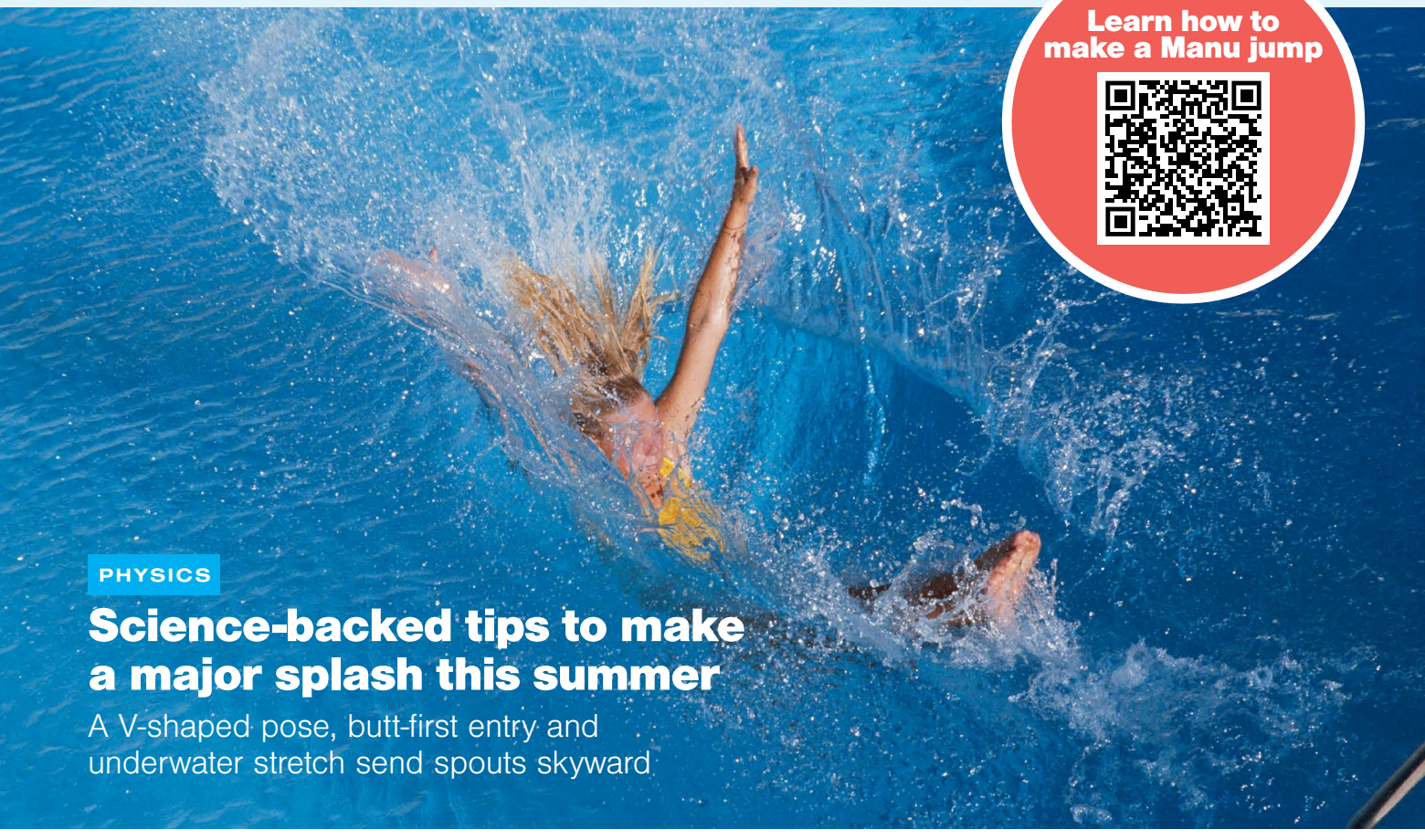
A Food additives improve taste by adding new flavors, textures and odors. For instance, fragrances such as hexyl acetate make foods taste fruity. Meanwhile, emulsifiers help keep liquids, such as salad dressings and ice cream, from separating. Starches and gums thicken soups, sauces and puddings. Other additives work by adding molecules that activate our taste receptors. On its own, monosodium glutamate (MSG) is odorless and tasteless. But when added to food, MSG molecules bind to umami receptors on the tongue. This results in food that tastes more meaty and savory. Food scientists combine these additives in carefully measured ways to reach what some researchers call the "bliss point." This combination of ingredients helps make highly processed foods seem irresistible, overriding the body's signals that it's full.

Q Why does the salt in salt water burn your eyes?

— Sarah C.

A The burning sensation you get when you open your eyes in salt water is an important signal from your brain. "The front of your eye is packed with tiny nerve endings called nociceptors, which are like little sensors," says Anat Galor. She is a medical doctor who studies eye pain at the University of Miami in Florida. These receptors sense touch, temperature and chemical changes, including saltiness. Salt water is much saltier than the thin layer of tears that protect eyes from irritants. The receptors in your eyes detect this difference right away, says Galor. Your brain then turns that signal into a stinging or burning sensation to warn you to close your eyes or rinse them, she says. "It's not that salt water is actually 'burning' your eyes. It's your eye's sensors doing their job and telling your brain that the environment has suddenly changed." Other junk, such as sand or bacteria, can also bother your eyes. So be sure to remember your goggles!

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



Learn how to make a Manu jump

PHYSICS

Science-backed tips to make a major splash this summer

A V-shaped pose, butt-first entry and underwater stretch send spouts skyward

For maximum splash at the pool, consider a V-shaped, butt-first entry into the water, followed by a rapid backward roll and leg extension.

When it comes to making a splash, technique tops brute force. Research has revealed the secret to record-setting splashes.

New Zealand's Māori and Pasifika communities developed the Manu jump. It's a cannonball-style sport. Key to its splashiness: Make a butt-first, V-shaped entry, researchers report. There must also be a well-timed, underwater follow-through. Researchers shared these findings in *Interface Focus*.

These insights could liven up a backyard pool party or help athletes vying for glory in Manu competitions. But aerospace engineering might also benefit from the findings. They might make spacecraft splashdowns smoother and safer.

Previous splash research had tended to focus mostly on minimizing surface disruptions. The point is to reduce damage to an object during water landings. Other studies have aimed to perfect an Olympic dive, where splash-free entries receive better scores.

Popping a Manu is "the diametric opposite scenario," says Saad Bhamla. He is a biophysicist at Georgia Tech in Atlanta.

To crack the code of a great Manu jump, Bhamla and his team first collected movement data from 50 online videos. On average, Manu jumpers enter the water at about a 45-degree angle. Their butts hit first, with legs and torsos slanted outward in a V-shape.

The researchers then used 3-D–printed projectiles, a robotic diver and high-speed photography while running controlled tests. These confirmed that a precisely angled entry was very important for maximizing splash. The entry formed a deep pocket of air in the plunging jumper's wake.

What happens underwater is most important for splashy success. Bum-first entry is followed by a rapid backward roll and leg extension.

This stretches out the body, and with it that pocket of trapped air from the V-bomb, the research showed. The gravitational pull of the water overcomes the inertia of the plunging jumper. At that point, the air pocket — a cavity — collapses and pinches off. Then, a towering jet of spray shoots skyward.

But when to execute this underwater unfurling?

The ideal moment depends on both the height of the jump and the size of the jumper, the splashbot revealed. Both affect how deep an air pocket forms.

Stretching out too early makes your body release the air pocket before it fully develops. Stretch out too late and your body expands after the pocket has already started collapsing. That will weaken a splash.

The biggest upward plumes occurred when a robot opened up about halfway through its

DAVID DE LOSSY/DIGITALVISION/GETTY IMAGES PLUS

underwater descent. That sweet spot was fleeting but powerful.

"These findings could lead to new training tools or techniques to help competitors get that edge," says Patria Hume. She's a sports biomechanics researcher at Auckland University of Technology in New Zealand. Hume is part of a team behind the "ManuTech" platform. This mix of high-speed video-capture and real-time digitization software judges splash sizes.

Splashers also get points for technique and pizzazz. These scores celebrate the expressive, freeform spirit that defines the event.

"While science can help athletes improve their splash, it shouldn't take away from the freestyle roots of the sport," Hume says. "Creativity, flair and fun in the air are what make it so unique."

— ELIE DOLGIN

HUMANS

77%

That's the staggering percentage of U.S. high school students who reported not getting their recommended eight to 10 hours of sleep in a 2023 survey.

Source: T.J. Bommersbach, M. Olfson and T.G. Rhee/*JAMA* 2026

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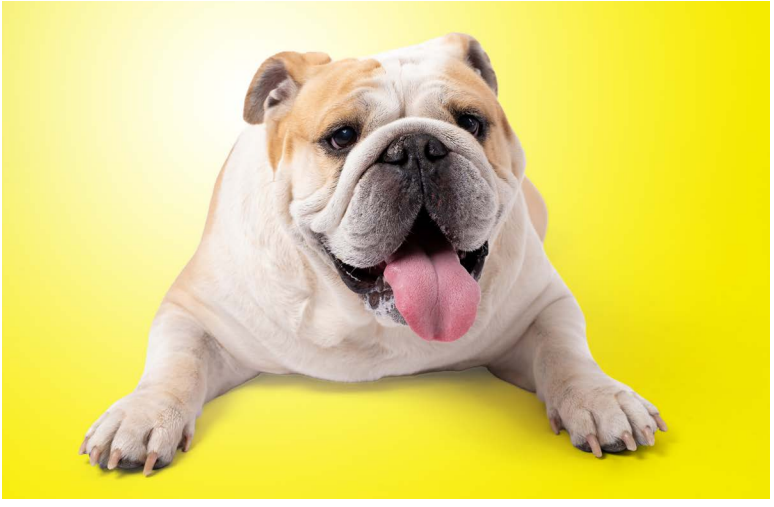
ANIMALS

Why flat-faced dogs struggle to breathe

A squished face, pinched nostrils and body fat all contribute to blocked airways



Dogs such as pugs and bulldogs (right) don't breathe easily. Researchers showed that this issue can be a problem in more than a dozen smoosh-faced breeds.

Dogs with squished faces, like pugs and bulldogs, may be adorable. But that cuteness can come at a cost to the pups. Among some breeds with such flattened faces, fewer than 11 percent can breathe easily, a new study finds.

Doctors describe the skulls of dogs with flat faces as brachycephalic. Finding this attractive, people have bred dogs to have these features. But a shortened skull can narrow a dog's airways. That can cause airway blockages, which lead to heavy and noisy breathing, and snorting.

The problem is known as BOAS (short for brachycephalic obstructive airway syndrome). It develops when the bones in the heads and faces of affected dogs are shorter than normal.

Researchers have long known BOAS is a big problem for pugs and bulldogs. But little was known about its risk to other flat-faced breeds. So, from 2021 to 2024, a team in England examined nearly 900 dogs across 14 short-skull breeds.

The researchers had dogs run for a few minutes. Then they ranked the pups on how easy they could breathe on a scale of 0 to 3. Those with a score of 3 had a lot of trouble breathing. Dogs scoring zero did not breathe noisily.

The researchers also took detailed measurements of the dogs' heads and bodies.

Risk of BOAS varied a lot by breed. Boxers and Staffordshire bull terriers, for instance, rarely had breathing issues. But Pekingese and Japanese chins were at high risk, along with bulldogs and pugs. Just 11 percent of Pekingese got an easy-breathing score of 0. In previous work, even fewer pugs — about 7 percent — got this score.

A few features put dogs at particular risk of blocked airways. One was that flat face. Another was narrow, pinched nostrils. A third was having more body fat.

The research team shared its findings in *PLOS One*.

— JAKE BUEHLER

FOSSILS

A prehistoric puke pile shows what one ancient predator dined on

The meal, older than dinosaurs, contained 41 bones from different animals

SOPHIE FERNANDEZ/CNRS

This illustration shows an ancient predator (*Dimetrodon teutonis*) throwing up the remains of its prey. Two smaller prey animals identified in the fossil vomit can be seen in the foreground (*Eudibamus cursoris*) and background (*Thuringothyris mahlendorffae*).

Some 290 million years ago — before dinosaurs roamed the Earth — a predator gobbled up several animals. Later, it barfed up their bones. Over the ages, that puke hardened into a fossil. A newly imaged cluster of bones inside it now offers clues about some of the world's earliest land predators.

Researchers shared their findings in *Scientific Reports*.

Scientists have a name for fossil vomit: regurgitalite. This new sample held bones from at least three different animals eaten by one predator. That means "we can literally say, for sure, that these three were living at exactly the same place and exactly the same time, maybe to the week or even to the day," says Arnaud Rebillard. He's a paleontologist and was part of the research team. He works at the Museum of Natural History in Berlin, Germany.

Rebillard's team discovered the lime-sized barf blob at a fossil site known as the Bromacker locality. It's in Germany. The researchers scanned the fossil with powerful X-rays to get a 3-D image of what was inside, without breaking it open. That CT scan revealed a cluster of 41 bones from different animals. This suggests the debris had come from a predator's gut.

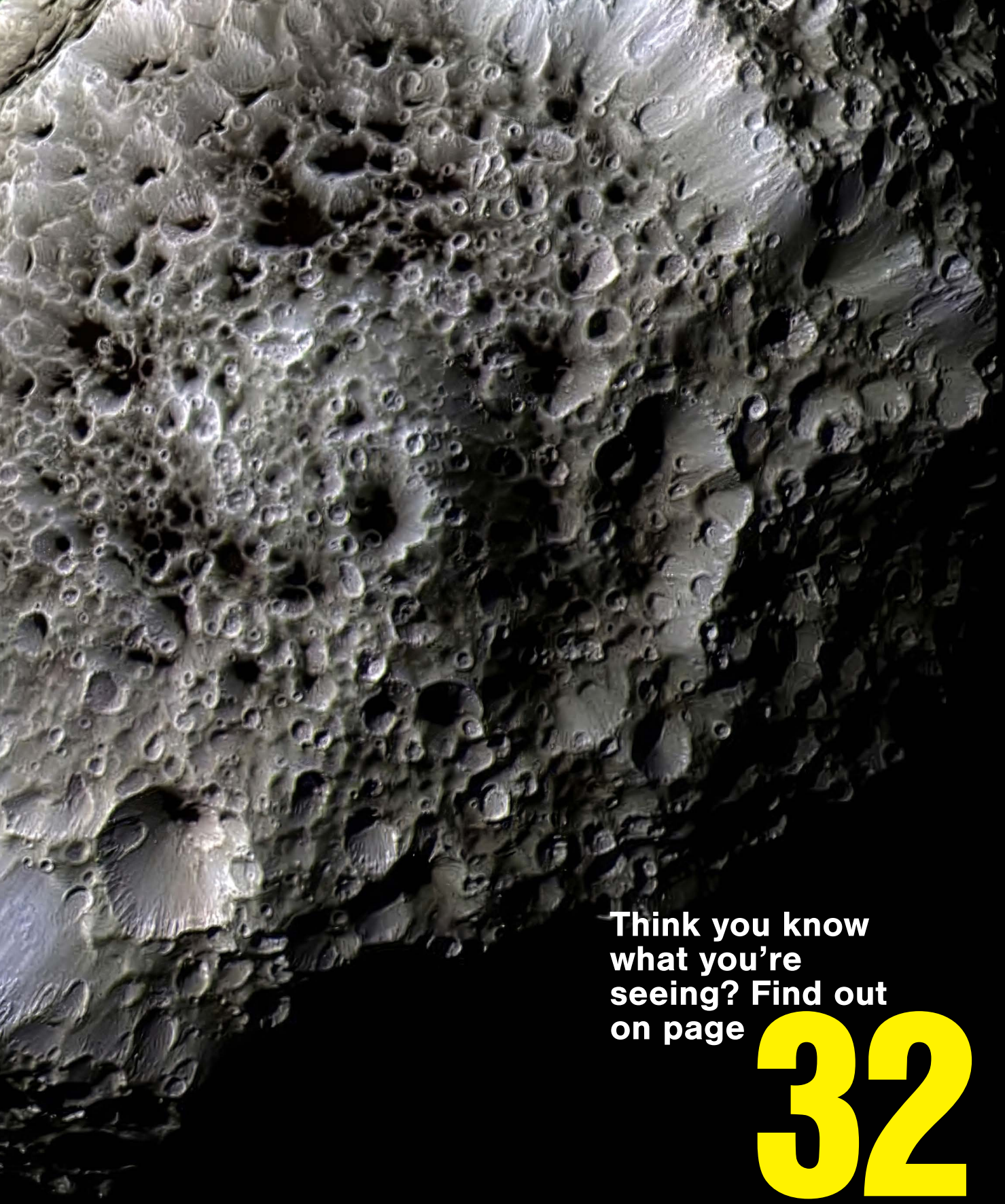
The researchers don't know which predator threw up the bones. They suspect it was one of two animals similar to today's monitor lizards (such as Komodo dragons). Both predators resembled dinosaurs. But they were not dinos. They weren't even reptiles. Instead, they belonged to a group known as synapsids. This group includes today's mammals and their extinct relatives.

Rebillard's group found two small, lizard-like reptiles among the barfed-up bones. They also found the limb bone from a larger, reptile-like plant eater. Several more bones came from animals that could not be identified.

These bones from different species suggest the predator did not have a taste for just one type of prey. It ate whatever it could find.

"It's kind of like a photograph of a moment in the past that is telling us about the animal that was living," says Rebillard. "Any data that we can find about their behavior is very precious."

— *Jay Bennett*

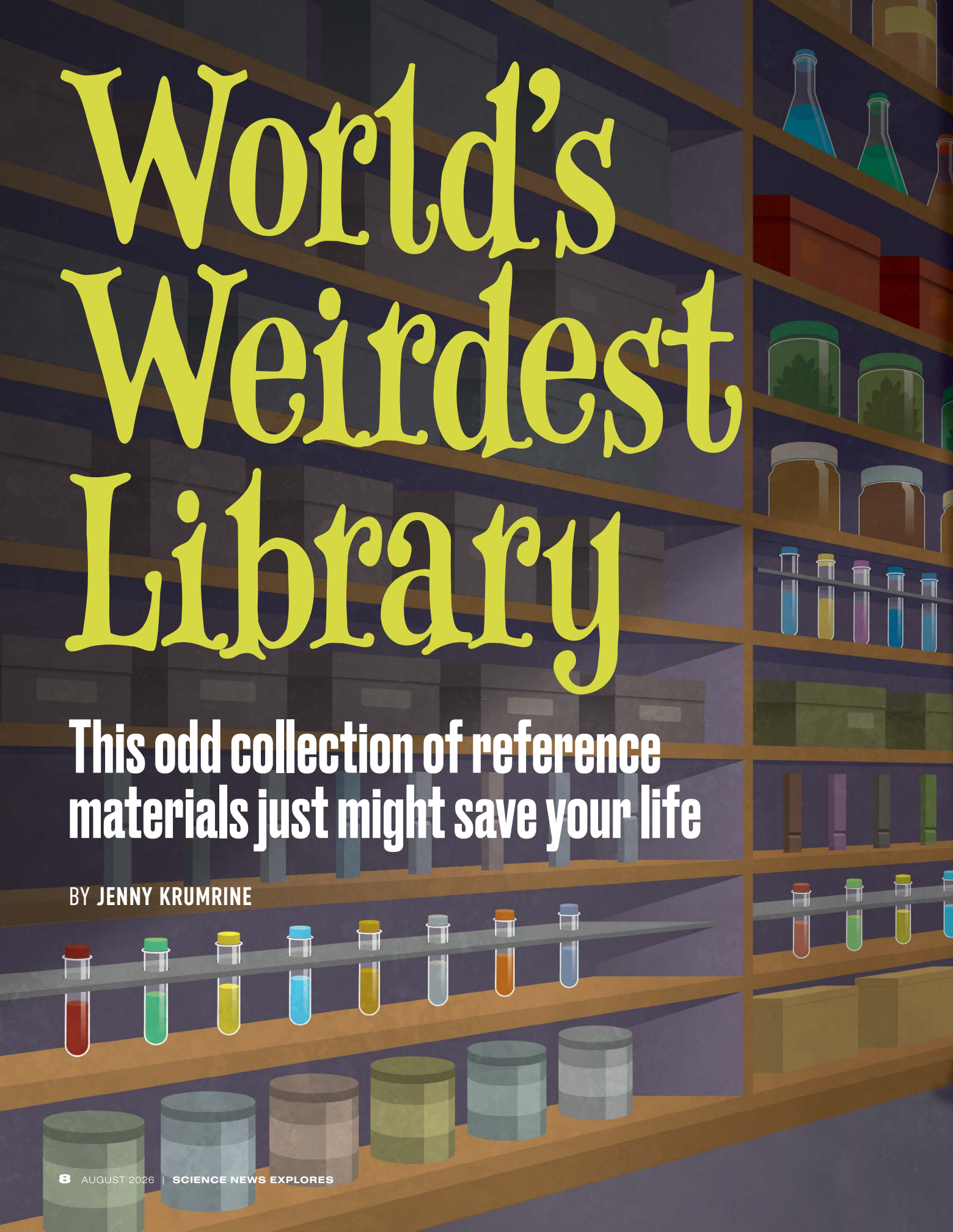


Think you know what you're seeing? Find out on page 32

World's Weirdest Library

This odd collection of reference materials just might save your life

BY **JENNY KRUMRINE**



STEVE MCCRACKEN

Imagine your family has driven to a local lake to cool off. The sun is scorching, but sweet relief is just seconds away. You sprint toward the water, about to leap in — when your parents suddenly yell, "Stop!"

Skidding to a halt, you turn to see a sign in the sand: "NO SWIMMING — WATER CONTAMINATED."

When water leaks from sewage pipes or washes off farmland into waterways, it can carry human and animal poop with it. Riddled with germs, that waste can make you sick. Fortunately, tests can quickly detect DNA from animal wastes in the water.

Key to the accuracy of these tests is having a good "standard" reference material, or SRM, against which other things can be matched.

Stephanie Servetas was on the "Poop Team" that developed an SRM for DNA detectors. A microbiologist, Servetas works at the National Institute of Standards and Technology (NIST). Its headquarters is in Gaithersburg, Md.

Her Poop Team's reference material contains bits of DNA that match wastes from people, cattle, pigs and other animals. The team mixed and measured their concoction's properties precisely. That way, they can say exactly what values a water-testing instrument should register to signify it found poop.

Water watchers can now use this material to check that their machines are working correctly.

Similarly, labs that run blood tests make sure their machines are up to snuff using other NIST materials — such as standards for vitamin D and cholesterol. Kibble companies use standard dry cat food to ensure each bag produced contains the stated nutrients for our furry friends. Even automakers rely on NIST-certified steel to confirm a car's metal has the right properties.

In a sense, these SRMs are the so-called "gold standards" for things. They're the benchmarks against which all materials of some type should measure up.

Each SRM sample comes with lots of data on its properties — data that NIST measures more accurately than almost any other lab can. "I call it truth in a bottle," says Steven Choquette. He directs the Office of Reference Materials at NIST. His lab provides more than 1,100 types of reference materials.

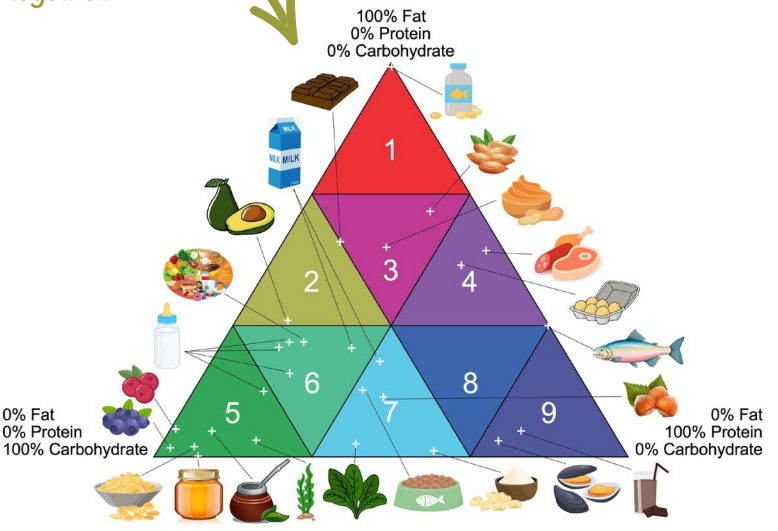
This bizarre collection is housed in a huge warehouse. Think of it as a library. As you wander along its shelves, you might see some labels familiar from your grocery store. There's peanut butter and soy milk. Other holdings here won't be found anywhere else — like "urban dust" and "trace metals in frozen human blood."

At a glance, these SRMs may seem random. But they're not. Each was carefully chosen and crafted to solve a serious problem or to support an important technology. And some might just save your life.

This sign at a beach in Washington state warns in four languages that the water is contaminated. Standard reference materials help water testers ensure their instruments are working properly so they yield accurate data.

PHILAUGUSTAVO/ISTOCK/GETTY IMAGES PLUS; CLOCKWISE: NIST; NIST; TRACEY SCHOCK/NIST

This isn't a typical food pyramid! Foods are grouped by nutrient profile, putting spaghetti sauce and baby formula together.



NIST chose about 30 food standard reference materials that span varying amounts of fat, protein and carbohydrates. Foods with similar nutrient profiles behave similarly during analytical tests.

NUMBER ONE IN NUMBER TWO

The fecal DNA used for water testing isn't the only reference material Servetas' Poop Team worked on. In 2025, it debuted an official sample of human poo. Sound gross? Well, don't turn up your nose. Experts think it will be a game-changer for monitoring health and diagnosing disease.

Our digestive tract is full of microbes. Scientists refer to the mix as our gut microbiome. It can offer clues to what's been going on inside us. For instance, those microbes affect how our bodies fight infection and cancer.

Those microbes travel with food through our bodies, exiting in our feces. And getting a poo sample is much easier than trying to access these microbes in the gut.

Some patients are already asking doctors how their gut microbes compare to a "healthy" set. But answering that would be challenging, says Diane Hoffmann. She studies healthcare law at the University of Maryland in College Park. That would be like "classifying all the kinds of straw," she says, then "counting all the straw in a haystack."

The "Poop Team" created standard feces for vegans and omnivores. The samples are stored in a deep freeze.

Right now, testing isn't accurate enough to take a good census of someone's gut microbes. And scientists today have only a loose understanding of how microbiome data relate to our health. Having an official set of human feces for comparison, however, might one day make analyses of our poop less murky.

The microbiomes of vegans and vegetarians differ from those of people who eat meat. So Servetas and her colleagues created two standard number twos. One is from vegans, the other from omnivores.

For each, the researchers blended donated feces with dry ice. Then they filtered the mix, combined it with water and stored it at -80° Celsius (-112° Fahrenheit).

Does it still resemble poop? "Not so much," Servetas says. But it allows different stool-analysis labs to compare data and interpret what they find. These are key steps for figuring out which microbes *should* be living in our gut and which might cause problems. That might pave the way to microbiome tests that one day guide health and medical decisions.

FOOD, GLORIOUS FOOD

NIST has a whole mini-mart of SRMs for food. Manufacturers use these to make sure their measurement equipment is accurate. That's how they put together nutrition labels that tell you how many grams of protein are in your peanut butter. Or whether your apple juice contains arsenic.

These labels help people look for the nutrients they need and help manufacturers (and diners) avoid ingredients that might make someone sick.

NIST scientists have developed more than 30 different standard reference foods. That might not seem like enough to accurately label the thousands

Standard food samples help inform food safety, nutrition labels and more. NIST scientist Melissa Phillips works with standard spinach, used to measure lead contamination. Standard peanut butter (inset) is used to test for toxins from a mold that can grow on peanuts.

of products in grocery stores. But food manufacturers don't need to test their instruments on the exact foods they're making. They can just use the food with the closest nutrient profile.

One surprising match: spaghetti sauce and infant formula.

A sauce maker can use standard infant formula to calibrate their machines. If a machine is working accurately on infant formula, it can measure nutritional info for sauce, too. The foods definitely aren't interchangeable on your plate. But the nutrient results a machine spits out will be pretty spot on.

Of course, plenty of stuff can wind up in our food that isn't listed on the label. Molds that grow on peanut crops can produce a poison (aflatoxin) that ends up in peanut butter, for instance. These contaminants are dangerous. So NIST has been developing food SRMs with known amounts of toxic materials. Once food companies tune their machines using such SRMs, they can now accurately measure contaminants in our food supply — even in small amounts.

Especially when it comes to food allergies, small amounts can have big consequences. That's why NIST developed standard references for each of the eight main categories of food allergens: milk, egg, wheat, soy, peanuts, fish, shellfish and tree nuts. The U.S. Food and Drug Administration requires that food labels must list whether they contain these allergens (or might contain them due to cross-contamination on farms or in factories).

This is a Charpy before (bottom) and after (top) a Charpy test. How it breaks tells metal-makers whether their Charpy machine is working properly.

HEAVY METAL SCIENCE

In the hardware aisle, you'll find something called a Charpy. This small, rectangular piece of steel with a V-shaped notch in the middle might not look like a big deal. But these metal bits are NIST's most popular reference material — and for good reason. They help prevent many types of disasters.

To imagine how, just consider the *Titanic*. When the *Titanic* smashed into an iceberg in 1912, rivets holding together the boat's hull popped apart. Scientists at NIST examined pieces of the sunken ship in 1998 that had been hauled up from the bottom of the icy North Atlantic Ocean. Their findings were chilling: The *Titanic*'s steel lacked the right properties for shipbuilding. It hosted too much slag, a byproduct of steelmaking. That slag impurity made the rivets brittle at cold temperatures. And when they broke, ocean water gushed into the ship's hull.

With proper steel testing, catastrophes like the *Titanic*'s sinking can be prevented. The "Charpy test" is a simple but powerful way to see whether a batch of metal is "good" or "no good" for building things such as ships, skyscrapers and even nuclear reactors.

To run the test, you need a Charpy machine. This device has a massive pendulum that swings down from a set height and — *wham*! — hits a Charpy right on its notch. That snaps the Charpy in half. The pendulum doesn't swing as high after the collision.

The difference between the starting and ending heights shows how much energy it took to break the Charpy. This is the metal's "impact toughness."

The impact toughness of each NIST Charpy is precisely known. So metal producers use them to confirm their Charpy machines are working well. This can "verify that the machine keeps providing reliable results," says Enrico Lucon. He leads NIST's Charpy Machine Verification Program. "They can even tell from marks on [a Charpy] what parts of the machine might need maintenance."

Metal-makers around the world use NIST Charpy specimens to ensure their metals are sturdy enough to hold up bridges and buildings and to prevent other titanic catastrophes.

BURNING QUESTIONS

For smaller-scale disasters, standard cigarettes play a perhaps surprising role in keeping us safe. Their role: fire prevention.

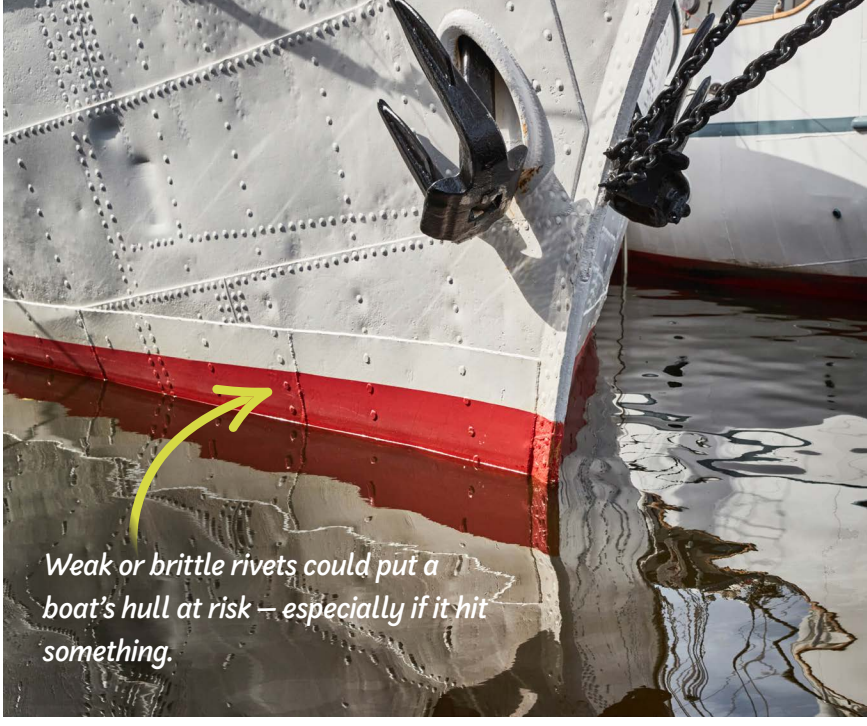
Most fatal house fires in the United States start with cigarettes. Back in the 1980s and '90s, the problem was particularly bad. The government and fire experts wanted to know how to bring the death toll down. So NIST scientists investigated. They discovered that both cigarettes and furniture play a role in whether a fire ignites. That led to the development of two standard reference cigarettes.

The first one looks and acts like an ordinary cigarette. It has thin bands in the paper that are less flammable. They slow the burning of a lit but unattended cigarette. That's a safety feature. Some states have passed laws saying that if a cigarette burns faster than the NIST standard, it can't be sold.

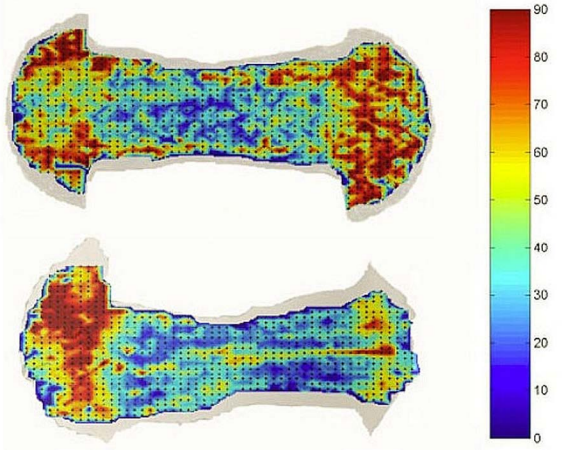
The second type of standard cigarette is for testing furniture. "I call them road flares," says Rick Davis. "They're intended to burn — and burn *intensely*," explains this materials-science engineer. He leads NIST's Fire Research Division.

It's important that this cigarette is good at lighting fires. Say a mattress is tested with a cigarette that doesn't burn well. The mattress might pass as fire-safe, even if it would go up in flames with a faster-burning cigarette. Today, all mattresses sold in the United States must pass tests using the NIST "road flare" cigarette.

Flammability testing has almost certainly saved lives. The United States has nearly halved its rate of fire deaths since 1980. But Davis warns against giving too much credit to standard cigarettes. "You have to be careful with fire statistics," he says. A lot of other things have changed, too. For one, fewer people now smoke cigarettes.



Weak or brittle rivets could put a boat's hull at risk — especially if it hit something.



Boat hulls are held together with rows and rows of metal rivets (above). An analysis of rivets from wreckage of the *Titanic* (left) revealed three times more slag impurity than would be allowed today. Slag makes steel brittle, especially when it's cold. In this image, high amounts of slag appear red, orange and yellow.

WHAT'S NEXT?

NIST is developing new SRMs all the time.

One SRM in the works would aid forensic DNA testing. Samples collected by law enforcement, including the FBI, often contain the DNA of more than one person. That DNA may be damaged, or "degraded." NIST is working to help forensic scientists interpret tests on such less-than-perfect DNA samples.

Such works-in-progress are called "research-grade test materials." They haven't yet reached Choquette's "truth in a bottle" status. But each aims to one day help people accurately measure new things.

Not all research-grade test materials will reach the shelves of NIST's warehouse of standards. Sometimes, it's impossible to make something that performs the same way every time it's tested, is easy to handle or has a long shelf life. But when a new reference material is born, the world becomes safer, healthier and more productive — one ultra-precise measurement at a time.

VLADIMIR DROZDIN/ISTOCK/GETTY IMAGES PLUS; T. FOECKE/NIST

ONE BITE AT A TIME

Parrotfish are breaking coral reefs down — and building them back up

BY **LISA S. GARDINER**

A midnight parrotfish (front) and rainbow parrotfish (center) are nibbling on Alacranes Reef in the Mexican Caribbean. This area has small living corals, sea fans and large spans of algae-covered reef.

CREDIT: L. ALVAREZ-FILIP

Like underwater cities on the floor of tropical oceans, reefs are bustling hubs of activity. Corals — relatives of sea anemones and jellyfish — have built much of these cities. Over time, corals' limestone skeletons grow into structures that can tower above the seafloor. At least a quarter of all marine life needs coral reefs.

Reef dwellers include a colorful mix of sharks and other fish, sea turtles, sponges, sea stars, shrimp and more. Many types of algae also live on reefs. Some, when left unchecked, can overgrow a reef, taking space from corals. If algae overtake the corals, a reef may stop growing.

But just as deer and other grazers on land keep plants trimmed, many animals graze and trim back a coral reef's algae.

Parrotfish are especially avid algae eaters. These large fish can be as brightly colored as parrots. They also have somewhat beak-shaped mouths.

"They're beautiful and colorful and the most prominent fish on most reefs," says Katie Cramer. She's a marine ecologist at Arizona State University in Tempe. By eating so much algae, parrotfish directly affect the amount of coral, Cramer and other scientists think. The fish clear space where new coral can come in and grow.

But the limestone structure of reefs in many areas is in trouble. This is especially true in the Caribbean Sea. Reefs there have less coral and more algae than a few decades ago.

One reason: fewer grazers. Many algae-eating urchins died from disease in the 1980s. And overfishing has caused parrotfish numbers to fall.

Boosting parrotfish populations has seemed like a promising solution. Today, parrotfish are now protected in many reefs.

But algae aren't the only threat in these waters. And hungry parrotfish won't eat just the algae. They'll also chomp on chunks of the reef itself.

Scientists are now working to understand when nibbling parrotfish help reefs grow and when they reduce its limestone to sand. Indeed, parrotfish play a more complex role on reefs than once thought. And knowing more of that story may help guide projects that aim to restore and protect reefs as they face threats — from pollution and poisons to diseases and a warming climate.

CLUES FROM ANCIENT PARROTFISH

To understand parrotfish in today's reefs, Cramer is exploring their history. "I've always been interested in what things used to look like," she says.

In the Caribbean, many people catch parrotfish for food. As a result, many reefs have fewer parrotfish than they used to. Cramer wanted to learn whether overfishing is a recent problem. She also wanted to know what reefs were like before fishing took its toll.

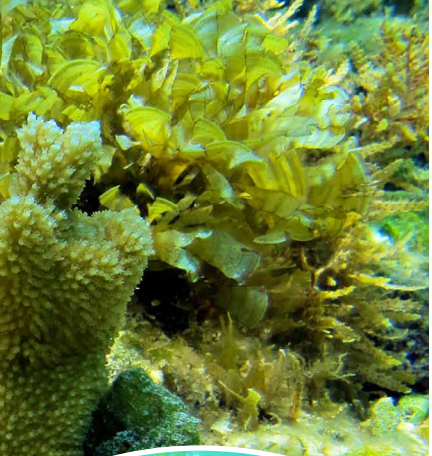
Cramer is part of a team that has studied layers of sediments below living reefs near Belize. Off the coast of this Central American country are some of the most expansive reefs in the Caribbean. They are part of the second largest barrier reef in the world, the Mesoamerican Barrier Reef. Only Australia's Great Barrier Reef is bigger.

Over time, sediments accumulate under living reefs. Their layers hold the remains of animals that used to live there. These include coral skeletons, shells — and fish teeth.

Parrotfish have "a lot of teeth," notes Cramer — more than other fish. Those teeth fall out and get replaced as a parrotfish grows. The number of teeth

This elkhorn coral (top) on a reef near Andros Island, Bahamas, is surrounded by several types of leafy-looking algae. Without grazers like parrotfish, algae can spread to cover reef surfaces. Parrotfish have about 1,000 tiny teeth that come in many different shapes (left). Each tooth is only about a quarter of a millimeter (roughly one-hundredth of an inch) across. These photographs were taken through a microscope.

SEAN NASH/FLICKR (CC BY-NC-SA 2.0); K. CRAMER



In addition to the toothy jaws visible here, parrotfish have another set of teeth deep in their throat.

Katie Cramer and her colleagues hammered this gravity corer — similar to a giant metal straw — into sediment below reefs to find fish teeth.

LISTEN TO PARROTFISH MUNCHING ON CORAL

in sediment is one clue to how many parrotfish have lived on a reef. But because the fish keep making new teeth, there are far more teeth than parrotfish.

Researchers use a gravity corer to collect sediment. It looks like a giant metal drinking straw. It gets hammered into the seabed. When pulled up, it brings a cylinder — or core — of sediments. Layers at the core's bottom are oldest. The oldest layer of Belize cores formed 1,300 years ago.

By comparing samples from different layers, scientists see how the reef has changed over time.

Before searching each core for fish teeth, researchers must first pick out larger items, such as corals and shells. They put what remains into a weak acid. It's about as acidic as vinegar. This dissolves everything except fish teeth. (Tooth minerals are so tough that they don't dissolve easily.)

A parrotfish tooth is tiny — only about a quarter of a millimeter (one-hundredth of an inch) across. That's smaller than a grain of salt!

Scientists must use microscopes to identify these teeth. "We had tons of students helping out with that," Cramer recalls.

They found thousands of fish teeth in the cores. In layers from the 1700s, nearly half of all fish teeth present — 45 percent, on average — came from parrotfish. By the 1900s, that number dropped to just 24 percent. That suggests that far fewer parrotfish dwell in reefs today than in the past.

It also suggests overfishing has been going on for a long time, Cramer says. Human populations in the Caribbean have grown over the past several centuries. High demand for seafood has upped the harvesting of many sea species, including parrotfish.

PARROTFISH CAN HELP REEFS GROW

The sediment cores also told Cramer that reefs with more parrotfish had grown faster in the past. She was part of a team that dated the ages of coral skeletons in each core. Based on the core lengths, they could calculate how much the reefs had grown each year. With more corals, a reef grows faster.

More parrotfish eating more algae seem to have allowed corals to dominate these reefs, she says.

Parrotfish are now protected in many reefs. Fishing them is limited in some places and banned in others. Although these fish can swim in and out of protected reefs, their numbers tend to be higher where rules are in place.

Coral in the Bahamas grew more in reefs with protected parrotfish. These reefs had less algae, too. And in Belize, scientists found more parrotfish and less algae in reefs where these fish were protected. But there, the amount of coral did not increase.

CHRIS ANGIOLETTI; TARIK TINAZAY/AFP/GETTY IMAGES PLUS

After corals die, parrotfish can help reefs rebound. Near the Caribbean island of Bonaire, a hurricane killed corals in 2008. Heat in 2010 killed even more. This left reefs with less coral and more algae. But between 2010 and 2017, young corals again started to grow in these reefs.

Scientists now believe that hungry parrotfish, which are protected in Bonaire, helped those corals out.

Most corals start their lives as larvae carried in waves and ocean currents. When they find an open space on a reef, they attach to it. Now they can start to grow their limestone skeletons. By clearing away algae, parrotfish may have made more space in which new corals could settle.

TURNING REEFS INTO SAND

But parrotfish cannot fix all reefs. In some cases, their chomping may actually damage the reef's limestone structure.

Some species of parrotfish nibble, trimming just the tops of algae. Some scrape algae off a reef. But many parrotfish swim toward the reef with their mouth wide open and — crunch! — bite at both the algae and the limestone.

"Unlike most fish, you can hear them," says Anthony Martin. Crackling sounds of parrotfish munching rock can resonate through reefs.

Martin is a geologist and paleontologist at Emory University in Atlanta, Ga. He studies trace fossils — signs of what animals did in the past. And parrotfish-bite marks on reefs can become trace fossils.

But the main thing these fish leave behind is sand.

After eating limestone, these fish poop it out as sand. Some species crunch so much limestone that a single parrotfish can make about 1,000 kilograms (2,200 pounds) of sand each year.

The sand these fish produce can be helpful, says Martin. Some becomes home to algae and sand-dwelling animals on the seafloor. Other sand adds to the beaches on nearby islands. All that sand is made as parts of reefs are destroyed.

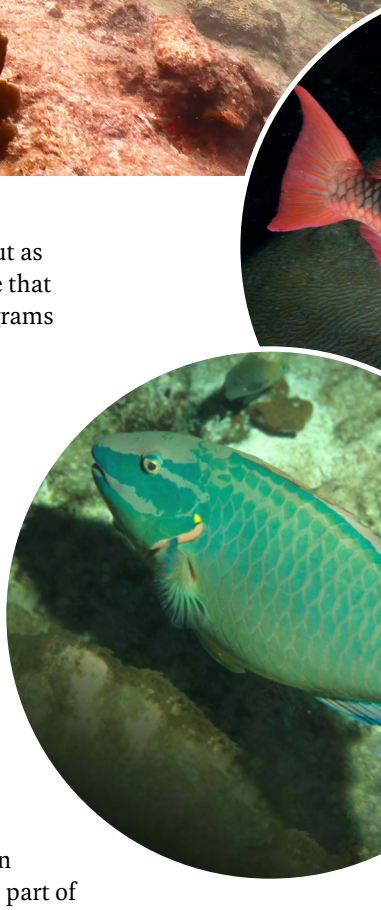
Ana Molina Hernández studies how parrotfish eat reef limestone. A marine ecologist, she works at the National Autonomous University of Mexico in Puerto Morales. There, she studies bioerosion — how living things eat away at rock.

Parrotfish aren't the only animals that chip away at reef limestone. But they're the main culprit at reefs she studies in the Mexican Caribbean. Like the Belize reefs, these are also part of the Mesoamerican Barrier Reef.

A NOTABLE REEF SCULPTOR

The Caribbean is home to 16 species of parrotfish. Molina Hernández compared 10 of them. The stoplight parrotfish — the largest there — "is the most amazing," she says. "He's a great herbivore. But he also is a good eroder."

This species grinds the most limestone into sand of all the fish she studied. Some smaller parrotfish species eat more algae and less reef limestone. These are better at clearing algae off the reefs, she says.



On a reef with little living coral, like the one above, parrotfish munch away more limestone than gets added. Over time, the reef shrinks.

L. ALVAREZ-FILIP; DWAYNE MEADOWS, NOAA/NMFS/OPR/NOAA PHOTO LIBRARY/FLICKR (CC BY 2.0)

Marine ecologists Ana Molina Hernández (left) and Lorenzo Alvarez-Filip (right) survey a coral reef in the Mexican Caribbean. They're holding meter-long (39-inch-long) sticks to take measurements.

Stoplight parrotfish change color as they grow. Young fish are mottled reddish-brown (top inset). Adult males eventually become a smoother bright green (bottom inset).

ESMERALDA PEREZ-CERVANTES; G. P. SCHMAHL/FLOWER GARDEN BANKS NATIONAL MARINE SANCTUARY/NOAA/FLICKR (CC BY 2.0)

How much algae and limestone parrotfish eat also changes as a fish grows, she discovered. In general, older ones eat more rock and algae than younger ones.

On a healthy reef, corals grow at least as much limestone as parrotfish and other creatures eat away. "Coral reefs that are in good shape — that have a lot of living corals — can endure really, really high bioerosion rates," says Molina Hernández. But on a reef where corals have died, little limestone gets added. So over time, these reefs will shrink.

"This is a really tough problem," she says. Molina Hernández is seeing this unfold now on reefs in the Mexican Caribbean. These reefs protect the Mexican coast from incoming waves, she explains. Without that protection, "we are going to start to see more [loss] of the beach."

REEFS NEED MORE THAN PARROTFISH

Parrotfish can't help corals that are struggling to survive due to other threats.

"We can fill our reefs with parrotfish, but this will not save corals," says Lorenzo Alvarez-Filip. He's a marine ecologist who works with Molina Hernández at the National Autonomous University of Mexico.

"It somehow seemed that this beautiful [fish] — because they are beautiful — could be the perfect superhero that will save reefs," he says. But, he adds, "they will not save all the reefs from all the threats."

Alvarez-Filip points to one big problem: too many nutrients.

Corals adapted to live in low-nutrient water. But nutrients like nitrogen from fertilizers and sewage wash into the sea from towns and farms. Just as fertilizer helps plants grow, nutrients carried into reefs spur the growth of algae. With too much algae, reef corals will struggle.

Warming oceans due to climate change also harm corals. Over the past three years, extreme heat killed millions of corals in the Caribbean, Great Barrier Reef and other parts of the world. And then there's disease. One killer — stony coral tissue loss disease — has been spreading through the Caribbean since 2014.

Parrotfish alone may not save reefs. That's why it's important that people help where they can. Spewing fewer greenhouse gases could slow climate change. Cutting nutrient runoff would help corals.

Even if you live a long way from a coral reef, you can help by protecting nature, says Alvarez-Filip. "Put your energy into solving the issues where you are," he says. "If enough people do this, it will be helping coral reefs."

Not long ago, Alvarez-Filip was diving in a reef in the Mexican Caribbean. He saw several young corals he had not seen before. In the same reef, older corals of the same species had died. He had feared the species might never return. But it did.

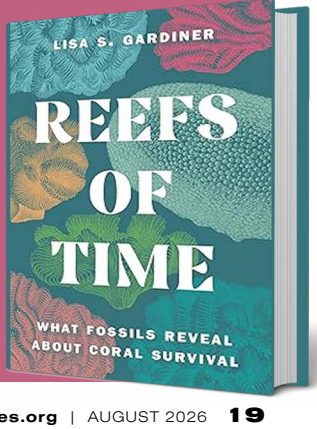
The young corals were small, just two or three centimeters (about an inch) across. But they gave him hope. If there's enough space on the reef, young corals may make a home there. "We need to trust in corals that they are capable of coming back."

READ MORE

Reefs of Time: What fossils reveal about coral survival

By Lisa S. Gardiner

Learn about how scientists are studying fossil coral to better protect modern reefs in this book by the author of this parrotfish tale.



This evolutionary biologist fuses art into her science

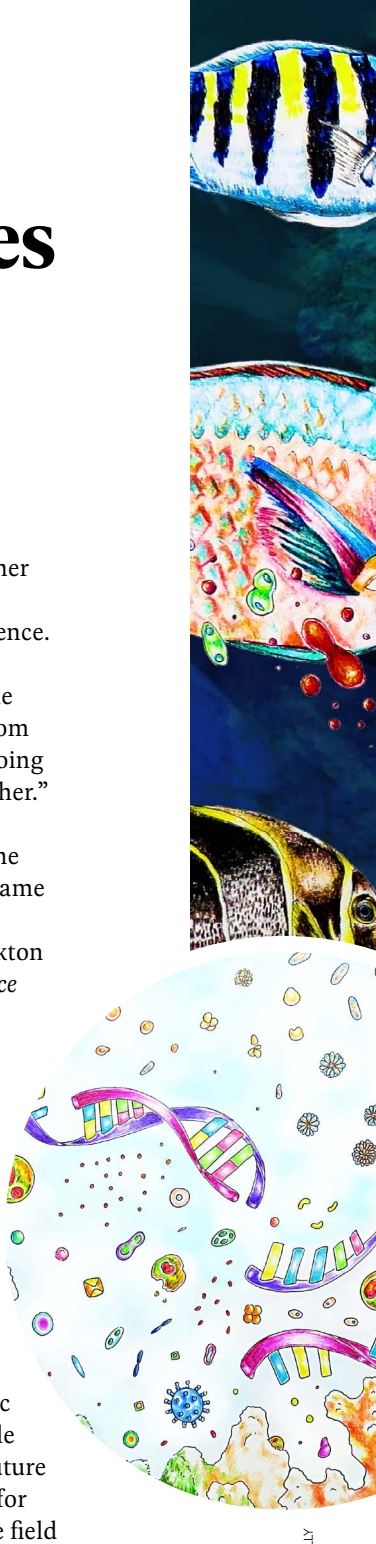
Victoria Glynn has turned to art to reach learners from different backgrounds

When Victoria Glynn was a teen living in Honduras, she enjoyed making art. But that wasn't her only interest. "Growing up in Central America, I was just surrounded by all of this amazing biodiversity," she says. So, when it came to college, Glynn opted to study environmental science.

For undergrad studies, Glynn moved to the United States to attend the University of California, Berkeley. While there, she worked in a lab that genetically engineered yeast to produce biofuel. But she had a problem: Glynn was struggling to find diagrams to accompany talks about her research. Her mom suggested that she use her skills in art and make her own. "At the time, I wasn't seeing other people doing that," Glynn says. "It felt like science was in one corner, and all the arts and humanities were in the other."

Glynn soon found other ways to bridge science and art. As an undergrad, she taught refugees and children who had recently arrived in the United States. She sometimes worked in classrooms where the students spoke many different languages. Art became a "common language for all of us to be on the same page," she says.

Now as a visiting researcher at the University of Connecticut, Avery Point, Glynn studies how plankton are adapting to high temperatures. In this interview, she shares her experiences and advice with *Science News Explores*. (This interview has been edited for content and readability.) — *Aaron Tremper*



Q What inspired your career?

A One of my best friends recommended that I take this particular genetics course at Berkeley. I remember something just clicking in my brain during one of the first lectures. Genetics and DNA felt so powerful. All organisms have DNA, which means you can track it and directly measure how it's changing over time. After this class, I really wanted to dive into this topic more deeply.

Q How did you get to where you are today?

A During my Ph.D. at McGill University in Montreal, Canada, I studied how corals build up resistance to bleaching. But corals, while beautiful, are very hard to rear in the lab. So I switched to studying plankton. I needed an animal that could evolve quickly over multiple generations. Plankton are much easier to grow. In as little as 11 days, you can have adult plankton that lay eggs. Compare that to corals. Some species are so long-lived that they will not reproduce within our lifetime.

Q When did you start scuba diving?

A Both of my parents are divers. When I was younger, they would always talk about it. Honduras is also one of the most affordable places to get dive certified. So when I turned 12, I decided to go for it.

As I was applying for my Ph.D., my mother suggested that I add diving onto my CV. [A CV, or curriculum vitae, is the academic version of a resume.] I doubted whether people were going to care but added it anyway. My future Ph.D. advisor at McGill, though, was looking for someone who could handle both diving in the field and doing molecular work in the lab.

That taught me that the experiences you may not see as valuable in professional settings may be what sets you apart. You don't know where these experiences are going to lead.

Victoria Glynn uses traditional media such as colored pencils and watercolor to create scientific illustrations. Past subjects include the symbiotic relationship between coral and algae (bottom left) and microbes that support Tropical Eastern Pacific coral reefs (bottom center). As an evolutionary biologist, Glynn has also conducted field work, such as sampling corals in Panama's Las Perlas Archipelago (bottom right).

SU REID-ST. JOHN; ART: V. M. GLYNN; MICHAEL CONNELLY

HUMANS

Real vs. AI images

Can you spot the difference?

By Science Buddies

Images created by artificial intelligence have exploded in popularity. New AI-powered programs and websites can make photo-realistic pictures based on simple text prompts. An AI-generated image of an animal or flower might seem harmless. But fake images of people or events can spread misinformation. Let's investigate whether people can tell the difference between images made by humans and those made by computers.

OBJECTIVE

Find out if people can distinguish real versus AI-generated images.

EXPERIMENTAL PROCEDURE

1. Pick a topic for your pictures, such as animals, flowers, vehicles or people.

2. Collect at least 10 real photos of your topic.

3. Find or make at least 10 realistic AI-generated images of the same topic.

4. Label the images 1 through 20 and put them in a random order. Keep track of which images are real, but keep it secret.

5. Show each picture to a volunteer and ask whether they think it's real or AI-generated. Record their responses.

6. Repeat step 5 with other volunteers.

7. Calculate the percentage of volunteers who correctly identified whether each image was real or AI-generated.

8. Tally up the volunteer responses for all your real images and all your fake ones.

9. Overall, how good were your volunteers at correctly identifying real images? How good were they at spotting fakes?

10. Are there big differences in your results between individual pictures? Looking at the pictures, why do you think this occurred?

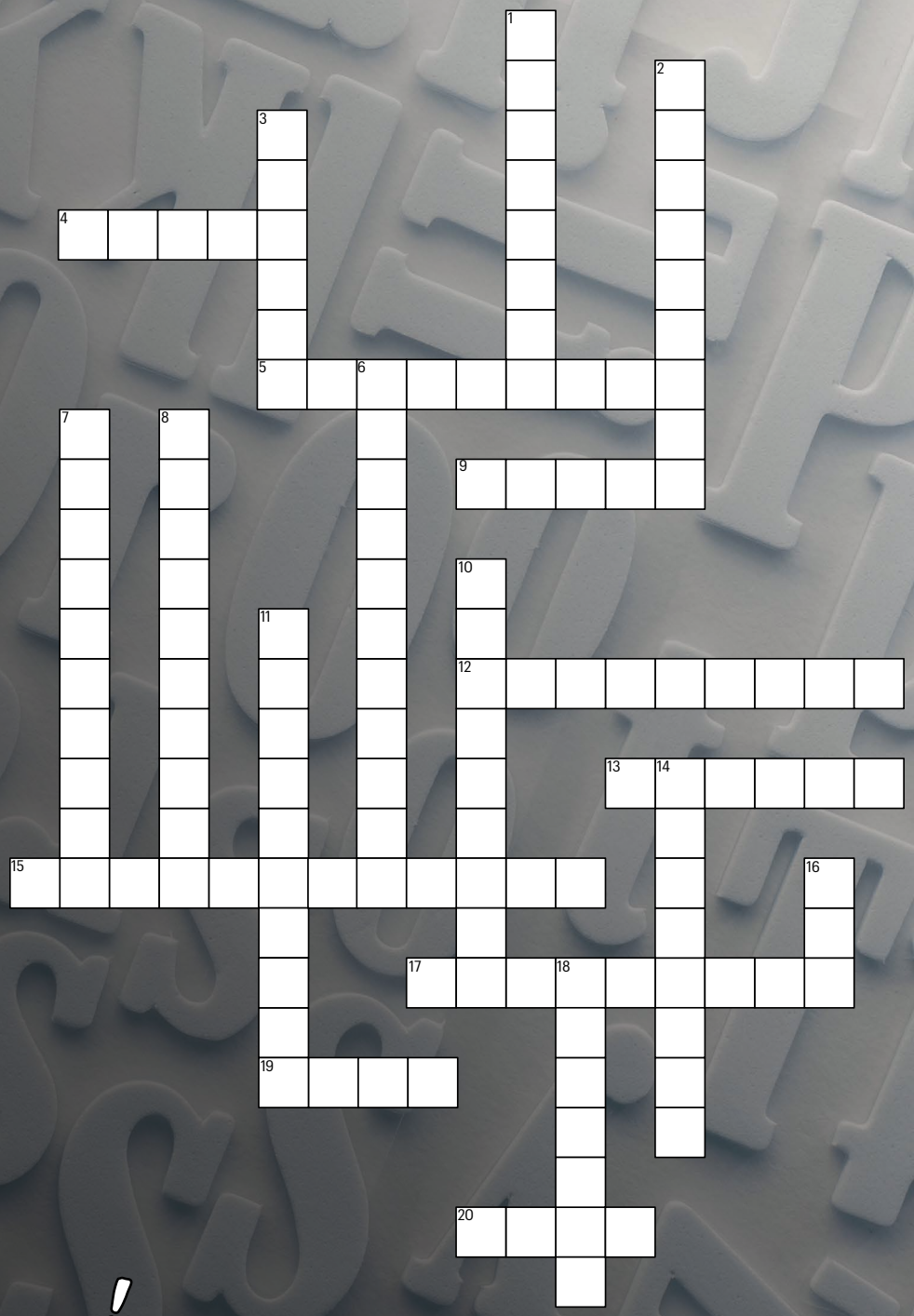
Find the full activity, including how to analyze your data, at snexplores.org/AIimages. This activity is brought to you in partnership with Science Buddies.

A real photo (left) and an AI-generated image (right) of a tiger look nearly the same. Can you — or your friends — spot the difference?

ERIC ISSELEE, SHUTTERSTOCK AI/SHUTTERSTOCK

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.



ACROSS

4. This tech sends out laser pulses and detects the light that bounces back

5. This group includes mammals and their dino-like ancestors

9. Human and animal waste

12. This cell-sized tech can move and sense on its own

13. Small, rectangular piece of steel with a V-shaped notch

15. This weather type forms when warm, moist air and cold air meet

17. Fast, narrow band of wind that moves weather across continents

19. A jumping style sure to make a big splash

20. These flat-faced dogs have a high risk for breathing problems

DOWN

1. Earth's longest-lasting tropical storms

2. Two organisms benefit by associating together

3. Relatives of sea anemones and jellyfish

6. Nerve endings in eyes that can sense saltiness

7. These colorful algae eaters have beak-like mouths

8. How living things eat away at rocks

10. Some fish eat this and poop it out as sand

11. A single-celled organism that lives in water

14. This moon of Saturn looks a bit like a sponge

16. Considered the "gold standard" for measuring objects (abbreviation)

18. Particles may be made of these tiny, vibrating loops

BART SADOWSKI PL/SHUTTERSTOCK

TECHNOLOGY

Tiny 'microbots' are smaller than a grain of salt

The small-but-mighty robots move and sense all on their own

You wouldn't know this teensy speck was a robot if you saw it. At less than a millimeter across, you might not notice it at all. But the itty-bitty machine offers big opportunities to explore the microscopic world. It's the smallest robot that can move, think and act on its own, its creators say.

The mini robot was inspired by nature's tiny, complex machines. "Cells and microorganisms are phenomenally sophisticated," says Marc Miskin. "Nature has chosen this length scale to organize all of life." An engineer, Miskin works at the University of Pennsylvania in Philadelphia. He hopes that similarly tiny robots will help uncover the secrets of the cellular realm.

The new robot is as small as a paramecium — a single-celled organism that lives in water. It isn't the first robot less than a millimeter long, Miskin says. But it's the first one that's fully autonomous. Once programmed, it decides where to go, how to get there and what to do.

Such small robots might someday be able to travel through the human body to study cells or deliver drugs.

SUPER SMALL SCALE

Designing the microbot was a challenge, says Miskin. Robots need sensors, computer processors and memory, power sources and pieces to control their motion. In large robots, these systems can be separated. But in tiny robots, everything is squished in close. And at such small scales, different forces affect how objects can move around. As a result, engineers had to rethink how to design this robot.

The new robot is powered by mini solar cells on its surface. From an LED overhead, it produces 100 nanowatts of power. Microwave ovens produce 10 billion times more. The tiny amount of power available to run the machine limited its design options. The team had to be clever about how the robot gets around and processes information, Miskin says.

To move, the robot needs to be in a liquid. It can't swim, though. At very small scales, objects interact differently with liquids than we do. For a cell-sized thing, swimming through water feels more like swimming through tar. So the microbot uses a low-power process called electrokinetic propulsion. That means electricity ("electro") drives its motion ("kinetic").

Four electrodes on the robot can send and receive electric current. As current travels through the liquid from one electrode to another, it generates a force on any charged particles that are in the liquid. The force pushes the particles in one direction, but the liquid tries to pull them back. This creates a flow that carries the robot along with it.

To move in different directions, the robot sends current between different electrode combinations. It changes speed by adjusting the current strength.

Once their robot could move, it was time for the team to give it sensors and a "brain." Temperature might be a useful thing for little robots to measure. That's because it can be an indicator of cells' health. To that end, the researchers attached a couple of tiny thermometers to their robot.

The microbot's "brain" is a teeny computer with only a few hundred bits of memory. Most laptops, meanwhile, have at least 64 billion bits. Because of this, the designers had to write computer programs that used hardly any memory. They used tricks like organizing many small commands under one super command and writing programs on a normal desktop computer, then sending them to the robots.

In experiments, the cell-sized robot was programmed to measure the temperature of its surroundings and move from colder to warmer areas. When the liquid near the robot was cooled, the robot moved around until it found a warmer spot, just as programmed. When that area was cooled, the robot resumed its search for warmth.

Miskin's group shared these results in *Science Robotics*. The microbots are made using a common technique and are cheap, the researchers note. They estimate that if made in large batches, the robots would cost just a penny each.

— *Kendra Redmond*

These itty-bitty robots move through liquid using electric currents. The microbots are powered by tiny solar cells and contain temperature sensors and computers. Hundreds can be built at the same time for a low cost.

These robots, smaller than a salt grain (left), could one day track the health of individual cells.

ILLUSTRATION BY STEVE MCCRACKEN

CLIMATE

Could a storm last forever?

In Hyrule, from *The Legend of Zelda*, thunderstorms defy physics

The weather forecast can get extreme in the land of Hyrule, found in the Nintendo series *The Legend of Zelda*. A downpour in the coastal province of Faron, for instance, prevents Link, the game's hero, from reaching Calora Lake. And constant lightning and rain threaten the skybound Thunderhead Isles. These storms only end once Link completes a series of quests.

Never-ending storms make for moody gameplay. But real storms "can't last forever," says Stephanie Spera. She's a physical geographer at the University of Richmond in Virginia. Storms result from imbalances between moisture and temperature. "A storm kind of fixes a temporary imbalance," she says.

"The whole purpose of anything in weather is to get the atmosphere back in balance," explains Chris Vagasky. He directs the Wisconsin Environmental Mesonet, a network of weather stations. Though violent at times, thunderstorms help balance and redistribute heat, moisture and electrical charges.

To fuel constant thunderstorms like those seen in Faron, such imbalances would have to persist. But on Earth, atmospheric physics ensures that even the strongest storms eventually fade away.

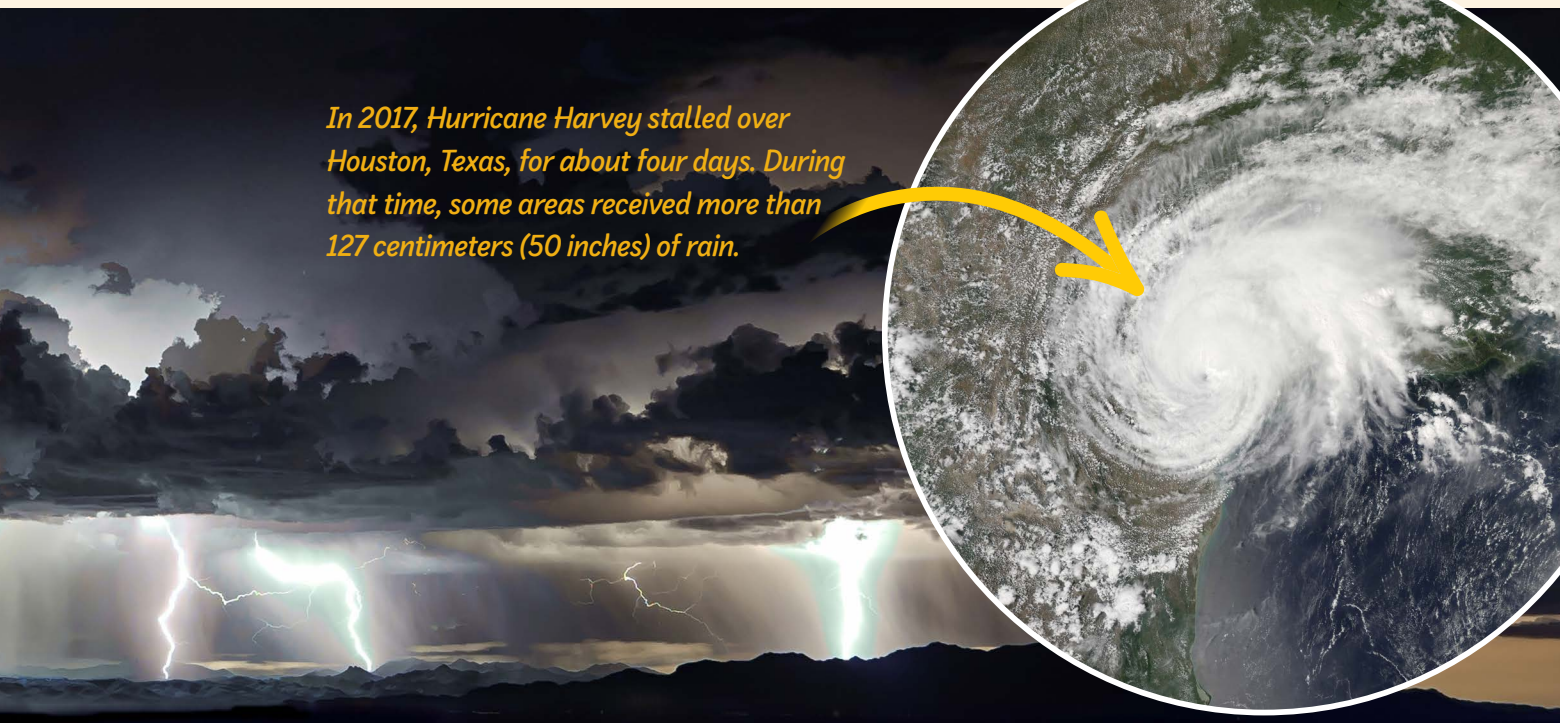
NO STORM LASTS FOREVER

Thunderstorms form when warm, moist air rapidly rises and meets cooler air in the atmosphere. This creates instability. As moisture-filled, warm air rises, it creates updrafts — upward air movements. Water vapor in this air condenses into droplets, forming a cumulus cloud. This cloud formation, in turn, releases energy as heat. That heat fuels stronger updrafts, which power the storm.

Within the clouds, water droplets collide with ice crystals. This creates static charges and, sometimes, lightning. As a cloud grows, water droplets become heavy enough to fall through it. The resulting rain and ice create cooler downward winds, or downdrafts. Eventually, they overpower the warmer updrafts. As the atmosphere regains its balance, the storm ends.

Most thunderstorms only last an hour at most. Constant thunderstorms, such as those seen in Faron, would need ongoing supplies of

In The Legend of Zelda video games, the protagonist Link faces never-ending thunderstorms.



In 2017, Hurricane Harvey stalled over Houston, Texas, for about four days. During that time, some areas received more than 127 centimeters (50 inches) of rain.

Quirks in geography can prolong harsh weather, such as the Catatumbo lightning (above) that plagues Venezuela's Lake Maracaibo. This lightning occurs when bowl-shaped mountains hugging the lake prevent cumulonimbus clouds from moving. The resulting thunderstorms can produce lightning flashes up to 300 days per year.

ARIEF SYAUQI, UNO_MAS_BAJO_EL_SOL/SHUTTERSTOCK; JESSE ALLEN/NASA

storm ingredients, says Vagasky. First, you'd need a "persistent conveyor belt of warm, moist air." It would have to be heated, maybe by 24-hour sunlight. And the Thunderhead Isles would likely need to hug mountains that could help condense that moist air into clouds.

KEEPING THINGS MOVING

Even if a storm could sustain its own internal energy, it couldn't stay in the same place forever. That's because Earth's atmosphere is in constant motion. Large belts of wind blow in particular directions (based on their latitude). Some storms get an extra boost from fast, narrow bands of wind called jet streams. Like conveyor belts, these streams move weather across continents.

Sometimes these wind patterns can increase how long storms last. High-pressure systems or the jet stream can make Earth's longest-lasting storms — tropical cyclones — hang out in one place for a bit. In August 2017, for instance, Hurricane Harvey stalled over Houston, Texas, for about four days. Fueled by warm coastal waters, some areas received more than 127 centimeters (50 inches) of rain before the storm moved inland and broke up.

Like Houston, Faron lies along a coast. Perhaps it's in a cyclone-prone part of its planet. But even a cyclone couldn't last year-round unless the oceans stayed consistently warm. On Earth, cyclones die when they make landfall, face windshear or reach colder water in higher latitudes. "They need to be refueled, which is why they die over land," says Spera. "There's no energy source."

EARTH'S FLASHIEST STORMS

Thanks to physics, perpetual storms like those in Faron are impossible on Earth. But certain scenarios come close.

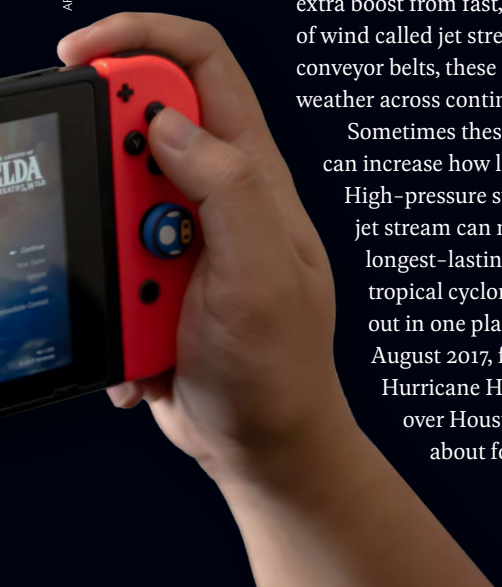
The storm plaguing the Thunderhead Isles looks similar to a region called the Intertropical Convergence Zone (ITCZ), says Spera. This solid band of clouds encircles the globe near the equator. Here, prevailing winds from the northern and southern hemispheres meet. This lifts warm, humid air heated by the intense sunlight found in the tropics.

But the ITCZ isn't a single, massive thunderstorm, like that seen in *The Legend of Zelda* games, Spera adds. Instead, a series of intense but short-lived events develop here. This zone also moves back and forth across the equator, leading to seasonal monsoon rains like those found on the Indian subcontinent.

For flashier storms, head to Lake Maracaibo in coastal Venezuela. Here, a phenomenon called Catatumbo lightning flashes up to 300 days per year and can last for nine hours at a stretch! The region holds the world's record for the most concentrated lightning.

The key to Catatumbo lightning is geography. The nearby Caribbean Sea offers huge amounts of warm, humid air. Lake Maracaibo adds more moisture. Winds whisk this moist air up the northern end of the Andes Mountains. There, it meets colder air. The bowl-shaped mountains hugging the lake prevent the resulting cumulonimbus clouds from moving. This can lead to stagnant thunderstorms, similar to those of the Thunderhead Isles. Says Vagasky, "Catatumbo is one of the closest things that we might see to that."

— *Aaron Tremper*



OCEANS

What are corals?

These marine animals support the most diverse ecosystems in the sea

Take a plunge into Australia's Great Barrier Reef, and you'll come face to face with what looks like a gorgeous rocky garden. This dazzling array of corals is the largest living structure on Earth. Some, like staghorn coral, look like leafless bushes sprouting from the ocean floor. Others, such as honeycomb coral, resemble rocks dotted with tiny holes. Then there's brain coral, which, you guessed it, look like brains. And that's just a small sample of the brilliant diversity to be found in a reef.

Despite their appearance, corals are animals. These invertebrates are close relatives of jellyfish and sea anemones. Corals can be found all over the world. Most live in colonies of thousands of tiny individuals called polyps growing together. Each polyp sports a cylindrical body topped with a ring of tentacles surrounding its mouth.

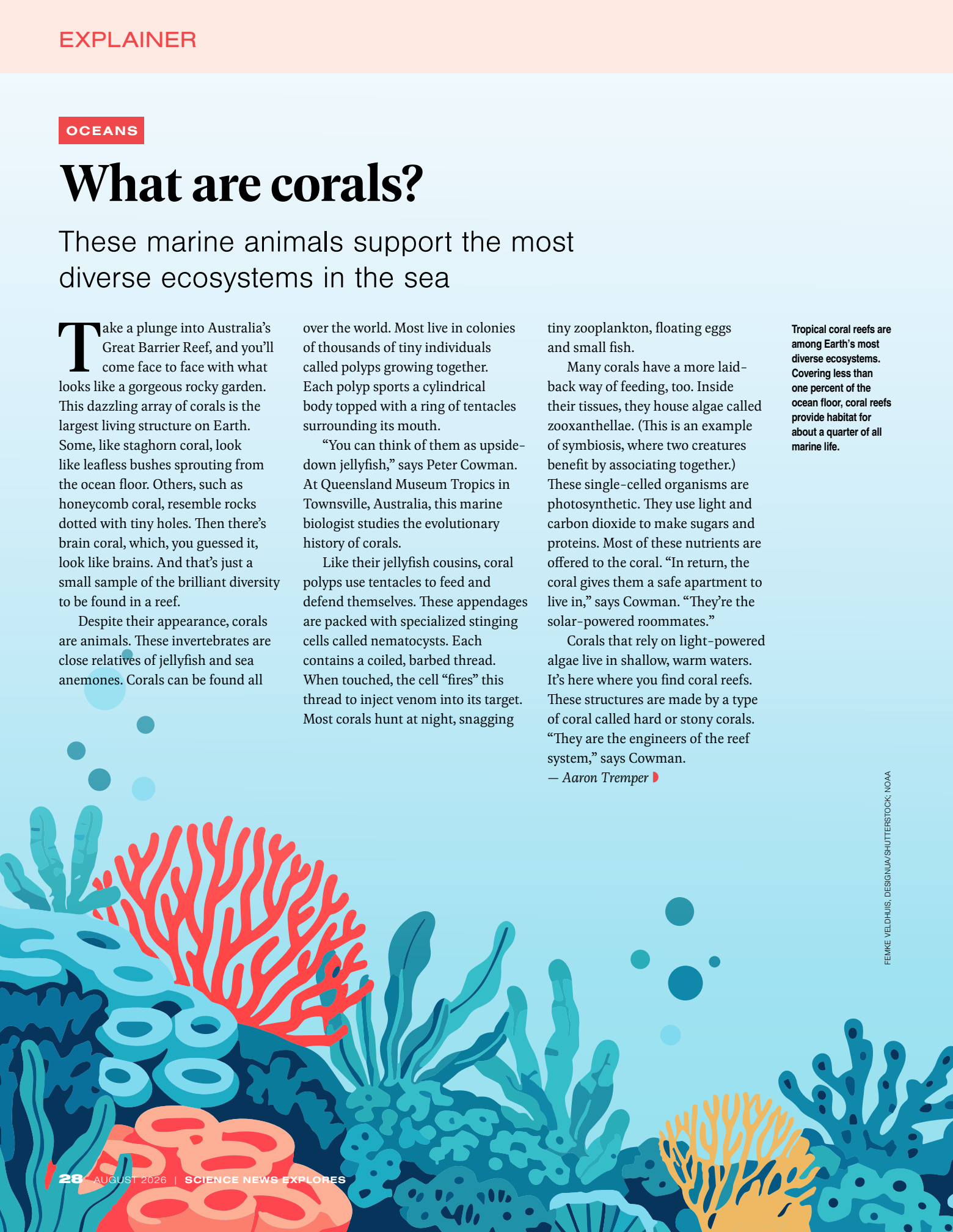
"You can think of them as upside-down jellyfish," says Peter Cowman. At Queensland Museum Tropics in Townsville, Australia, this marine biologist studies the evolutionary history of corals.

Like their jellyfish cousins, coral polyps use tentacles to feed and defend themselves. These appendages are packed with specialized stinging cells called nematocysts. Each contains a coiled, barbed thread. When touched, the cell "fires" this thread to inject venom into its target. Most corals hunt at night, snagging tiny zooplankton, floating eggs and small fish.

Many corals have a more laid-back way of feeding, too. Inside their tissues, they house algae called zooxanthellae. (This is an example of symbiosis, where two creatures benefit by associating together.) These single-celled organisms are photosynthetic. They use light and carbon dioxide to make sugars and proteins. Most of these nutrients are offered to the coral. "In return, the coral gives them a safe apartment to live in," says Cowman. "They're the solar-powered roommates."

Corals that rely on light-powered algae live in shallow, warm waters. It's here where you find coral reefs. These structures are made by a type of coral called hard or stony corals. "They are the engineers of the reef system," says Cowman.

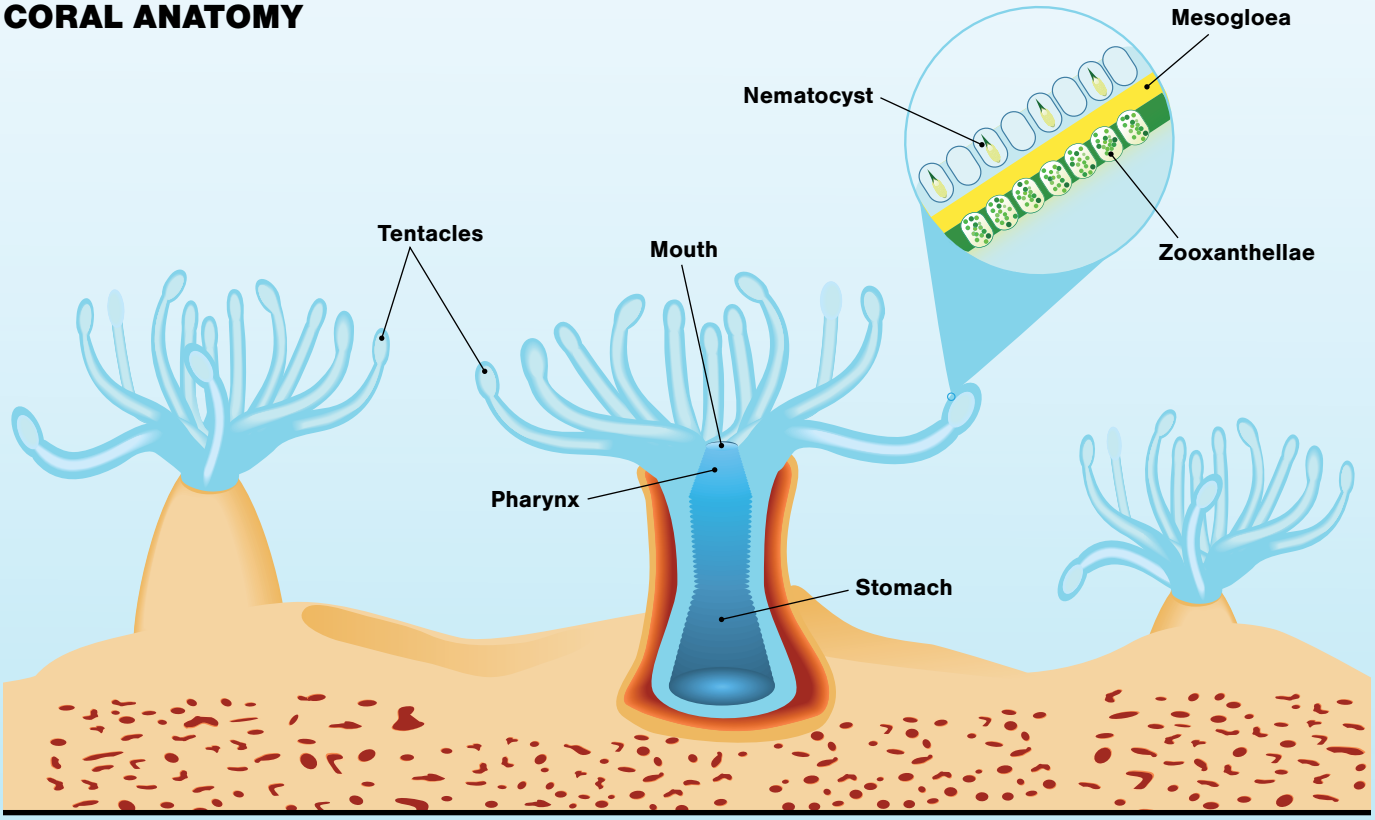
— Aaron Tremper



Tropical coral reefs are among Earth's most diverse ecosystems. Covering less than one percent of the ocean floor, coral reefs provide habitat for about a quarter of all marine life.

FEMKE VELDHUIS, DESIGNUA/SHUTTERSTOCK; NOAA

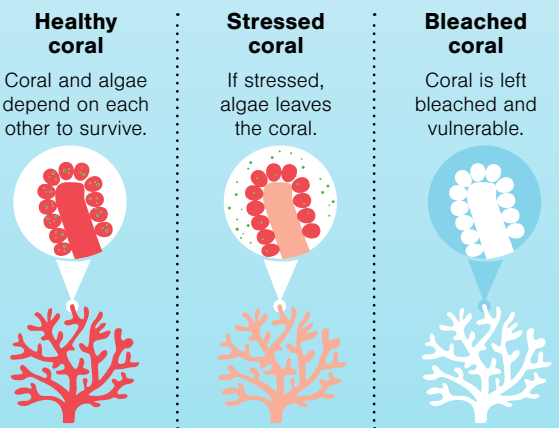
CORAL ANATOMY



CORAL BLEACHING

High water temperatures and too much sunlight can stress corals, leading to a phenomenon called coral bleaching. "When the water gets too hot, the coral gets stressed and they evict their zooxanthellae," says Cowman. These microbes are also responsible for a coral's bright colors. In their absence, the coral's tissues turn transparent. All that remains visible is the coral's white skeleton.

Bleaching doesn't kill the coral immediately. If conditions improve, the coral may recover and even take the algae back in. But if coral go too long without their algal partners, they may get sick or die. "If they can't get the zooxanthellae back in again, they [will] actually starve to death," says Cowman.



EARTH

Space junk pollutes the atmosphere

This debris could damage Earth's ozone layer

D. DUCROS, 2014/EUROPEAN SPACE AGENCY

In February 2025, part of a SpaceX rocket broke up in the atmosphere over Europe, creating a cloud of metal pollutants. As companies launch more and more stuff into space, pollution from such devices is likely to increase.

For the first time, scientists have measured metal pollutants from a piece of space junk in the atmosphere. They caught a burst of lithium as a rocket burned up high above Earth's surface. Such pollutants can damage the ozone layer and may impact global climate.

Humans have been launching metal things into orbit around Earth for nearly 70 years. But the pace of launches has recently skyrocketed. Consider the Starlink system, run by the company SpaceX to provide internet service. This system will eventually consist of more than 40,000 satellites. Already, nearly 10,000 Starlink satellites orbit Earth.

After a planned lifetime of about five years, each piece of Starlink equipment burns up in the atmosphere. This releases metals, including lithium. Those metals may speed up chemical reactions that destroy ozone. That's a problem, because the ozone layer of Earth's atmosphere protects life on the ground from the sun's ultraviolet light.

Space junk could also affect Earth's climate. Metal pollution could change the balance of light that reaches the ground or bounces back to space.

The stratosphere is a layer of the atmosphere from 10 to 50 kilometers (6 to 31 miles) above Earth. A 2023 study found that about 10 percent of particles there contain pollutants from burnt-up satellites and rockets.

Scientists wondered if they could directly trace such particles to a piece of space debris. They got their chance on February 19, 2025, when a cloud of lithium appeared about 100 kilometers (60 miles) above Germany. It was blowing away from a SpaceX rocket part that broke up over Ireland and the United Kingdom.

"A few hours after the reentry of this rocket, we could see 10 times more lithium than we would have observed otherwise," says Claudia Stolle. She's a meteorologist at the Leibniz Institute of Atmospheric Physics in Germany.

The measurements relied on lidar. Lidar sends out laser pulses and detects the light that bounces back. The laser light is tuned to wavelengths that reflect off particular materials, such as lithium. The team also ran computer models of the atmosphere. These showed that wind had carried the lithium from where the rocket came down to the lidar's location in Germany.

The researchers shared their findings in *Communications Earth and Environment*.

The technique could help monitor harms from falling space junk. More companies and countries are planning to launch satellites to orbit, Stolle notes. "All of them will burn up sooner or later."

— Adam Mann and Carolyn Wilke

DATA DIVE

1. Look at Figure A. When did the density of lithium increase?

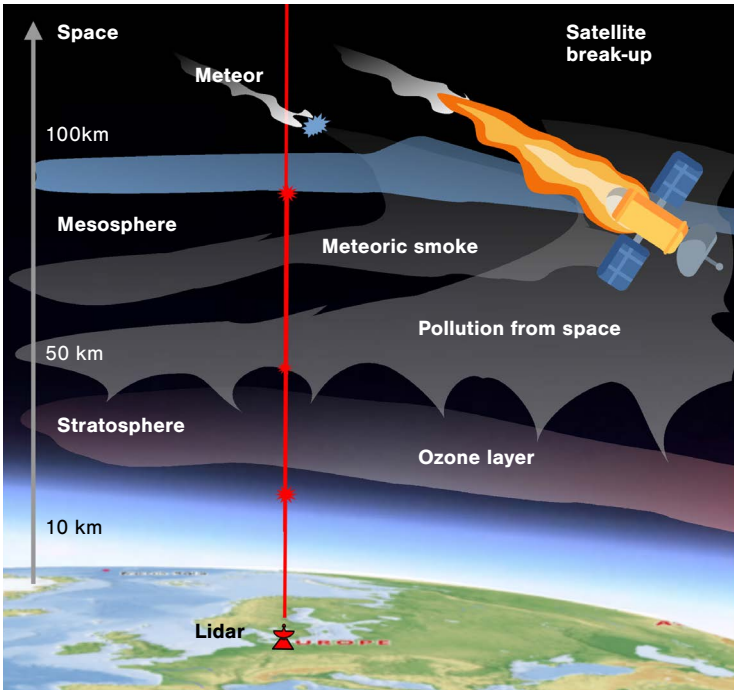
2. What was the altitude of the lithium plume?

3. What was the lithium density at the center of the plume? At the edges?

4. Look at Figure B. How tall was the plume, top to bottom, at 1:30 a.m. on February 20?

5. If the data continued recording after 2:00 a.m. on February 20, what would it likely look like?

MEASUREMENT OF POLLUTION FROM SPACE



This diagram shows different layers of the atmosphere. The breakup of meteors forms natural metal layers. But space junk can also cause pollution in the upper atmosphere that may mess with the ozone layer.

LEACHING LITHIUM

FIGURE A

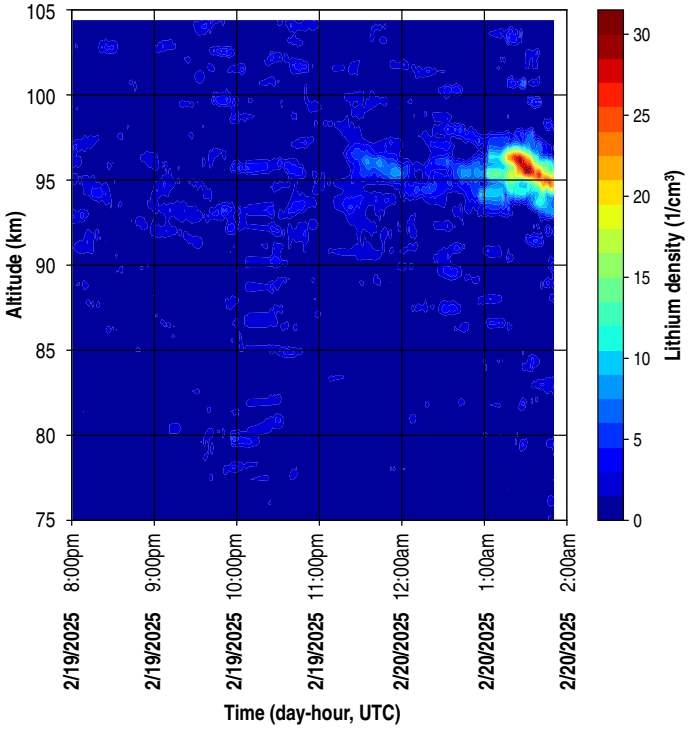
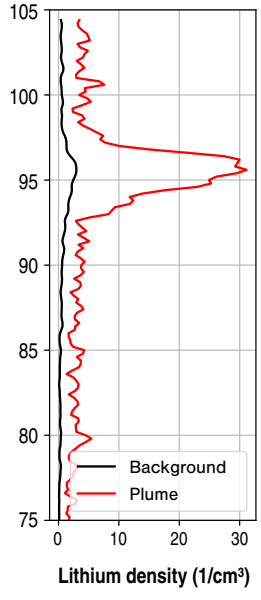


FIGURE B



Using a technique called lidar, researchers in northern Germany caught a burst of lithium in the upper atmosphere. The lithium came from a piece of a Falcon 9 rocket. Carried by the wind, the lithium spread from one point to a wider area. This type of spread is called a plume. The figure on the left is a heat map. It shows the density of lithium (per cubic centimeter) at different altitudes over time in time (shown in local German time). The plot on the right shows the lithium density at different altitudes at 1:30 a.m. on February 20, 2025. The amount of lithium is higher in the center of the plume and lower at the plume's edges.

R. WING ET AL/COMMUNICATIONS EARTH & ENVIRONMENT 2026

Saturn's extremely porous moon Hyperion is only about half as dense as water.

ANSWER

A collision could explain Saturn's weird moon Hyperion

The ancient smashup may also have spawned the planet's rings

A two-moon pileup about 400 million years ago could have formed Saturn's spongy-looking moon Hyperion. The chaos following the collision could have also formed the planet's rings.

Clues about this collision came from NASA's Cassini spacecraft. While orbiting Saturn from 2004 to 2017, it watched the wobble of the planet's spin.

Those data hint "there was some disruption in the outer Saturn system," says Matija Ćuk. He's a planetary scientist at the SETI Institute in Mountain View, Calif.

Computer models showed Ćuk and his colleagues how this disruption could have happened. First, a moon that no longer exists collided with Saturn's biggest moon, Titan. Debris from the wreckage could have clumped together to form Hyperion. This odd, egg-shaped moon tumbles chaotically through space.

The collision might also have caused Titan's orbit to slowly widen. The massive moon's gravity could have triggered moons closer to Saturn to collide and grind each other down into rings.

Ćuk's team proposed this scenario in a paper posted to arXiv.org. But more detailed models of Saturn are needed to confirm this is what happened.

— *Lisa Grossman*

Saturn's strange moon Hyperion, photographed by NASA's Cassini spacecraft in 2005, might be the debris of an ancient lunar smashup.

SPACE SCIENCE INSTITUTE/JPL-CALTECH/NASA

INSIDE THE MIND OF A YOUNG SCIENTIST

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

Science competitions can be fun and rewarding. But what goes on in the mind of one of these young scientists? Khushi Karthikeyan, a finalist at the 2026 Regeneron Science Talent Search, shares their experience.

Q What was your favorite part of your research project?

A "I was actually able to make my own contributions toward the field that has so long fascinated me," Khushi says. Their research showed that huge stars from the early universe can collapse into intermediate-mass black holes. When these medium-size black holes collide, a supermassive black hole can form. Khushi's results hint that today's supermassive black holes could trace their origins back to these giant, ancient stars. "I've so long learned from [black hole research] and loved to learn from it. And now I can kind of give back to it."

Q What were your most important resources?

A "My mentors," Khushi says. "I would not have been able to do it without them." Khushi found their research mentors by emailing dozens of scientists. "My [main] mentor was one of the few people who actually responded," Khushi says. If at first you struggle to find a mentor, they say, "don't lose hope."

Q Any other advice for research newbies?

A "Start small," Khushi says. "You're not trying to cure cancer on your first project. The goal is to make your own contribution to [a field you care about]. You don't need to try something way too enormous, because if you do that, you're likely going to be faced with disappointment. ... If it's achievable and you're passionate about it, you will go far."

Regeneron Science Talent Search finalist

Khushi Karthikeyan

Khushi Karthikeyan, 18, ran computer models of huge stars in the early universe. The simulations showed that these stars could indeed collapse into intermediate-mass black holes at the ends of their lives. Khushi attended Ardsley High School in Ardsley, N.Y.

Learn more about the Regeneron Science Talent Search

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