Science News for Students

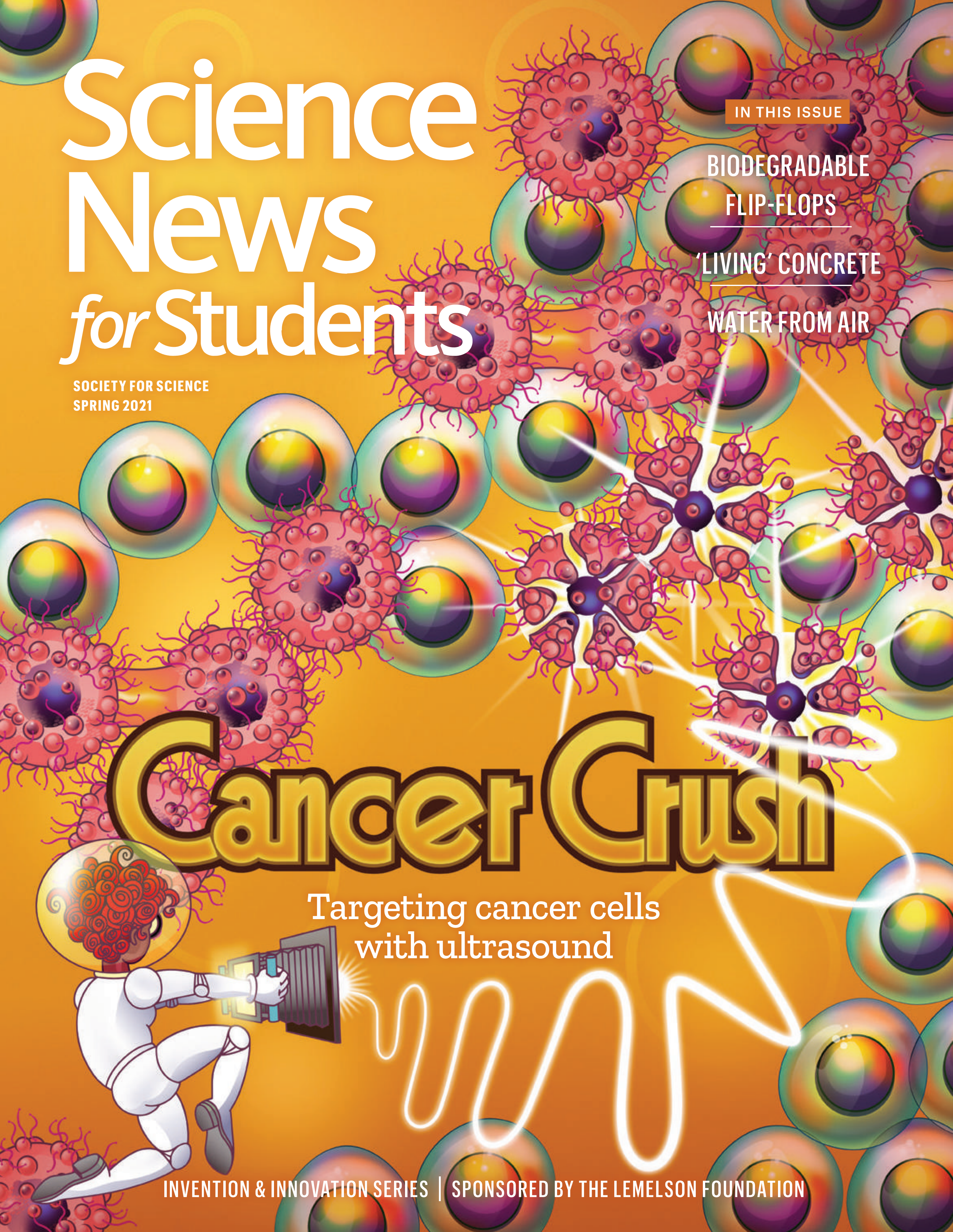
SOCIETY FOR SCIENCE
SPRING 2021

IN THIS ISSUE

BIODEGRADABLE FLIP-FLOPS

'LIVING' CONCRETE

WATER FROM AIR



Cancer Crush

Targeting cancer cells with ultrasound

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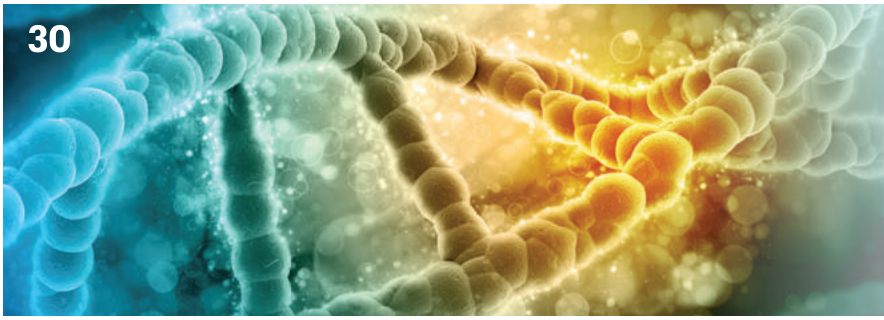
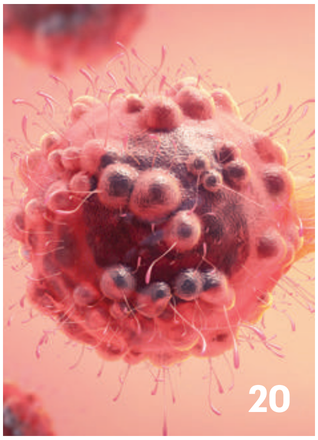
Science News for Students

CONTENTS





CLOCKWISE: DENNIS SCHROEDER/NREL; KIRSTYPARGETER/ISTOCKPHOTO; CHRISTOPH BURGSTEDT/ISTOCK/GETTY IMAGES PLUS; COLLEGE OF ENGINEERING AND APPLIED SCIENCE AT UNIVERSITY OF COLORADO BOULDER ; EMPA

JIM WEBB

Innovation tackles a world of new challenges

Most people will remember 2020 as the year a coronavirus emerged and spread like wildfire across the planet. While persistent, widespread concerns about this COVID-19 pandemic dominated headlines, important and clever research on plenty of other topics debuted throughout the year, as well. *Science News for Students* covered many of those developments, including the 18 innovations reported here.

Read about tree-powered forest-fire alarms and artificial skin that can "feel." Silk is becoming a new source for body implants, and bacteria could form the basis of a new "living" concrete for builders. Some scientists have found a way to turn trash into a cool raw material known as graphene. Others are working to cloak sound by giving some construction materials a new twist — literally. For people interested in medicine, there are new technologies to kill cancer with ultrasound and to administer medicines with painfree microbarbs. New studies in mice show it may soon be possible to edit our genes to treat or lower someone's risk of obesity. Engineers even unveiled new ways to get life-saving oxygen to patients with COVID-19 or other diseases. And if you wear flip-flops, you may enjoy the news on efforts to at last make these rubbery sandals biodegradable.

Dive into these stories and more, together with explainers that allow you to explore the science behind some of the new inventions. And for fun, check out this year's crossword puzzle based on terms found in the stories. — *Janet Raloff*

100 SOCIETY FOR SCIENCE CELEBRATING A CENTURY

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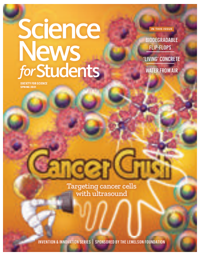
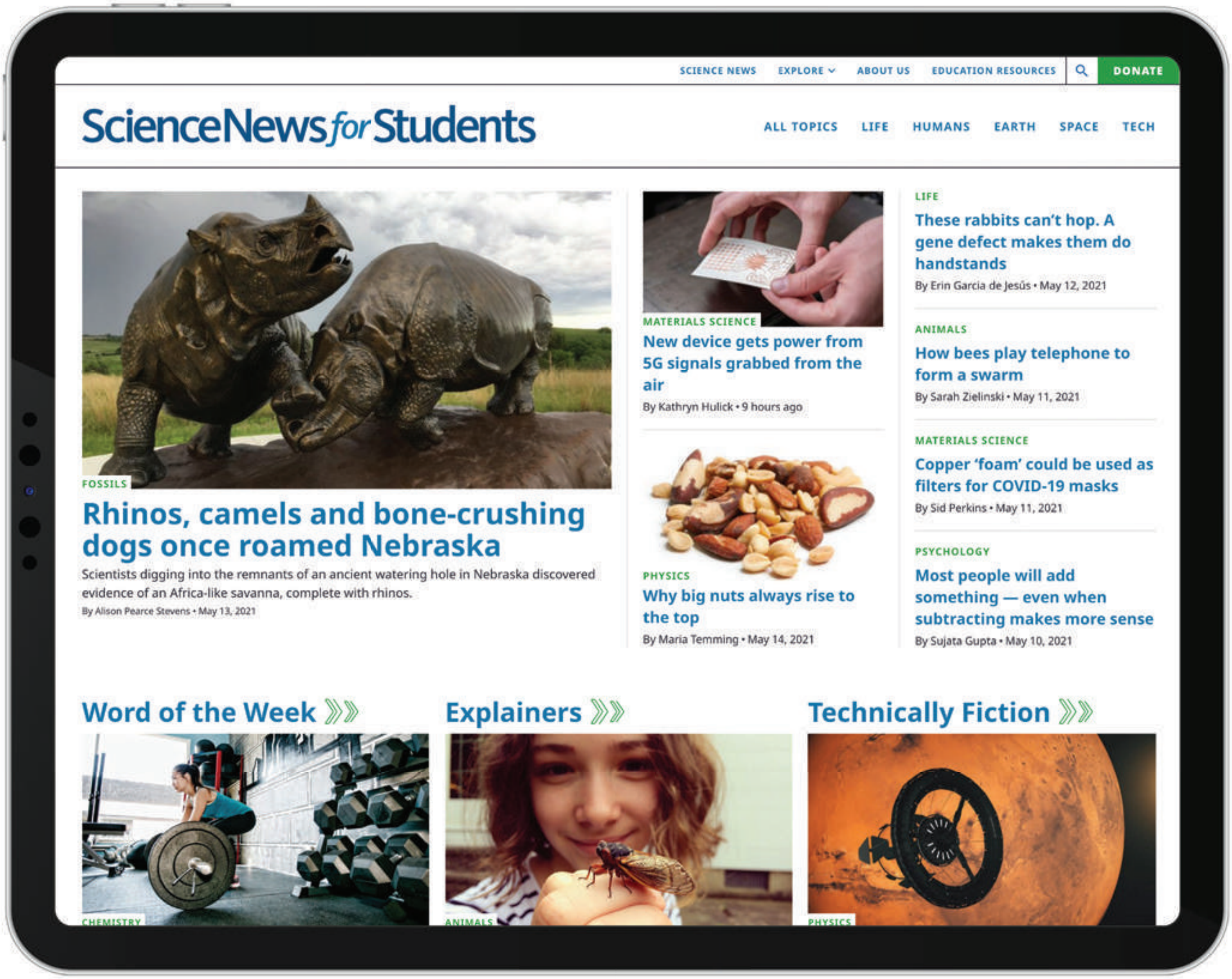


ON THE COVER: Despite this fanciful image, quashing cancer with ultrasound is not science fiction. It already works on cells, and hopefully will scale up to treat people, too. *Illustration by Stephen Egts*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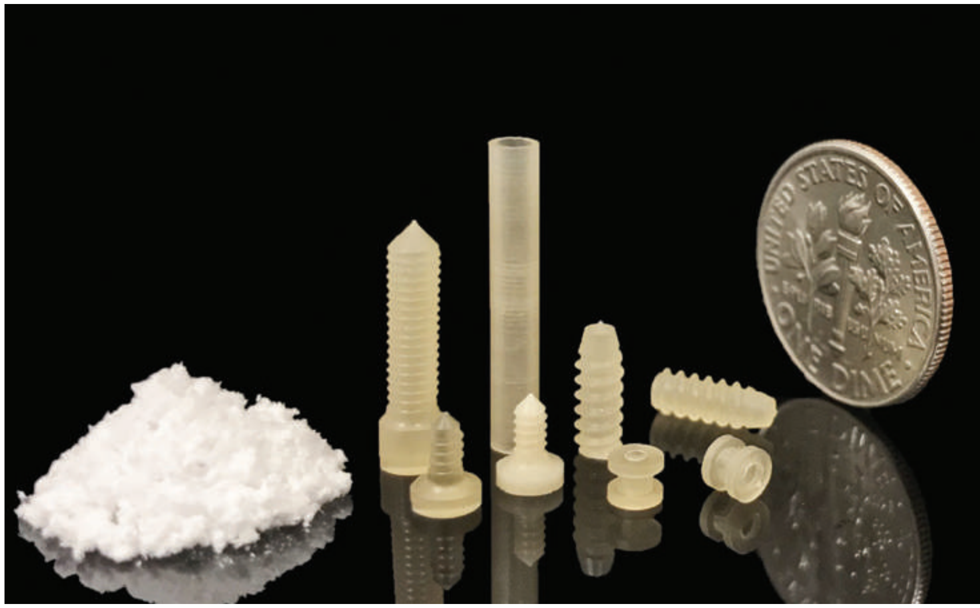
By Kathryn Hulick • 9 hours ago
PHYSICS
Why big nuts always rise to the top
By Maria Temming • May 14, 2021
LIFE
These rabbits can't hop. A gene defect makes them do handstands
By Erin Garcia de Jesús • May 12, 2021
ANIMALS
How bees play telephone to form a swarm
By Sarah Zielinski • May 11, 2021
MATERIALS SCIENCE
Copper 'foam' could be used as filters for COVID-19 masks
By Sid Perkins • May 11, 2021
PSYCHOLOGY
Most people will add something — even when subtracting makes more sense
By Sujata Gupta • May 10, 2021
Word of the Week
Explainers
Technically Fiction

Silk can be molded into strong medical implants

The trick is to first freeze-dry it and turn it into a powder

By Kathiann Kowalski



The powdered cocoons of the silkworm (left) need considerable processing before their proteins can be molded at high pressure and temperature into medical implants (center) for use in the human body.

CHUNMEI LI AND DAVID KAPLAN/TUFTS UNIVERSITY

Silk is a marvelous material with a long history and many uses. People have been weaving silk fabrics for more than 5,000 years. Doctors have been using the material to sew wounds shut for more than 1,800 years. Now, biomedical engineers are using silk to make medical implants. A new approach will make it much easier and cheaper for innovators to build such devices.

Many sorts of animals produce silk. The type most useful to people comes from what are often called silkworms. They're actually the caterpillars of the domestic silk moth, *Bombyx mori*. Each caterpillar spins a cocoon before it becomes a pupa. That cocoon is woven from a silk fiber hundreds of meters (yards) long.

Doctors like silk for a variety of reasons, says David Kaplan. He's a biomedical engineer at Tufts University in Bedford, Mass. For one thing, silk is a natural material that will break down in the body over time. So any implanted parts made of silk don't have to be removed by surgery. Plus, few people are allergic to it. That makes it generally safe to implant parts made of silk.

One problem, though, is that the materials used to make silk parts don't have a long shelf life, says Kaplan. Those materials are made of proteins called silk fibroin. They are what's left behind when chemists remove a gummy substance from silk fibers. Silk proteins are typically kept dissolved in water until needed. But like all proteins, they can break down over time.

Another problem: All that water adds a lot of weight and volume to silk materials as they're stored. And that makes them expensive to ship.

Kaplan and his colleagues set out to solve those problems. They began by removing the gummy material from silk fibers. Then they dissolved the silk proteins in a solution with high levels of a salt called lithium bromide. Next they added water to dilute the mix. Then they froze it with liquid nitrogen. Afterward, they put the icy mix into a chamber where the air pressure was very low. That combination of very low temperature and pressure triggered water to evaporate.

Finally, the researchers ground this freeze-dried material into a powder. Its particles measured between 30 nanometers (a little over one-millionth of an inch) and 1 micrometer (40 millionths of an inch) across.

"This is a totally different way of processing silk," says Chris Holland. He's a scientist who works with natural materials at the University of Sheffield in England. He did not take part in the new research.

Kaplan and his team found they could mold really strong parts from the silk powder. They shaped the parts at high pressure, more than 6,400 kilograms per square centimeter (some 91,000 pounds per square inch). They also tested different heating temperatures. The silk parts were strongest when molded at a temperature of 145° Celsius (293° Fahrenheit). These powdered-silk parts were stronger than ones made the previous way, with dissolved silk proteins. They were even stronger than wood.

Kaplan and his team reported their development in the January 2020 *Nature Materials*.

Powdered silk is chemically stable and lightweight because a lot of the water has been removed.

Many different sorts of medical implants can be made from powdered silk, notes Kaplan. That includes screws used to hold a broken bone together. It also includes small tubes used to drain fluid buildup from an infected ear.

Scientists describe as "biocompatible" any materials that can be used in the body without causing harm. "The fact that [powdered silk] is biocompatible is the icing on the cake," says Holland. And that suggests to him another possible use: embedding the molded implants with drugs (such as infection-fighting antibiotics or cancer drugs). The implants could slowly release a drug over time. That way, patients might not need to take pills or get painful injections. ✖

Self-powered surface may evaluate table-tennis play

Engineers have used wood to create self-powered sensors that track the ball

By Stephen Ornes

Zhong Lin Wang started playing table tennis only five years ago. But two years ago he and other researchers came up with a clever way to up their game: Build a smart table.

Their new prototype can measure where a ball lands, how fast the ball's going and where it's headed. It can do this because its surface forms the top layer of a novel self-powered sensor. The data it acquires could guide players to perform better.

Wang is a materials scientist at the Georgia Institute of Technology, in Atlanta. He's an expert at inventing devices that provide their own power. In 2012, he invented a *triboelectric nano generator*. He calls it TENG, for short. You know "triboelectricity" by its more common name — static electricity.

Over the years, Wang has worked with researchers to build many devices using TENGs. What makes the new game table truly unique is its use of wood as the source of one of the TENG's layers.

Lignin is the stuff that makes wood and other plants rigid and hard. But after boiling in chemicals, this lignin now flexes and bends easily. Squares of it become the top layer of a TENG. Beneath it, Wang's team added a layer of copper to conduct electricity. They attached that layer to a copper wire.

As a ball strikes the table's TENG surface, the top layer pushes against the copper layer. Electrons accumulate. When the surface bends back to its original position, a small amount of electric current travels through the wire. In lab tests, the engineers showed that a grid made of wood TENGs could be used to measure where the ball hit, how fast it was going and the angle it was traveling. Table-tennis players can use such data to learn more about their game and how to play better, says Wang. (Fact: He's been using it to improve his own technique.) Importantly, the new smart table won't need a battery to detect the ball.

Wang's team published its findings on the innovative sensors November 26, 2019, in *Nature Communications*. ✖

JONATHAN STOREY/GETTY IMAGES PLUS; ANGELO D'AMICO/ISTOCK/GETTY IMAGES PLUS

Can a smart surface up your table-tennis performance? Engineers at Georgia Tech have built a self-powered one that tracks your plays — no batteries or power cord required.

Explainer
What are polymers?

Polymers are everywhere. Just look around. Your plastic water bottle. The silicone rubber tips on your phone's earbuds. The nylon and polyester in your jacket or sneakers. The rubber in the tires on the family car. Now take a look in the mirror. Many proteins in your body are polymers, too. Consider keratin, the stuff your hair and nails are made from. Even the DNA in your cells is a polymer.

By definition, polymers are large molecules made by bonding (chemically linking) a series of building blocks. The word polymer comes from the Greek words for "many parts." Each of those parts is what scientists call a monomer (which in Greek means "one part"). Think of a polymer as a chain, with each of its links a monomer. Those monomers can be simple — just an atom or two or three — or they might be complicated ring-shaped structures containing a dozen or more atoms.

In an artificial polymer, each of the chain's links will often be identical to its neighbors. But in proteins, DNA and other natural polymers, links in the chain often differ from their neighbors. *—Sid Perkins*

Here, electrical energy is being routed into a batch of carbon, reformulating almost all of the bonds between carbon atoms at once, to make graphene. The excess energy appears as the visible flash.

JEFF FITLOW/RICE UNIVERSITY

Converting trash to valuable graphene in a flash

This so-called flash graphene can strengthen other materials — and fight climate change

By Alison Pearce Stevens

Plastic, food wastes, tires and coal all have one thing in common: They contain lots of carbon. When those items break down or burn, they release that carbon into the air as carbon dioxide or methane. Those heat-trapping gases contribute to a warming of Earth's atmosphere. But scientists in Texas have discovered a way to convert anything with carbon — even trash — into graphene. This keeps carbon out of the atmosphere. In fact, adding graphene to other materials can make them "greener."

Graphene consists of a flat layer of carbon atoms just one-atom thick. Each atom bonds to three other carbon atoms. This creates a honeycomb-like grid. A single sheet of graphene is the thinnest material on Earth. It's also the strongest.

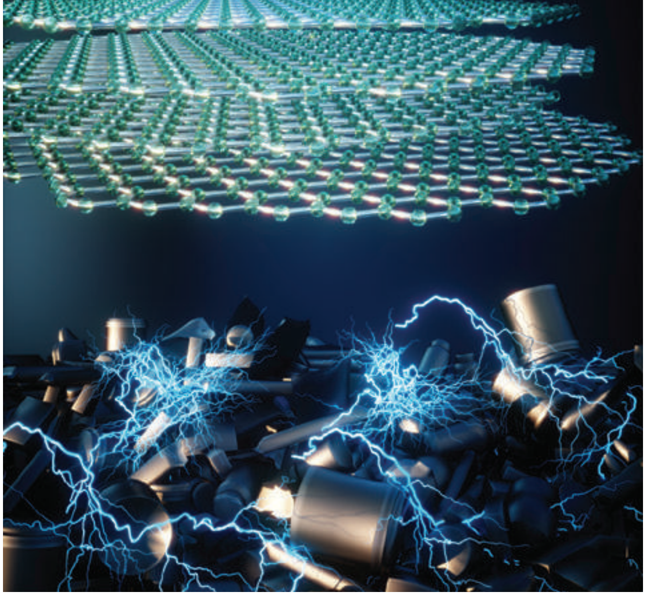
Scientists have been testing graphene for use in all types of materials. And although graphene has huge potential, it faces some problems. It's hard to make more than just a tiny amount at one time. The usual methods also tend to create multiple layers of graphene that are tough to separate. And the end product can be quite costly — up to $200,000 per ton. That's why chemists have been searching for a cheap way to make large amounts of single-layer graphene.

Chemist James Tour is a nanotechnology specialist at Rice University in Houston, Texas. He works with physicist Duy Luong. Luong had used a laser to make graphene before. He zapped carbon-rich materials to rapidly — and briefly — heat them. That heat caused carbon atoms to morph into layers of graphene. Luong quickly found that "Anything [with carbon] can be converted into graphene if it is heated up hot enough and fast enough." That was an important first step.

He then turned to findings from another lab. It had used a process called flash joule heating to create nanoparticles. (A joule is a unit of energy.) This flash process superheated materials with electricity, not a laser. That got Luong wondering: Could flash joule heating turn everyday wastes into graphene? To find out, he ran tests.

Luong started with a very-carbon-rich material called carbon black. It's what's left behind after burning wood or thick petroleum. Luong placed some powdered carbon black inside a tube made from quartz. Then he stuffed copper wool into each end to press the powder together. He poked brass screws into each end of the tube. These acted as the electrodes of a capacitor. (That's a battery-like device.) The electrodes were connected to the rest of the setup. This safely supplied power.

When Luong flipped the switch to turn on the electricity, the carbon black flashed a blinding white. Inside the flashed tubes he found graphene. Even more exciting: It didn't have lots of tightly stacked layers. The many layers were arranged loosely and separated with ease.



This artist illustration shows graphene sheets (above in blue-green), a valuable resource, that form when flash-joule technology heats a carbon-rich material quickly and to very high temperatures.

Would flash joule heating make graphene out of anything with carbon in it? To find out, Luong tested the setup with coal and coffee grounds. Both tests converted 80 to 90 percent of the carbon into pure graphene. Non-carbon atoms simply vaporized at the high temperature, Luong says.

How black can become the new 'green'

Luong believes this flash graphene could have a huge impact on how we make things. It "can be put back into plastic," Luong says. That would strengthen the plastic, cutting how much would be needed for any application. To test this, he and his coworkers added a bit of flash graphene to a plastic polymer. It more than doubled the strength of the polymer. And that was when the added graphene made up only a tenth of a percent of the polymer.

They added even less graphene to cement — just a twentieth of a percent by weight. After letting the cement cure for 28 days, it now was at least 25 percent stronger than graphene-free cement. In all of these products, adding graphene would reduce the overall amount of plastic or cement that would be needed for some application.

What's more, adding graphene to products traps carbon atoms in these solid objects. Left to decompose, trash and recycled goods break down into methane or carbon dioxide. Both act as greenhouse gases. By trapping the sun's heat close to the ground, those gases work to warm Earth's climate. Adding graphene — especially that made from trash — to new materials should cut greenhouse-gas releases and help slow that rate of warming. The team published its findings on January 27, 2020 in *Nature*.

This innovation could work like King Midas's golden touch, says Zhiwei Peng. He's a graphene researcher at the University of Maryland in College Park who was not involved in the new study. "In the blink of an eye," he says, you can turn "used plastic wastes and discarded food into 'black gold' — graphene." And all it would cost to make a single gram is enough energy to light a 60-watt bulb for two minutes, he says. ✖

ROUZBEH SHAHSAVARI/C-CRETE GROUP; THEERAPONG28/ISTOCKPHOTO

Explainer
CO_2 and other greenhouse gases

Carbon dioxide is just one of several chemicals that contribute to the greenhouse effect

Many different gases make up Earth's atmosphere. Nitrogen alone accounts for 78 percent. Oxygen, in second place, makes up another 21 percent. Many other gases comprise the remaining 1 percent. Several (such as helium and krypton) are chemically inert. That means they don't react with others. Other bit players have the ability to act like a blanket for the planet. These have come to be known as greenhouse gases.

Like windows in a greenhouse, these gases trap energy from the sun as heat. Without their role in this greenhouse effect, Earth would be quite frosty. Global temperatures would average around -18° Celsius (0° Fahrenheit), according to the National Oceanic and Atmospheric Administration (NOAA). Instead, the surface of our planet averages around 15 °C (59 °F), making it a comfy place for life.

Since about 1850, though, human activities have been releasing extra greenhouse gases into the air. This has slowly propelled a rise in average temperatures across the globe. Overall, the 2017 global average was 0.9 degree C (1.6 degrees F) higher than it had been between 1951 and 1980. That's based on calculations by NASA.

Not all greenhouse gases trap the same amount of heat per molecule. The best known of these gases is carbon dioxide, or CO_2. Humans have the most direct control over it and three others: methane, nitrous oxide and a group that contains chlorofluorocarbon refrigerants (and their replacements). *—Sarah Zielinski*

This ‘living’ concrete slurps up a greenhouse gas

Growing microbes make more of the needed raw materials

By Carolyn Wilke

A structure made of a new “living” concrete sits next to vials of green, photosynthesizing bacteria in a lab.

COLLEGE OF ENGINEERING AND APPLIED SCIENCE AT UNIVERSITY OF COLORADO BOULDER

While the look of buildings may impress, the materials that make up houses, schools and skyscrapers mostly just sit around. They may seem boring, actually. But scientists are now designing new building materials that respond to the environment and might even help improve it. One example: “living” concrete.

Bacteria inside it help form the material and make more of it. In the process, this concrete sucks a greenhouse gas out of the air and stores it. That would be good for the environment.

The researchers reported their work in the February 5, 2020 *Matter*.

Concrete is made of sand or rocks plus binders — such as cement — that hold it all together. Billions of cubic meters (cubic yards) of concrete are produced every year. That makes it one of the most common building materials. But all of that concrete comes at an environmental cost. Making it releases a lot of carbon dioxide (CO_2).

CO_2 is a potent, heat-trapping greenhouse gas. Most people know that the burning of fossil fuels spews a lot of this gas. So does making cement, including that used in concrete. Cement accounts for more than one-twelfth of all CO_2 released into the air each year.

Stayin’ alive

Bacteria help make the new concrete in a different way. These microbes pull CO_2 out of the air and use it to grow. In the process, they make a mineral that helps toughen the new concrete, notes Wil Srubar. He is a materials scientist at the University of Colorado Boulder. He’s also part of the team that developed the concrete. The green-colored bacteria they use make for environmentally better concrete that is literally green, Srubar says.

His team mixes the microbes together with sand and gelatin. Then they add nutrients, such as calcium. The researchers chose cyanobacteria for their microbes. These are like the bacteria or green algae that grow in a fish tank, Srubar explains. They thrive on CO_2, using it and light to make the sugars that fuel their growth. That process is known as photosynthesis.

As they photosynthesize, the microbes suck CO_2 out of the air. So this process is “not releasing carbon. It’s storing carbon in the materials,” explains Anne Meyer. As a synthetic biologist, she engineers bacteria to make materials. She works at the University of Rochester in New York and was not involved with this study.

As the bacteria photosynthesize, they increase the pH of the mixture. This more alkaline environment causes little crystals of calcium carbonate to form. Calcium carbonate is an important ingredient in cement. Those bits make the new concrete tougher once it is shaped into bricks and cooled. Cooling the mixture also hardens the gelatin, similar to the process that solidifies jiggly desserts in the kitchen.

If the microbes can survive in the hardened concrete, Srubar’s team thought they might help make material for new bricks. To test the idea, they split a block and melted its pieces. They added more nutrients to the mix — and the bacteria grew. With additional sand, the mix had enough organisms to build two new concrete blocks.

The team then molded this mix into a new pair of blocks. By splitting, melting and growing three times, they made eight great-grandkid bricks using offspring of the original microbes. Since the growing bacteria help produce the material, this concrete could be made where it would be used, Srubar points out.

“It’s such a great approach,” says Meyer. “All of their techniques are so easy.” This could put the means of making building materials into the hands of non-experts, she says.

Real world limitations

This approach won’t put an end to regular concrete, however, at least not yet. “You have to be careful about contamination,” Meyer says. Srubar’s

group worked in a lab where contamination is easy to avoid. In the real world, other microbes might get into the mix. If those microbes grow faster than the cyanobacteria, they could take over, she says. Those other microbes might prove harmful. Or they might change properties of the concrete. For instance, they might not help store carbon or grow to help make new materials.

These bacteria need certain conditions to stay alive. They won't survive well where it's dry. Meyer also suspects that these microbes wouldn't fare very well during the snowy, cold winters of her town of Rochester, N.Y. Such building materials may only work in places that are warm and humid all year.

That's why Sarah Glaven suspects that "living building materials are not going to replace our existing building materials anytime soon." Glaven is a biologist at the Naval Research Laboratory in Washington, D.C., and was not involved in this study.

Still, she is excited about how biology might someday play a role in engineering our buildings. "Bacteria are everywhere," she notes. "If we make them happy, then they may help to repair our materials or reuse those materials." ✖

RIDDISH MORDE

Micro-barbs could make shots less painful

The devices help drug-delivering needles give shallower shots

By Stephen Ornes

Getting a shot is no fun. "I hate them, and everyone hates them," says Howon Lee. But they're an effective way to deliver protective vaccines and medicines. So this engineer at Rutgers University in Piscataway, N.J., has helped develop a new type that can barely be felt.

The idea is to deliver a liquid drug, but with a needle so small it doesn't sting. A microneedle pokes into the skin just a fraction as deeply as an ordinary needle. But most such devices are so smooth, notes Lee, that they slide out before they deliver a full dose. To keep those needles in place longer, his team added backward-facing barbs.

His group described its innovation March 10, 2020 in *Advanced Functional Materials*.

Lee began working on the project in 2016 with engineer Giuseppe Barillaro at the University of Pisa, in Italy. Barillaro had been working on microneedles for years. And Lee had experience with 3-D printing.

The engineers used a kind of 3-D printing to create the new microneedles. 3-D printing involves making an object by building it up, layer by layer. For the "ink" in their printer, the researchers used a special solution that combines a material called a polymer with a light-absorbing chemical. This mixture cures, hardens and becomes strong when exposed to ultraviolet light. They made a layer, cured it, then added the next layer. They repeated these steps over and over to build the whole object.

To make the microneedle's barbs, they applied a thick layer of the ink that doesn't solidify evenly. Its surface becomes uneven or curved. On exposure to ultraviolet light, the resulting barbs curved downward.

"Barbs" may sound painful, but don't worry. They stick out only about 450 micrometers (0.02 inch). That's about the thickness of a pinkie nail. Yet they anchor the device in the skin. ✖

The tiny barbs on these needles anchor the device to skin. That allows the needles to deliver shots at a fraction of the depth of ordinary ones.

This artificial skin feels ghosts — things you wish were there

Stretching fabric across skin makes the brain think you're touching distant surfaces

By Stephen Ornes

Long-distance communication may benefit from a robot's touch. And that may come in the form of a new gadget developed by engineers in Australia.

Haptic is a term for things that relate to one's sense of touch. The new haptic device slips over someone's finger like the tip of a glove. And it lets people feel something that isn't actually at their fingertips.

Its inventors see a variety of potential uses. "A surgeon can wear our gloves and touch a patient far away," says Thanh Nho Do. He's an engineer at the University of New South Wales in Australia who led the design of the new device. "In the deep sea or in space, a robot can pick up things. This can let you feel [what the robot touches]. When a person has an artificial limb, they can wear this and feel [what it touches]."

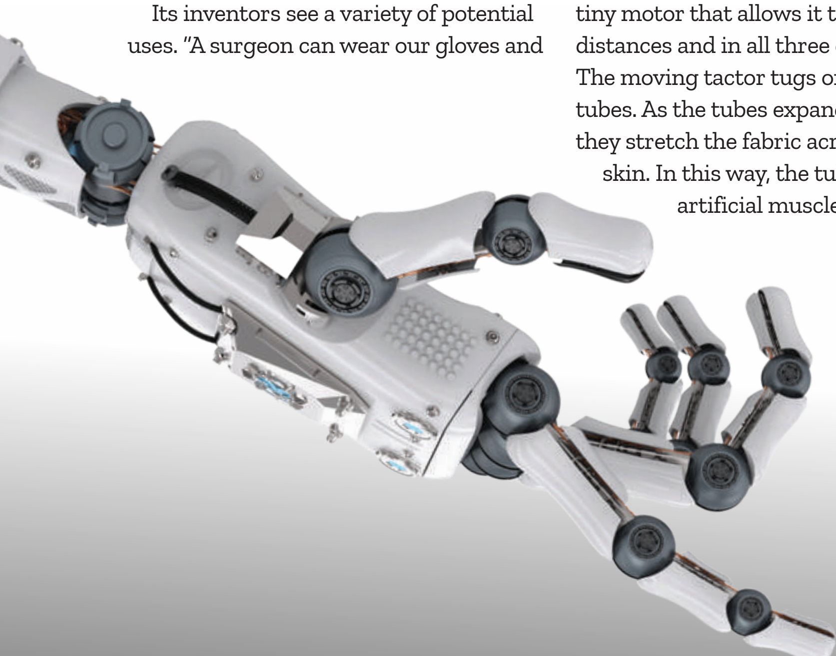
Scientists have been working on haptic devices for years, but the sense of touch is hard to share, Do says. It's unlike vision, which can be communicated over distances with cameras and monitors. It's also unlike hearing, where sounds can be relayed to the ears with microphones and speakers.

Do's group realized the brain gets haptic information when something moves across the skin. With that idea in mind, they wanted to design something that could slide and stretch.

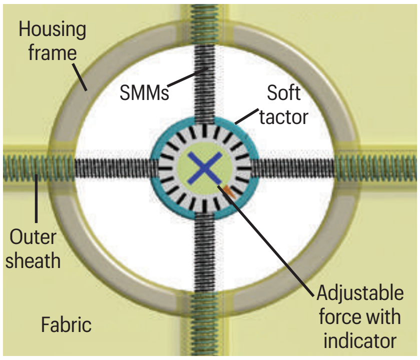
Their device is made from a piece of fabric into which tiny, fluid-filled tubes have been sewn. Those tubes all connect to a small disk, called a tactor. It has a tiny motor that allows it to move short distances and in all three dimensions. The moving tactor tugs on the tiny tubes. As the tubes expand and contract, they stretch the fabric across someone's skin. In this way, the tubes act like artificial muscles.

Do says he was inspired to work on this skin stretch device, or SSD, after spending many years working on surgical robots. One day, a doctor asked him: When will I put on a glove and feel what the robot feels? Do kept that question in mind as he spent years learning about the sense of touch and haptic technology.

His group first developed the tubes that simulate muscles around 2017. They had their first test model two years later. Its tactor was about 10 millimeters (0.4 inch) across, which Do thought was still too bulky. His team's latest SSD has a tactor only 5 millimeters (0.2 inch) across and a smaller one is in the works. His team also is working on adding the ability to sense hot or cold. The researchers described their new device August 27, 2020 in *IEEE Access*. ✖



A closeup (below) of the working parts of the new "skin." SMM stands for soft microtubule muscles. These are tiny, fluid-filled tubes that stretch the fabric similarly to how muscles pull on the skin in the body.



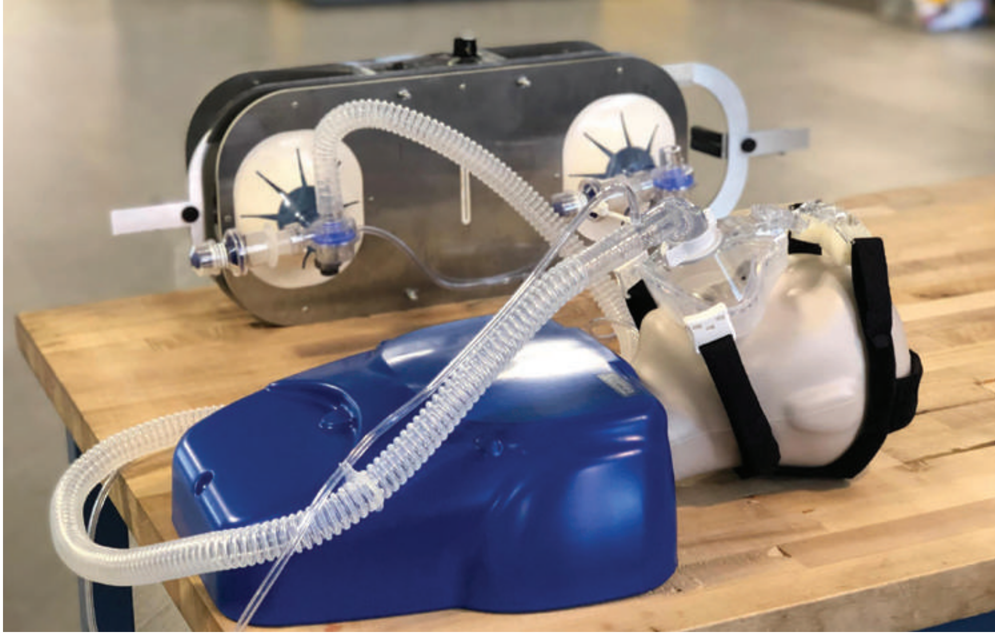
ROBOT HAND: PHONLAMAIPHOTO/ISTOCK/GETTY IMAGES PLUS; DIAGRAM AND HAND: UNSW SYDNEY

A device made from a new kind of artificial skin, shown covering a finger, simulates the sense of touch.

COVID-19 victims could breathe easier with these innovations

The low-cost technologies could help oxygen-starved patients around the world

By Kathiann Kowalski



This low-cost ventilator was designed by a U.S.-British team. At its heart are breathing bags commonly carried on ambulances.

STEVEN NORRIS/GEORGIA TECH

The coronavirus pandemic left large numbers of people gasping for air. Many patients with COVID-19 wind up needing extra oxygen. Sometimes they even need to be put on machines that breathe for them. But shortages of these ventilators developed as the pandemic first emerged in 2020. That inspired researchers to explore new low-cost ideas to help these patients breathe more easily.

Their work might help both big-city hospitals and medical centers in remote parts of the world. More importantly, what they are engineering could help patients long after the pandemic ends.

Shannon Yee is a mechanical engineer at the Georgia Institute of Technology in Atlanta. After hearing of shortages, he recalls, his team asked: "How can we design a low-cost ventilator that can be made globally?" His team and colleagues in England looked at how these machines are used. And they thought about which of their parts might be available nearly anywhere in the world.

Most ambulance crews use hand-operated "ambu bags" to help patients breathe. A machine could be added to squeeze them. And unlike a person, it could work nonstop for days.

The simple motor and mechanical system that Yee's team designed inflates and squeezes the bags. A plug-in power adapter or standard 12-volt battery runs it. Add separate tubing and volume controls and this device can breathe for two patients at once. Filters in the tubing keep each patient's exhaled air from infecting others. And the system can hook up to an oxygen supply. Kits can be packaged flat for shipping, Yee says.

Other patients might be able to breathe on their own, but not easily. Air contains 21 percent oxygen. But air can be enriched with extra oxygen so that each breath can deliver more of the life-sustaining gas.

The common process to concentrate oxygen forces air through an expensive mineral-based material called lithium X-zeolite. Only a few companies make the zeolite needed to do this. Now researchers with UniSieve in Switzerland have come up with a non-zeolite alternative.

They tweaked a filtering membrane their company had already developed. The membrane has teeny, tiny pores. It works as a filter at the molecular level, notes chemist Elia Schneider at UniSieve. To separate oxygen from the nitrogen in air, the pore diameter must be roughly one-third of a nanometer (billionth of a meter).

Using this filter, "We can supply concentrated oxygen on demand," Schneider says. It fits into a cartridge about 30 centimeters (12 inches) long and 4.5 centimeters (1.8 inches) across. A compressor squeezes air into one end. The oxygen gets filtered out and the nitrogen molecules exit into the room's air. Tubing then carries the concentrated oxygen to a patient.

> "There are numerous wonderful ideas about how to help people breathe." **—Shannon Yee**

Another new system delivers a mix of helium and oxygen. This mix is lighter than regular air, so it takes less effort to breathe it in, explains Sairam Parthasarathy. He's a lung doctor at the University of Arizona College of Medicine in Tucson.

The idea has been known for more than 40 years, he says. But helium is pricey. And patients would need a lot of the mix.

Before the pandemic, Parthasarathy had talked about the problem with Marvin Slepian. He heads the university's center for biomedical innovation. Their fix: Recycle the helium that people breathe out. But people also exhale carbon dioxide and it had to be removed.

"We ended up putting a carbon-dioxide scrubber in there," Slepian says. Scrubbers are devices used to remove materials from a gas. "It is off-the-shelf technology," he says.

"There are numerous wonderful ideas about how to help people breathe," says Yee at Georgia Tech. "It has been really encouraging to see so many people respond and so many great ideas coming out of our universities." ×

Ordinary paper turns into flexible human-powered keypad

Tapping fingers power the device, which works even after folding or a spray of water

By Kathryn Hulick

Smartphones, tablets, fitness trackers, headphones. Most of the electronic devices we use today are made of rigid metal, plastic and glass. But electronics don't have to be, says Marina Sala de Medeiros. Consider her team's new paper keypad. It has no batteries. The user's touch gives it all the power it needs to run.

"Any electronics you have — just think if you could make that out of paper," she says. Paper is cheap and plentiful. It's also flexible and lightweight.

Sala de Medeiros is an engineer at Purdue University in West Lafayette, Ind. She and her colleagues found a way to turn a sheet of ordinary paper into a simple electronic keypad. Many teams around the world are working on paper-based electronics. But this new device is the first to power itself and also repel water and dust.

You can't buy this keyboard yet. But the researchers described the new invention in the December 2020 issue of *Nano Energy*.

No single moment inspired her paper keypad, Sala de Medeiros says. Instead, she focused on devices other engineers have been working on. Then she asked herself, "What are the gaps? What can I overcome?"

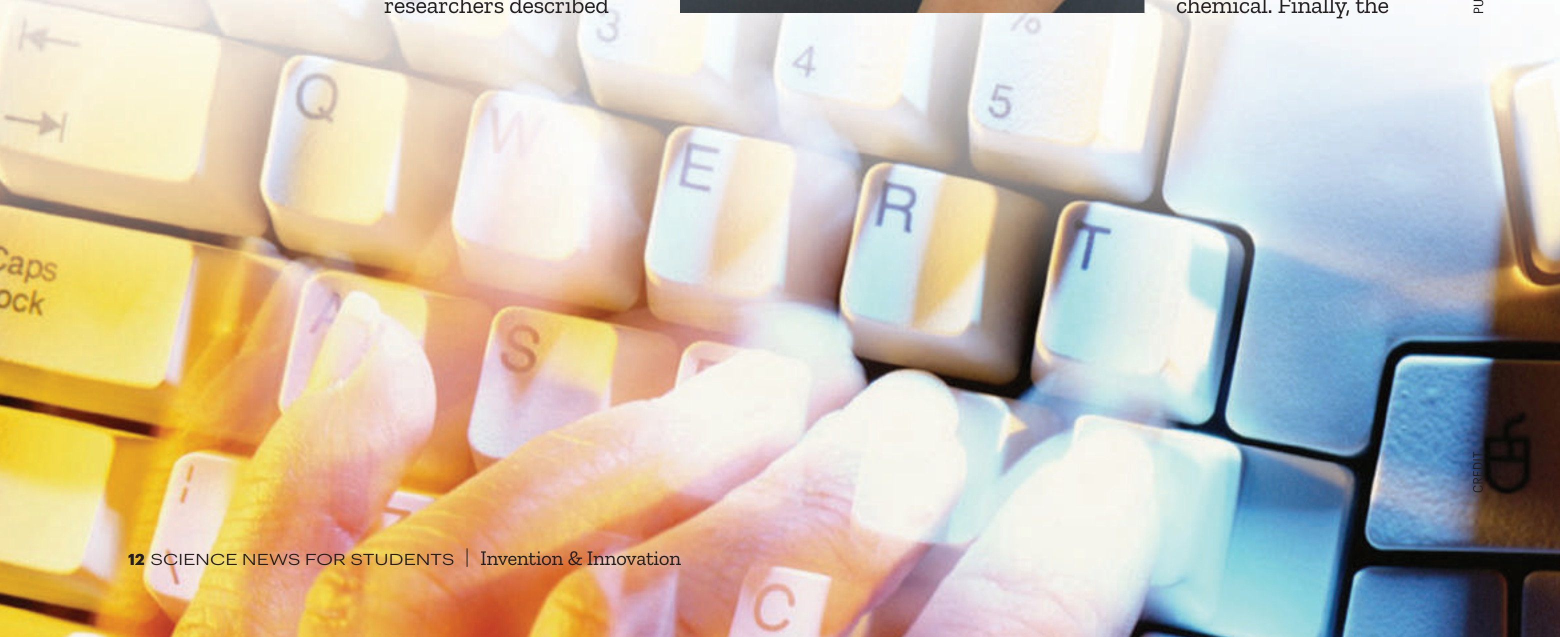
High cost was a problem for some flexible electronics. So she decided to work with low-cost materials. That would make it easier to turn her idea into something most people could afford. She recalls also wanting something that felt like regular paper but wouldn't easily get wet or dirty. It also should "fit in your pocket," she says.

Teflon is a chemical coating that keeps food from sticking to pots and pans. Similar compounds can also make paper waterproof. So she started testing some of these. With some trial and error, she found one that worked as planned. After the researchers sprayed the paper with water, the liquid beaded up on the paper's surface instead of soaking through.

The next step was to add an electronic circuit. The team placed a stencil with the shape of a circuit onto the back of the paper. Then they sprayed on several layers of materials. Two layers contained tiny nickel particles. These act like wires to carry electricity through the circuit. The final layer is another coating of the Teflon-like chemical. Finally, the

If you had a device made out of the new electronic paper, you could fold it up, stick it in your pocket and take it to the beach. It resists sand and water and it's "cheap and easy to replace," says Sala de Medeiros.

PURDUE UNIVERSITY; BELOW: GETTY IMAGES PLUS



"Any electronics you have — just think if you could make that out of paper"
—Marina Sala de Medeiros

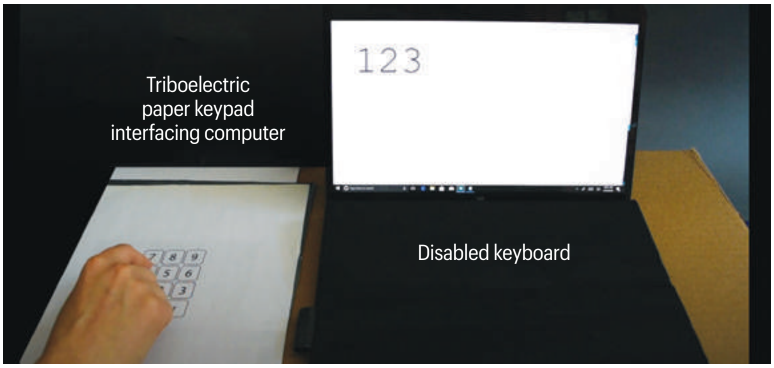
team flipped the paper over and printed a keypad of numbers on the other side. They also added a tiny Bluetooth chip. This let their paper device talk to a computer.

The circuit needs a source of electricity. That comes from the tap of a finger. The pressure of a finger tap rubs together the layers of material sprayed onto the paper. This generates a small amount of power, usually around 20 volts. That sends electricity along the printed wires to the Bluetooth chip. The chip then signals a computer, telling it which number the person had pressed. That number now shows up on the computer's monitor.

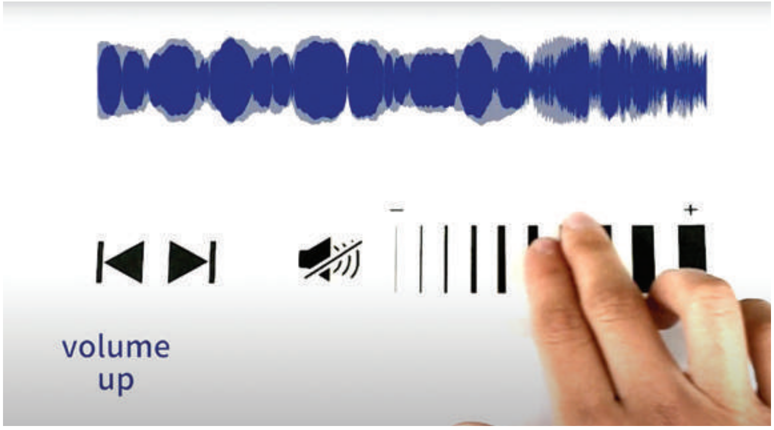
The voltage the device generates from a finger tap isn't a lot, says Manos M. Tentzeris. An electrical engineer at Georgia Institute of Technology in Atlanta, he did not take part in the research. "For simple structures like a keyboard," he observes, "it's more than enough." But for a more power-hungry device, such as a movie player, it would be nowhere near enough.

In fact, many useful devices don't require lots of power. Sala de Medeiros' team also printed a controller for a music player. Tapping arrows switches between songs. Sliding a finger along a printed bar turns the volume up or down. The music plays from a computer, not the paper.

In the near future, such paper electronics will be most useful as sensors. For example, a simple sensor printed onto money could help prevent counterfeiting. Sensors printed on packages of food or medication could detect if the product got too hot or too cold and was no longer safe to use. And one day, the researchers say, people may be able to print their own paper tablets or music players. ✖

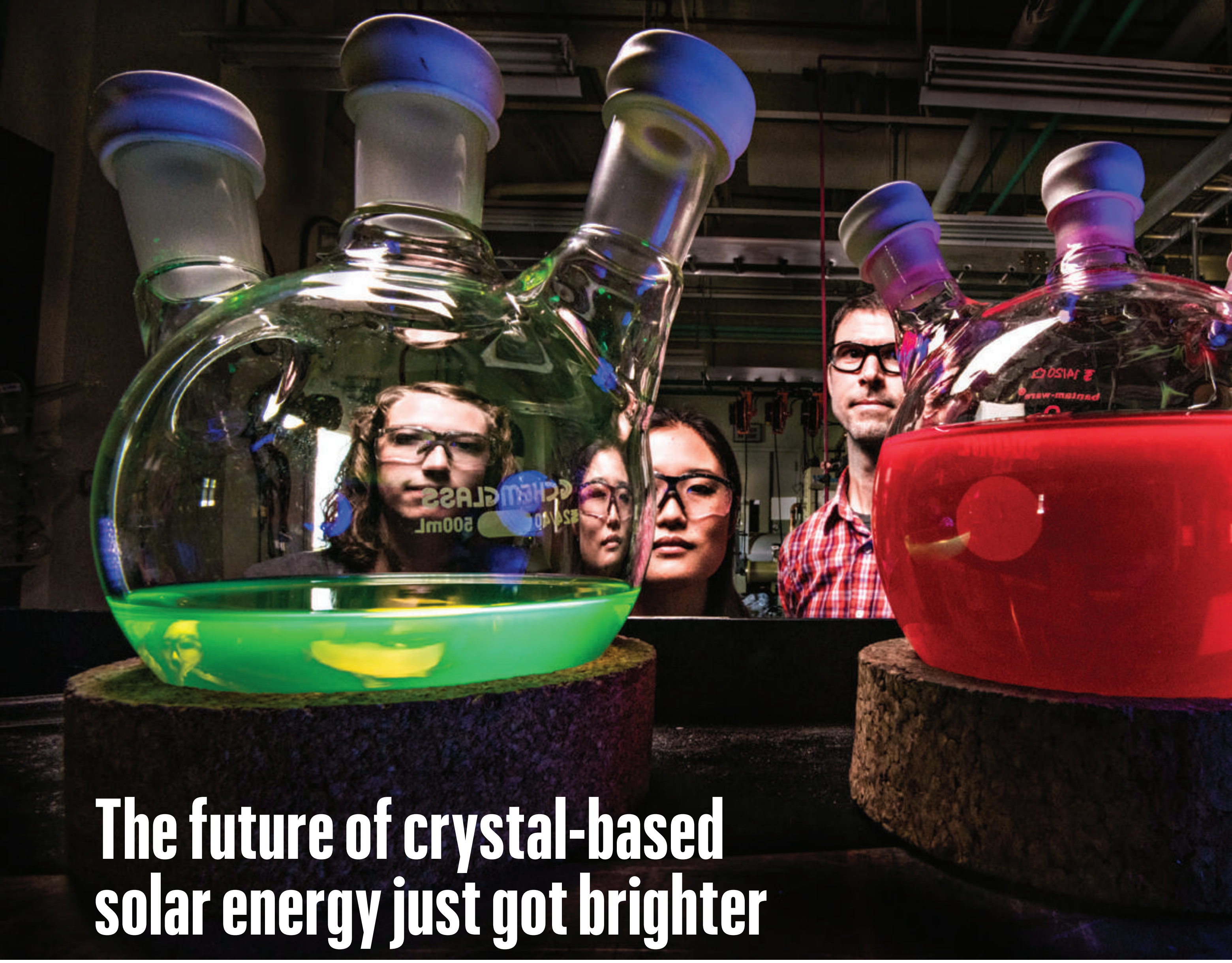


That ordinary-looking sheet of paper is actually an electronic keypad. Very thin layers of material printed onto the back of the paper detect when a number is tapped and generate enough power to send a signal to a nearby computer.



To make this volume controller out of paper, Sala de Medeiros had to figure out how to generate power and transmit a signal from sliding fingers instead of the tapping fingers used on the electronic keypad. (Blue sound bar has been superimposed on the paper controller.)

PURDUE UNIVERSITY



The future of crystal-based solar energy just got brighter

Tweaks make more efficient solar cells that can be printed or painted onto anything

By Kathiann Kowalski

Two recent innovations are boosting prospects for a new type of solar-energy technology. Both rely on a somewhat unusual type of crystal. Panels made from them have been in the works for about 10 years. But those panels had lots of limitations. New tweaks to their design might now lead to better and potentially less costly solar panels.

Photovoltaic panels convert sunlight into electricity. One tweak to the materials designed for use in the new type of panel would let them tap more of the energy in sunlight. A second advance makes it easier to stack layers of this material into a sandwich. Each layer is most sensitive to different wavelengths, or portions of sunlight. Stacking the layers can harvest more incoming light.

Researchers at the National Renewable Energy Laboratory (NREL) in Golden, Colo., have been leading efforts to develop this solar technology. They unveiled new developments in October 2019 to visiting reporters.

A big industry already exists to make solar panels. Today, almost all are made from thin but rigid wafers of silicon. Silicon, the basis of sand, is cheap. Making wafers from it is not. The wafers must be made in carefully controlled conditions. And the finished product won't bend.

In contrast, the new solar panels are made with manufactured crystals called perovskites. These contain some element with properties like bromine or iodine, plus a metal and other ingredients. A liquid mixture of these can be painted or rolled onto any surface.

As the liquid quickly dries, crystals form. The crystals line up in a way that makes them work well as semiconductors — materials that sometimes conduct electricity. Yet they're much easier and quicker to make than the crystals in panels of silicon-based solar cells.

So covering sheets with these crystals might one day be as fast as printing ink onto rolling panels of paper. But instead of

DENNIS SCHROEDER/NREL

There's lots of motivation to work toward better and longer-lasting solar panels. They tend to be cleaner than fossil fuels and better for the environment.

ending up with a newspaper, you'd end up with solar panels — ones that might be as flexible as a magazine page. Or, the perovskite liquid might be painted onto a structural surface. This could turn the sun-facing wall of a building into a massive solar panel.

Designed to see more light

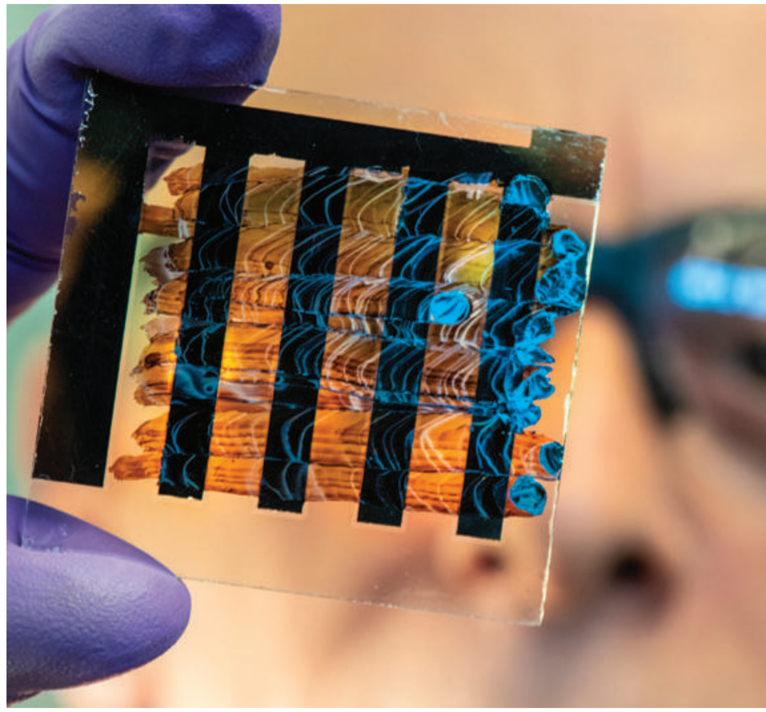
Photovoltaic materials usually work well with only certain wavelengths of sunlight. Lead-based perovskite crystals work well in the deep-red to near-infrared range.

Joe Berry is a physicist at NREL. He and others knew tin-based perovskites could produce power from lower-energy infrared wavelengths. But the solar cells weren't very efficient and broke down quickly. His team looked at where the cells were losing efficiency. The researchers found that the contact points between the crystals and other materials often develop defects.

So the team tried a number of fixes. Adding a chemical called guanidinium thiocyanate seemed to work best. Biochemists often use this chemical in the lab to protect bits of genetic material. Here, the team added it to improve the structure of crystals that touch surfaces. This tweak also let the solar cells harvest sunlight for a bit longer. Both innovations boosted the ability of the solar panels to produce electricity.

Crystal panels made with just the tweaked tin material were 20.5 percent efficient in NREL's tests. That means they harvested one-fifth of the incoming sunlight. The team also tested multi-layered solar panels. One layer was made from the improved tin-based crystals. A second, lead-based layer was most sensitive to other wavelengths of light. The two layers work together, side-by-side. This upped the panel's overall efficiency to between 23 and 25 percent. Until then, the best a tin-lead combo had been was 16 to 17 percent efficient, says David Moore. He's a materials scientist, also at NREL.

DENNIS SCHROEDER/NREL



NREL researcher shows a sample solar panel painted with a crystal-laced ink. The technique might one day make production of solar panels as fast as printing newspaper pages is today.

The NREL team shared its new data in the May 3, 2019, issue of the journal *Science*.

Divide and conquer

Most combo solar panels with the new crystals were made by pouring the solution for the top layer right over the bottom material. Often this messed up the bottom layer. To solve the problem, the researchers added a nanometer-thick divider between the two layers. (A nanometer is one billionth of a meter.)

The researchers chose a polymer — a chemical made from long chains of repeating groups of atoms. This nano-divider helped prevent damage to the bottom layer as the top perovskite layer went on. The NREL team described this fix in the September 18, 2019, issue of *Joule*.

Tweaking the recipe for the tin-based crystals gave them more time to harvest sunlight, notes Zhiqun Lin. That was "novel" and should make them more "practical," he says. A materials scientist at the Georgia Institute of Technology in Atlanta, Lin did not work on either project. He also lauds the nano-divider for overcoming that second problem in layered solar panels.

Only a few years ago, these materials would break down after a few hours. Thanks to advances, now they can last about a year. They have a long way to go, however, to match the 20-year lifetime of silicon solar panels.

But there's lots of motivation to work toward better and longer-lasting solar panels. They tend to be cleaner than fossil fuels and better for the environment. ✖

Here's how to make flip-flops biodegradable

Start with an algae-based plastic that microbes can break down

By Kathiann Kowalski

Flip-flops are great shoes for warm weather. But once discarded, they can last many years in landfills before decomposing. Old flip-flops also can break into tiny bits and add to the plastic polluting waters and soils around the world. Now researchers have invented a new type of flip-flop. Made from an algae-based plastic, it's designed to break down in soil or compost.

"I actually have a pair that I've worn for almost a year now. They're super comfortable," says Marissa Tessman. She's a chemist at Algenesis Materials in San Diego, Calif. As a graduate student, she also worked alongside the algal plastic's developers at the University of California, San Diego (UCSD).

Tessman compares different chemical formulas for plastics to recipes for cakes and cookies. By tweaking different ingredients, you can change the properties of the final product. For flip-flops, her group wanted the foam to feel right to the touch and feel comfy underfoot.

But this work all started with surfboards.

Most of those boards have a plastic core made from polyurethane. It's not biodegradable. And its ingredients come from crude oil or natural gas. Both are fossil fuels. Some years ago, a company asked the UCSD team to develop a greener surfboard, one that would biodegrade and not depend so much on fossil fuels.

Many surfers liked the idea of a greener board, Tessman explains. So the team turned to algae. Algae make lots of oils and other carbon-based chemicals. Those can be used to make compounds called polyols. These have multiple groups of linked hydrogen and oxygen atoms. And they can be used to make one of the ingredients that makes up just more than half of the polyurethane in the new flip-flops.

But one ingredient in the plastic still comes from crude oil. Teams at UCSD and elsewhere are now working to make it from algae, too.

The scientists unveiled a model of their new surfboard in 2015. Part of the team then started the company Algenesis to scale up the process. That board should go on sale soon, Tessman says.

"The chemistry behind a surfboard is actually almost identical to flip-flops," Tessman notes. "So it was a pretty natural transition to go from a surfboard to developing a flip-flop."

Designed to degrade

Things biodegrade when microbes chew up and break complex molecules into simpler ones. The microbes can then use these simpler molecules for energy and growth. Several things make these flip-flops digestible to microbes. Their foam has many pores — Swiss-cheese-like spaces inside the plastic foam. Microbes use the pores to reach more of the material and eat away at it.

The plastic's recipe also offers the microbes ingredients they find yummy. The researchers linked many parts of the molecules together with what are known as "ester groups." Those are groups of atoms. Each group contains an oxygen atom bonded to a carbon atom. And that carbon has a double bond linking it to yet another oxygen atom. The carbon atom and single-bonded oxygen atom also connect to the rest of the plastic's polymer structure.

Different microbes make enzymes that can break apart the esters' bonds, explains Natasha Gunawan. She worked on the flip-flops while a graduate student at UCSD. She's now continuing that work at Algenesis.

Last summer, she and others proved that by eating away at those esters, the

PLACEBO365/ISTOCK/GETTY IMAGES PLUS

microbes in compost and in soil can break down this algae-based plastic.

The team put blocks of the new foam in mixes of soil and compost. Those environments "are rich with microorganisms," Gunawan explains. And some of them can break apart ester bonds. The microbes can then dine on nutrients in the plastic.

The team checked the samples over time. This showed that microbes had come to feast on the foam. That foam broke down faster in the soil, clearly losing mass.

What ate the foam?

The next step was to find out which microbes were eating the plastic. The team put bits of the plastic in flasks containing a liquid. It held nutrients but no carbon. And that's important because living things need carbon for energy and growth. Then the team added a bit of material from either the soil or the compost. Every so often, researchers moved a tiny bit of the mix into fresh flasks with more plastic and liquid.

Any organisms that survived "must be using the foam as a carbon source," Gunawan says. That shows they're degrading it, she explains. The team found 10 organisms — groups of five each from compost and soil — that survived together by breaking down the foam.

"The whole structure degrades, despite the fact that it's only 52 percent algae," she observes. That means the whole shoe is biodegradable — even parts made from oil. The team described its findings in the September 2020 *Bioresource Technology Reports*.

"This work seems to be a promising start" to making a biodegradable product that people would choose to buy, says Stephanie Liffland. She's a researcher at the University of Minnesota in Minneapolis. Her work there focuses on the chemistry of sustainable polymers. She did not work on the flip-flop project.

Liffland likes swapping out algal ingredients for crude-oil products in this plastic. She notes that the new foam meets standards for a product many people want and use. And it's important that the foam can decompose in real-world conditions, such as soil and compost. It would be useful to know whether it also would break down in seawater, she adds. After all, plastic pollution is a big aquatic problem, and the material might break down differently in water than in soil.

For now, the team is working to scale up for large-scale manufacturing. The cost to buyers should only be a couple of dollars more than nonrecyclable flip-flips, Tessman notes. And if you're interested, she adds, "I think the flip-flops will be available next year." ✖

A researcher removes the sole of a new flip-flop from a mold.

STEPHEN MAYFIELD/UC SAN DIEGO

Plastic pollution by the numbers

8 million
marine species have been impacted by plastics in our oceans

530
tons of plastic end up in our oceans each year

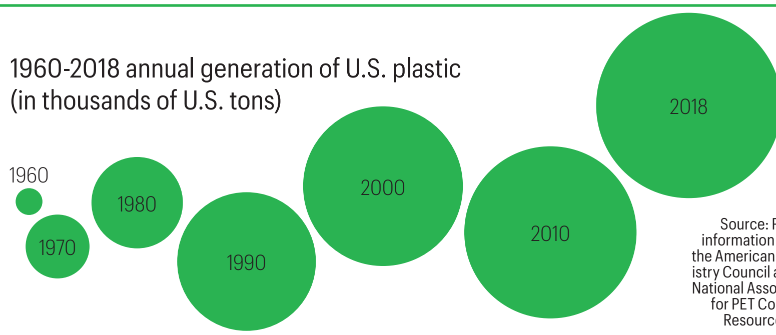
300 million
tons of plastic are produced each year

Source: The Nature Conservancy

Plastic production

The amount of plastic created in the United States has ballooned over time, and most lingers as pollution. Globally, only 9 percent of plastic will be recycled. Twelve percent will be burned and 79 percent will be piled up on land or enter waterways, according to a 2017 report in *Science Advances*.

1960-2018 annual generation of U.S. plastic (in thousands of U.S. tons)



Source: Plastics information is from the American Chemistry Council and the National Association for PET Container Resources; EPA

Nanowires from bacteria can turn water into electricity.

Will bacterial 'wires' one day power your phone?

These protein strings can pull electricity out of moist air anywhere

By Alison Pearce Stevens

When Jun Yao started a new job, this electrical engineer wasn't looking to create a "green" source of power. But chance helped him discover a way to use an all-natural protein to turn water into electricity.

Yao works at the University of Massachusetts (UMass) in Amherst. He uses nanowires in the electronics he's been designing. Super tiny, each is just a billionth of a meter (three-billionths of a foot) wide. But Yao had a hard time getting enough of them for his research.

Discouraged, he mentioned the problem to a microbiologist who also works at UMass. This Derek Lovley told Yao about bacteria that make nanostrands of protein. To find out if these

ELLA MARU STUDIO/COURTESY OF UMASS AMHERST might substitute for nanowires, the pair teamed up to work together.

Geobacter bacteria live in mud. Lovley first discovered them more than 30 years ago. Since then, these microbes have been used to clean up oil spills and radioactive waste.

The bacteria grow wire-like protein strands all over the outside of their cells. "They look like a miniaturized sea urchin," Yao says. As the microbes turn food into energy, they release electrons. Those electrons move through the protein strands, ending up on iron in the mud.

For the new research, Lovley removed the nanostrands from billions of these bacteria. Yao's team then sandwiched a cloud of the wirelike strands between two small, gold metal plates. (Imagine taking a handful of threads and smooshing them flat.) The gold serves as electrodes. They make contact with the non-metal part of an electric circuit (those protein wires). Graduate student Xiaomeng Liu then applied a voltage between the two electrodes. Yao likens this to connecting them to a battery. When Liu did this, electricity — the flow of electrons — moved through the system. The protein "wires" now behaved like metal ones.

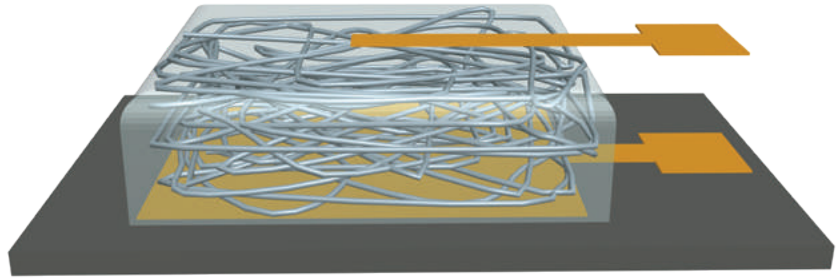
A beneficial mistake

One day, Liu forgot to turn on the voltage. Yet he saw electricity was flowing through the device anyway. To his surprise, the protein nanowires had created electricity. After testing, the researchers showed that the air's humidity — water content — had been powering the setup.

Excited, the researchers decided to test how well their new system worked. They started with one tiny device. Its bottom electrode was just 5 millimeters (0.2 inch) on a side. On top of this was a layer of nanowires 7 micrometers thick (that's much thinner than a human hair). Atop sat a smaller, square electrode, 1 millimeter on each side.

The device produced electricity at all humidity levels tested, but it made more when humidity was high. At top power, it produced a sustained 0.5 volt. When the researchers connected five devices, they got five times the energy output. Covering the device to keep water out of the nanowires shut off its electricity-making. Removing the cover turned the device on again. Though the output of a single device is tiny, a group of them could charge a phone or light a lamp, Yao says.

Key to the system are small spaces between



The lab's device sandwiches a film of protein nanowires between two gold electrodes.

LIU, X., GAO, H., WARD, J.E. *ET AL. NATURE* 2020

the nanowires, called nanopores. They allow water to move between the wires. More water collects on the side with the small electrode where the nanowire package contacts the air. Less gathers on the side where the nanowires touch the larger electrode. This difference, or gradient, makes a positive charge build up on one side of the "wires" and a negative charge on the other. It's a bit like how lightning forms, Yao says. "The movement of water molecules creates a charge separation in the cloud," he explains. "Eventually it reaches a threshold so the cloud discharges," producing lightning.

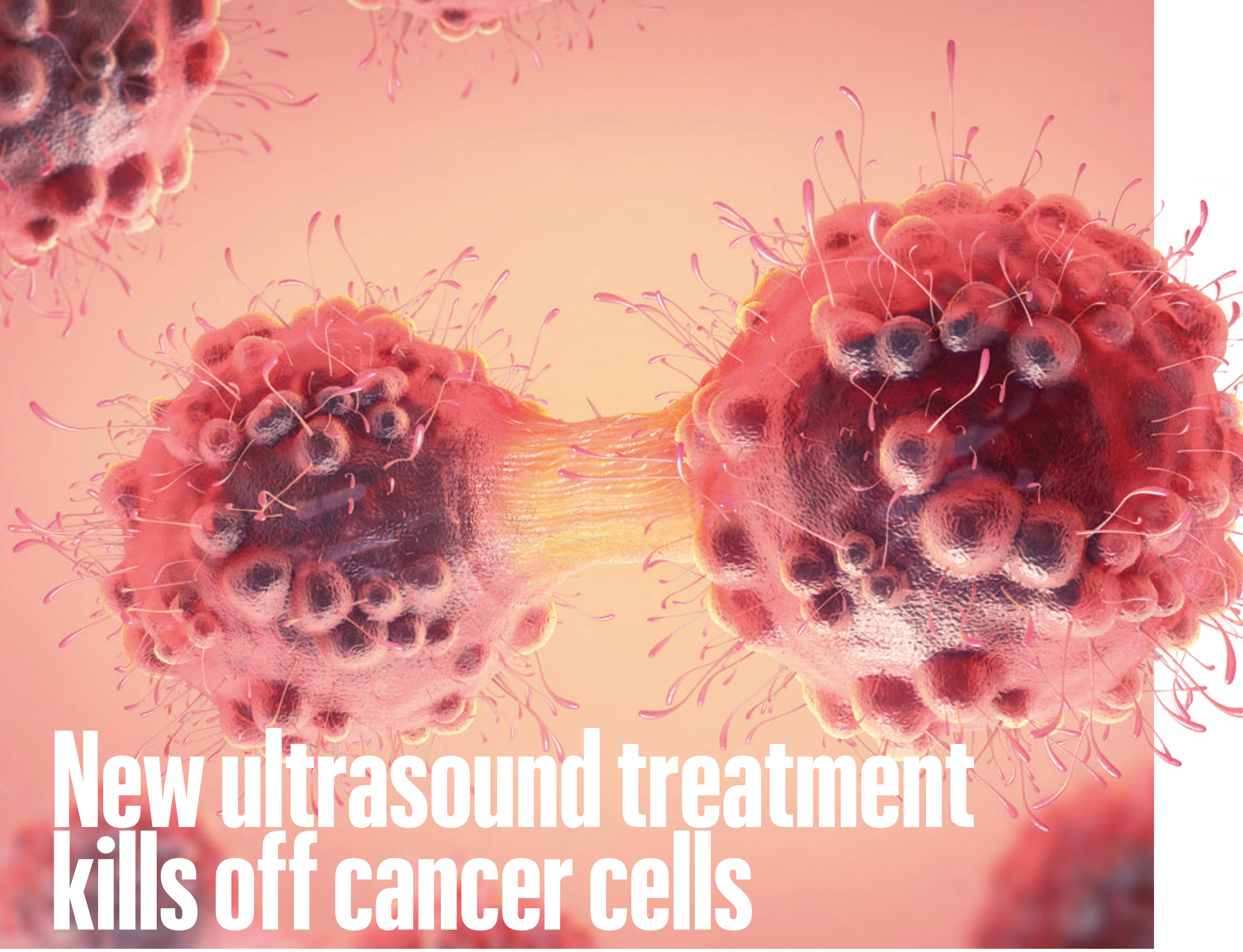
The team described its invention February 27, 2020 in *Nature*.

Powering the future?

The new device has the potential to be a major innovation in renewable energy, Yao says. After all, he notes, "humidity is everywhere." The devices are very thin and can be stacked. Unlike solar panels, they don't need light or to cover a big area. They can be used indoors or out. They can even become part of furniture, cell phones and more without being noticeable.

The best part, Yao says, is that harvesting the microbial wires produces no harmful chemicals. And when the devices are no longer needed, the gold electrodes can be reused or recycled. The nanowires can be tossed out, allowing the protein to break down naturally. This means that unlike other types of renewable energy, Yao says, there's no long-term waste to pollute the environment.

This looks to be an important technology, says Quanbin Dai. He's a nanotechnology researcher at Case Western Reserve University in Cleveland, Ohio. Many people have "cell phones and wearable electronics that need to be recharged," he notes. Protein nanowires could make electric power anywhere and at any time of day. ✖



New ultrasound treatment kills off cancer cells

It spares healthy cells while taking out cancerous ones

By Alison Pearce Stevens

Most cancer treatments involve surgery, chemical poisons or toxic radiation. Because they tend to take out healthy cells along with cancerous ones, these treatments can leave patients tired, hurting and more. So researchers are looking for new approaches that spare the healthy cells. One new idea would destroy cancer cells with ultrasound energy. Even this treatment, however, can sometimes damage healthy tissue. But a new development may help. It limits the ultrasound energy's damage to only the cancer cells. Healthy cells should suffer little if any harm from it.

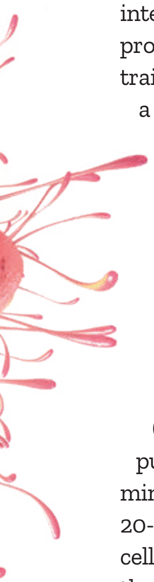
It's exciting, says David Mittelstein of his team's findings. Mittelstein is a biomedical engineer at the California Institute of Technology, in Pasadena. Low-intensity ultrasound, he says, "may allow physicians to target cancer cells based on their unique physical and structural properties." Any spillover of the energy should cause little harm to healthy tissue.

The treatment sends out pulses of sound waves — energy — that have a frequency above 20,000 hertz (cycles per second). That's too high for our ears to hear. (That's also what makes it "ultra" sound.) Medical imaging relies on very short pulses of this low-intensity ultrasound.

Doctors had already used high-intensity ultrasound to kill cancer cells. These sound waves send lots of energy to a small, focused area. The waves vibrate water inside cells within that area. This causes the cells to heat up. A lot. Targeted cells and their neighbors can reach 65° Celsius (149° Fahrenheit) in just 20 seconds. This kills cancer cells. The down side: It kills healthy ones, too.

Mittelstein's team tried a different approach. Another Caltech lab had studied effects of low-

CHRISTOPH BURGSTEDT/ISTOCK/GETTY IMAGES PLUS intensity ultrasound on cancer cells. These cells differ from healthy ones. They have a bigger nucleus. They're softer, too. This other Caltech team created computer models (see sidebar, p. 23) of cancer cells. These models suggested that low-intensity ultrasound might kill those cells. The process, Mittelstein explains, is "similar to how a trained singer can shatter a wine glass by singing a specific note."



This idea hadn't been tested, however. So his team set out to do that.

First, they mixed cancer cells with healthy blood cells and immune cells. The cells were all suspended in a liquid. Then the scientists directed short pulses of low-intensity ultrasound at this suspension.

The team tested different ultrasound frequencies (ranging from 300,000 to 650,000 hertz). They also tested different pulse durations (from 2 to 40 milliseconds). One minute of 500,000 hertz ultrasound, delivered in 20-millisecond bursts, killed nearly every cancer cell. It didn't hurt the blood cells. It also left more than eight in every 10 immune cells unharmed. Mittelstein rates it a huge success.

A role for microbubbles

The treatment caused super-small microbubbles — likely tiny bubbles of air present in the fluid — to merge. The ultrasound waves caused these bigger bubbles to oscillate (move back and forth). The oscillation caused these microbubbles to grow, then violently collapse. To kill cancer cells, Mittlestein reports, "microbubble oscillation was necessary — but not sufficient." Microbubbles oscillated in both healthy and cancer cells. "But only the cancer cells," he notes, "were vulnerable to certain frequencies of ultrasound."

More damage occurred when the ultrasound waves bounced back to hit the cancer cells more than once.

The initial ultrasound waves are known as traveling waves. They move out from the machine that produces them. But when those waves hit a surface of some type, they can reflect back — into the oncoming traveling waves. The colliding waves combine to form a special pattern known as "a standing wave," Mittelstein notes. And this wave has some "special stationary spots called 'nodes,'" he explains. At these, the pressure remains constant. Some other stationary spots, called "anti-nodes," also develop. In them, he says, "the pressure goes up and down at twice the amplitude [height] of the traveling wave." In

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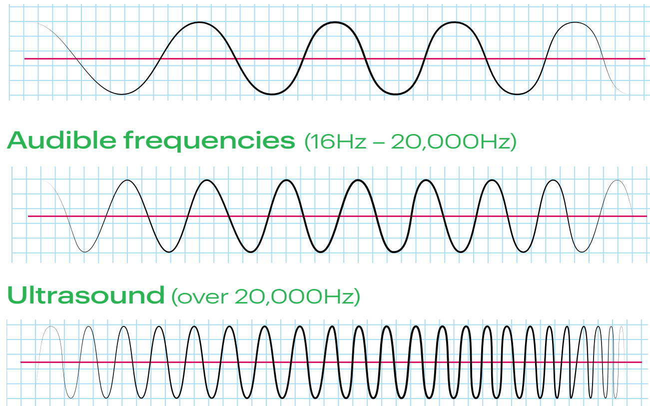
Sound Waves Ultrasound waves travel much faster and occur at a higher frequency (measured in hertz, or Hz) than sounds we can hear.



Explainer

Waves & wavelengths

A wave is a disturbance that moves energy from one place to another. Only energy—not matter—is transferred. Waves, of course, rock the ocean shores. But waves come in many forms. Seismic waves, for instance, shake the ground as earthquakes. And every sound we hear is a wave.

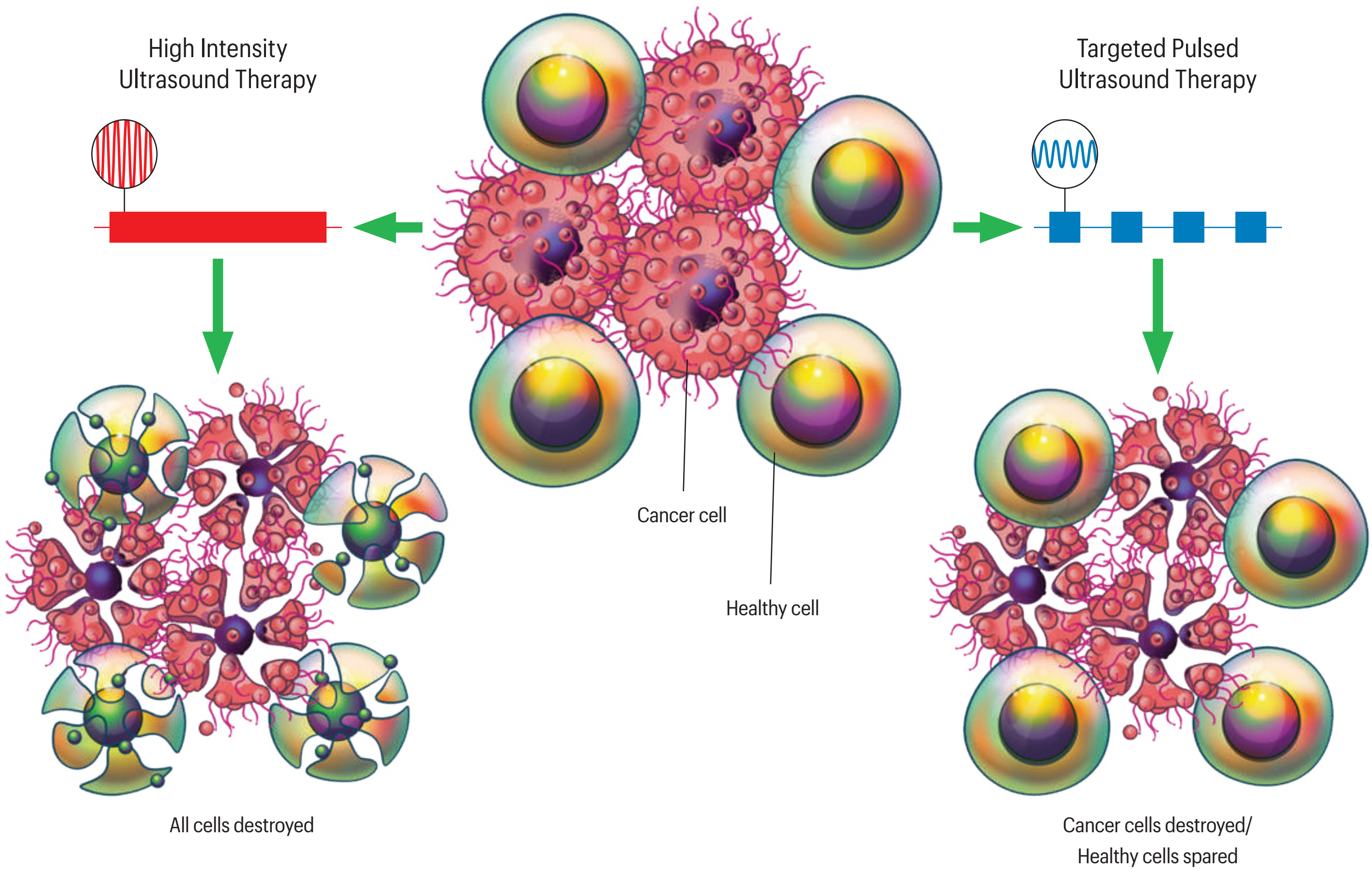
Imagine holding one end of a rope. If you shake it up and down, you create a wave. When your hand moves up, you create a high point, or crest. As your hand moves down, you create a low point, or trough. The rope never leaves your hand. But the crests and troughs do as the wave travels along the rope.

Light can also be described as a wave. It travels through what's known as an electromagnetic field. This field oscillates when energy disturbs it, just like the rope moves up and down when someone shakes it. Unlike a wave in water or a sound wave in air, light waves don't need a physical substance to travel through. They can cross empty space.

Wavelength is the distance from one point on a wave to an identical point on the next, such as crest to crest or trough to trough. The wavelength for an ocean wave might be around 120 meters (394 feet). But a typical microwave oven generates waves just 0.12 meter (5 inches) long. Visible light and some other types of electromagnetic radiation have far tinier wavelengths. Frequency describes how many waves pass one point during one second, which is one hertz. —*Jennifer Look*

Targeting cancer with ultrasound therapies

High-intensity ultrasound (left, depicted as red) kills all cells. In contrast, low-intensity ultrasound (depicted as blue), targets only cancer cells (depicted in red), leaving healthy ones (green) intact.



the end, bubbles in the standing wave oscillate more than do those in a normal wave. And that extra oscillation proved essential to killing cancer cells.

The team suspects the standing wave brings microbubbles closer together. That then boosts the ultrasound energy deposited on the cells, Mittelstein says. Not all cells respond equally to this standing wave. Which do will depend on their physical properties. Here, only cancer cells were harmed.

In his experiment, Mittelstein used a reflector to bounce the sound waves back into the suspension to create that standing wave. Bouncing ultrasound against bone might provide the same type of boosted impact, he suspects.

The team published its findings January 7, 2020 in *Applied Physics Letters*.

This study is exciting, says Timothy Meakem. He was not involved with the study. He does, however, know about ultrasound's value in medicine. He works at Focused Ultrasound Foundation in Charlottesville, Va., as its chief medical officer. If the effect seen in these cells also occurs in people, he says, it would let doctors target cancer cells in ways not currently possible.

However, he cautions, this technique is not ready for use in patients. This is just the first step in the process of developing a new treatment. But if the next stages go well, it "might be a huge benefit to patients."

Mittelstein is already moving ahead. His team's next experiments will go beyond targeting cells in a liquid. They will focus on mounds of cells, which model a cancerous tumor. If they get similar cell killing in treated tumors, he says, "we think this therapy could make a significant impact in cancer therapy." ✖

DAVID MITTELSTEIN/CALTECH

Explainer

What is a computer model?

Computers use math, data and computer instructions to create representations of real-world events. They also can predict what's happening — or what could happen — in complex situations, from climate systems to the spread of rumors throughout a town. And computers can spit out their results without people having to wait years or to take big risks.

The scientists who build computer models start with important features of whatever events they hope to represent. Those features may be the weight of a football that someone will kick. Or it might be the degree of cloud cover typical of a region's seasonal climate. Features that can change — or vary — are known as variables.

Next, the computer modelers identify rules that control those features and their relationships. The researchers express those rules with math.

"The math built into these models is rather simple — mostly addition, subtraction, multiplication and some logarithms," notes Jon Lizaso. He works at the Technical University of Madrid in Spain. (Logarithms express numbers as powers of other numbers to help simplify calculations when working with very big numbers.) Even so, there's still too much work for one person to do. "We are talking about probably thousands of equations," he explains. (Equations are mathematical expressions that use numbers to relate two things that are equal, such as $2 + 4 = 6$. But they usually look more complicated, such as $[x + 3y] z = 21x - t$, or even more complex.)

Solving even 2,000 equations might take a whole day at the rate of one equation every 45 seconds. And a single mistake might throw your answer way off.

More difficult math might bump up the time needed to solve each equation to an average of 10 minutes. At that rate, solving 1,000 equations could take nearly three weeks, if you took off some time to eat and sleep. And again, one mistake might throw everything off.

In contrast, common laptop computers can perform billions of operations per second. And in just one second, the Titan supercomputer at Oak Ridge National Laboratory in Tennessee can do more than 20,000 trillion calculations. (How much is 20,000 trillion? That many seconds would come to about 634 million years!)

A computer model also needs algorithms and data. Algorithms are sets of instructions. They tell the computer how to make decisions and when to do calculations. Data are facts and statistics about something.

With such calculations, a computer model can make predictions about a specific situation. For instance, it might show, or simulate, the result of a particular football player's kick.

Computer models also can deal with dynamic situations and changing variables. For example, how likely is it to rain on Friday? A weather model would run its calculations over and over, changing each factor one by one and then in various combinations. After that, it would compare the findings from all the runs.

After adjusting for how likely each factor was, it would issue its prediction. The model would also rerun its calculations as Friday got closer.

To measure a model's reliability, scientists might have a computer run its calculations thousands or even millions of times. Researchers also could compare a model's predictions with answers they already know. If the predictions closely match those answers, that's a good sign. If not, researchers must do more work to find out what they missed. It could be they didn't include enough variables, or relied too much on the wrong ones.

Computer modeling isn't a one-shot deal. Scientists are always learning more from experiments and events in the real world. Researchers use that knowledge to improve computer models. The better computer models are, the more useful they can become. —*Kathiann Kowalski*

PGIAM/E+/GETTY IMAGES PLUS

This “marshmallow-and-toothpick” design illustrates the novel structure in the sound-dampening materials being developed at EMPA in Switzerland.

EMPA

New twist can hush — even cloak — some sounds

These materials can be ‘tuned’ to block some sounds while letting others pass through

By Stephen Ornes

A twist can make a good thing better, as in the case of ice cream cones, braided hair and the end of a good story.

In October 2019, Swiss engineers revealed how a twist built into building materials can help dampen vibrations. Their innovation stops sound or other forms of vibrations from passing through.

To get some idea of what the new material looks like, imagine connecting the flat sides of two marshmallows — one on top, one on bottom — with three toothpicks. Now twist the top marshmallow. The toothpicks stay connected, but they lean to one side so they’re now diagonal instead of vertical. With more toothpicks and marshmallows, you can make the twisting tower as tall as you’d like.

But not just any twist will do.

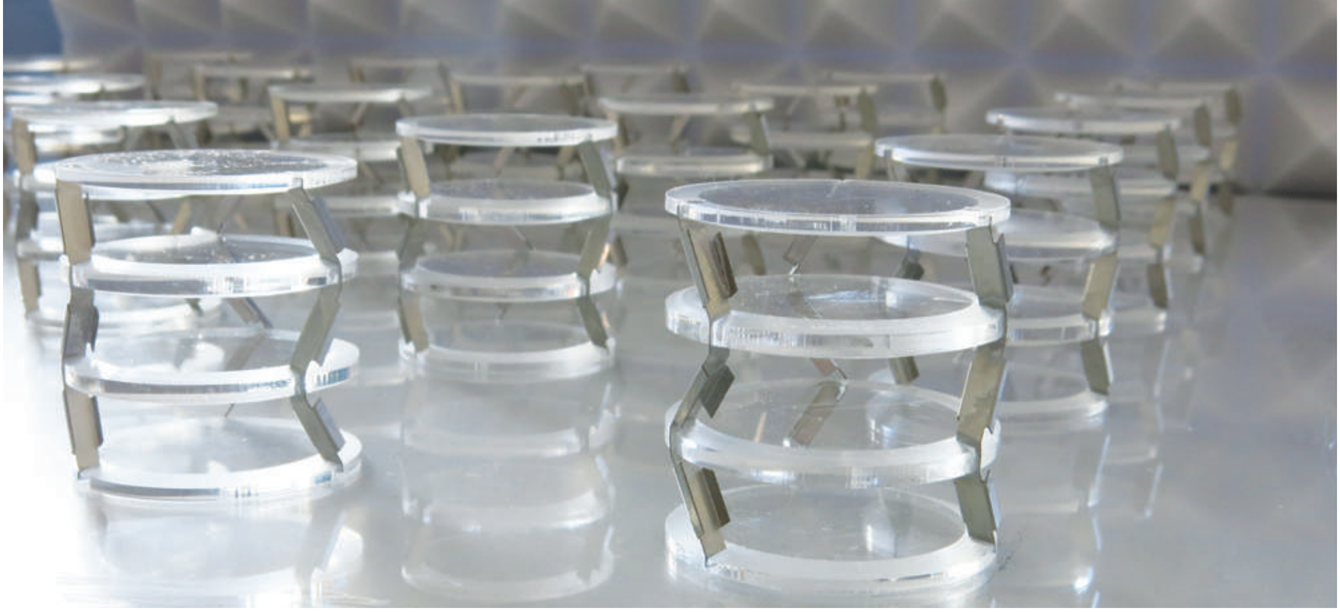
Some molecules come in right- and left-handed forms. That handedness is known as chirality. The two forms are mirror images of each other, like a right and left shoe. That chirality describes how the molecule twists along its length. The new materials employ a different type of chirality. The idea is similar, but engineers have used it on a much larger scale. Their material is made of a tower of flat round disks (think of those marshmallows), each connected by three long and narrow links (like the toothpicks). But instead of twisting a molecule, the researchers have twisted the connecting links.

“Chirality is a new twist” to dampen sound, says José Sánchez-Dehesa, who did not work on the new study. He’s an engineer at Polytechnic University of Valencia, in Spain. And he, too, designs sound-insulating materials.

Plenty of materials exist to dampen or block sound. But the new design is up to 100 times lighter-weight than previous materials, say its inventors. And it’s tunable. That means it can be made to block only specific frequencies of noise or vibrations.

Dampening — or quieting — unwelcome vibrations is important to many designs. Airplane makers want to reduce shaking and noise so passengers stay comfortable and the structure’s materials don’t come apart. So do carmakers. Concert halls and recording studios require quiet spaces. That means they need to block the entry of loud sounds from outside.

Because the new material can block certain ranges of vibrations, the researchers say it could fit all of these uses. “If you design a material, ideally you would like to know what knobs you can turn to obtain a certain effect,” says Andrea Bergamini. “You want to be able to control your



These new anti-noise materials, which have a crystal-like appearance, can twist certain vibrations to block some unwanted sounds.

EMPA

material." He is a mechanical engineer who worked on the new project at EMPA. That Swiss research institute, based in Dübendorf, specializes in designing new materials.

His team described its new chiral sound dampening materials October 4, 2019 in *Nature Communications*.

How it works

Snap your fingers. The sound it makes creates a disturbance in the air as some particles push against others. Those jiggled particles push against still more particles, and so on. Sound moves from one place to another — such as from your fingers to your ears — through this type of particle-shoving.

Vibrations can move through solids, too. That's why your pencil quivers if you hit a desk hard with your hand. It's also why you can hear people talking on the other side of a thin wall. The new invention controls at least some of those sound waves as they attempt to pass through.

The secret is that twist. The building blocks used in the new material look like small cylinders of stacked round plates (clear marshmallows). Narrow diagonal beams (like those toothpicks) separate each disk. Both the plates and beams are made of a hard plastic. When assembled, these structures resemble a type of large crystal. (A crystal is a material with an internal structure made of repeating geometric patterns.)

Entering sound waves pass through one plastic plate, then past the small plastic beams, and on through the next stacked plate. The crystal's shape twists the waves of some sound frequencies. (Frequency describes how closely together waves travel.) Those twists serve to bump the waves off course. The material refracts — changes the direction of — some or all of the waves passing through.

The researchers unveiled two designs for their crystal-like structure. One twists the waves, but rotates them in only one direction. That means sounds pass through. By the time the waves reach the end, however, they'll be distorted. If someone at one end had been speaking, their words could be unintelligible at the other end. Such a design might be useful for creating private rooms. Outsiders would not be able to eavesdrop on what was said inside.

The other design twists first one way, then the opposite. (Imagine you build a tower of many stories of marshmallows, each story separated by and supported by toothpicks. However, the direction of the marshmallow's rotation reverses with each new floor.)

The researchers demonstrated this design by sandwiching the twisting structures between two plastic windows. Their twisty material completely blocked — or cloaked — some ranges of vibrations. This shows that structures can be designed to have a bandgap, meaning a selected range of blocked frequencies, the researchers say.

The design was challenging

Finalizing this design took about five years of trial and error, says Bergamini. His team began by studying crystals. They have an internal structure made of repeating patterns. People often use crystals to redirect light and other types of electromagnetic radiation.

Recently, scientists realized that if they made larger structures out of repeating patterns, they could redirect larger waves. Such projects allowed them to cloak sounds and seismic waves. Bergamini's group wanted to find a new way to use a crystal-like design to dampen or mute sound waves. The breakthrough, says Bergamini, came one day at a Swiss cafe. They saw a tile pattern on the floor. For some reason, that design made them think of rotation.

"After a number of mistakes, we got to the idea of introducing chirality — this twist idea," he says. That was the real innovation.

Researchers used to have only two main ways to create the types of sound-dampening band-gaps that this new material demonstrates, says Marco Miniaci. "You can make the material very dense, or very soft." Miniaci is an engineer. He works at EMPA, too, where he led the project with Bergamini. Those past approaches to sound dampening had their limitations, he notes. A dense material will be heavy. It also can be potentially costly to make, use or maintain. If it's soft, however, the material may not be rugged enough to stand up in construction designs. The new material is the best of both alternatives, Miniaci says — lightweight and durable.

The EMPA team is now working with manufacturers to find ways to put their structural spin — or twist — on the materials that will be used to build cars, planes and other products of the future.

That should be possible, says Sánchez-Dehesa. Moreover, the new material can block a wider range of wavelengths and, potentially, lower pitches. He says that "the design is feasible." And, he adds, "thanks to advances in 3-D-manufacturing, I see no potential troubles" in building new sound-blocking windows. Their see-through glass would have an invisible, built-in twist. ✖

You can't listen Andrea Bergamini created a model, shown here, to demonstrate how his team's new innovation could be used to keep conversations private. Their so-called cryptography window consists of two plastic plates, with a series of rotating discs between them. The size of those discs has been chosen to interfere with the frequencies of the human voice. The discs alter sounds passing through the window in such a way that the words are hopelessly muffled. Someone on the outside can view speakers through the window. But what they say will be so distorted that not a single word will be understandable. And this window works without any need for electronics or power.

EMPA

Trees power this alarm system for remote forest fires

Swaying branches are all that's needed to power these temperature sensors

Once they become blazing infernos, wildfires are easy to spot. The trick to controlling fires is to catch them as they're just entering a forested area. New tree sensors can do this. And the only energy they need to power them is wind moving through tree branches.

By Stephen Ornes

Scientists in Michigan have developed a forest-fire alarm system. It not only can detect when a blaze begins but also call for help. This battery-free device dangles like an ornament from a tree and harvests all the energy it needs from the natural swaying of branches. Such a sensor could watch the woods for a decade without human attention.

"It's a great idea," says engineer Chris Knight in Newcastle, Australia. He works at CSIRO, Australia's national research agency. He didn't contribute to the new work but he knows about wildfire sensors.

Changyong Cao led the team behind the new device. It recharges itself about every 10 minutes with just enough power to take a measurement. That's plenty of time "to generate sufficient energy," says this engineer at Michigan State University, in East Lansing.

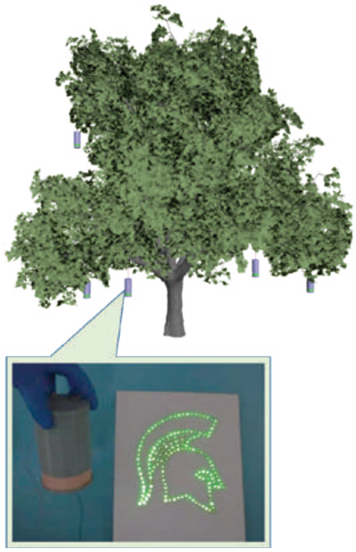
If it detects a fire, the sensor signals a device up to a mile away. That hub can relay an alarm. It can collect such data from tens or even hundreds of sensors, Cao says.

Right now, forest fires are spotted from satellites or fire towers. Neither, Cao notes, is as fast or low-cost as tree-hanging sensors would be. The new devices turn mechanical motion into static electricity. To do this, they use a pair of nested cylinders, one inside another. Each is coated with a copper film. The bottom is made of a similar batch of nested cylinders. But these are coated with a material called PTFE (which coats many nonstick frying pans).

The top and bottom slide into each other, then the package is hung from a tree branch. The bottom cylinder hangs from a rubber band attached to the upper part. When a tree branch sways, the top and bottom cylinders move together and apart. This causes the PTFE and copper to exchange electric charges, producing a current. That current is small, yet easily enough to power a thermometer to detect the temperature changes signaling a fire.

Cao's team described its new device August 7, 2020 in *Advanced Functional Materials*.

"A system like this is a great idea," says Knight. And, he adds, "You don't need that many of them to get a whiff of smoke and send off an alarm." ×



This shows a series of sensors (grey cylinders) hanging from a tree. An actual sensor (in blue-gloved hand below) created enough power to light this LED outline of Michigan State's symbol, the Spartan.

YELANTSEV/ISTOCK/GETTY IMAGES PLUS; CHANGYONG CAO

SPUKKATO/ISTOCK/GETTY IMAGES PLUS

Gene editing can alter body fat and may fight diabetes

In animals on a fatty diet, this DNA tweaking left them slimmer and healthier

By Silke Schmidt

People are among mammals that have "bad" fat and "good" fat. The bad, white type stores energy. But too much of it makes us obese. The brown type burns energy, helping us stay lean. Scientists have now created human brown fat cells in the lab and transferred them into mice. These rodents gained less weight from a fatty diet. They also became healthier.

Scientists hope such a strategy might do the same thing in people.

It's been well known that infants and hibernating animals have brown fat. Mice, for example, have deposits of it between their shoulder blades. This fat's color comes from a high flow of blood and many tiny power factories, known as mitochondria. Low temperatures turn on those power factories in brown fat. Mitochondria convert into heat the chemical energy in food and stored white fat. This helps infants stay warm and small mammals survive cold winters.

In 2009, researchers showed that adult humans have brown fat that responds to cold temperatures. Adults also have beige fat scattered within their white fat. Beige fat is not quite white or brown but somewhere in between. When needed, it becomes brown to turn more calories into warmth. It becomes white-ish again when that's no longer needed. How much brown and beige fat adults host is unknown. However, it's a lot less than what is in mice. The amount strongly depends on someone's body composition. Lean people tend to have more active brown and beige fat than do obese people.

Scientists had wondered whether they could treat obesity by turning white fat into brown, notes Yu-Hua Tseng. She is a molecular biologist at Harvard Medical School in Boston, Mass.

Her team has now done this in mice. The group described how on August 26, 2020 in *Science Translational Medicine*.

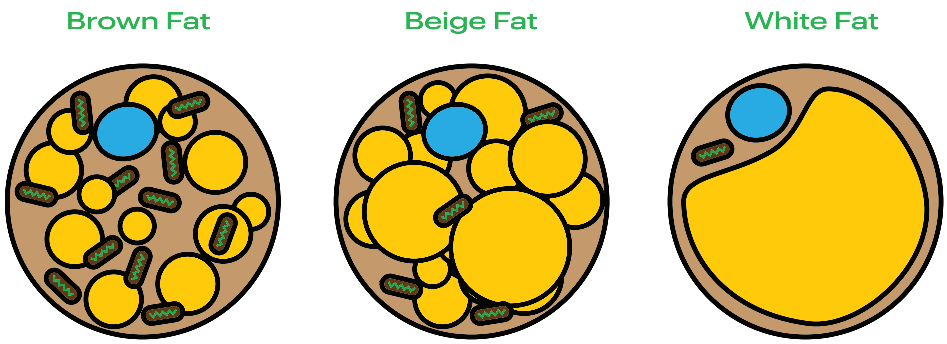
HUMBLE is powerful innovation

Plastic surgeons on Tseng's team took cells that will become fat from the necks of patients. In the lab, this tissue grows into white and brown fat. To make the white fat behave like brown fat, the researchers used a technology for modifying DNA known as CRISPR/Cas9.

CRISPR often is used to swap out some genetic building blocks with others. Tseng's team instead used the technology to insert a molecular switch into the DNA of white fat cells. This switch turned on a gene called UCP1. In brown fat, that gene causes mitochondria to churn out heat.

The inserted switch boosted almost 20-fold how much protein the UCP1 gene made. That extra protein turned the white fat cells into cells the researchers call HUMBLE. It's an acronym for "human brown-like." They then transplanted HUMBLE cells into mice. (First, they disabled the immune system. Otherwise, a mouse's immune cells would have attacked and destroyed the foreign human cells.)

One set of mice were normal weight. They ate fatty food for two weeks before the transplant and for four weeks after. A second set of mice was already obese.



People have three types of fat cells. Brown fat burns energy, but we don't have much of it as adults. White fat stores energy. Beige fat is scattered within white fat. Activated beige fat behaves like brown fat and can help us stay lean.

Each set of mice included three groups. One group received HUMBLE cells. The second group received white fat cells and the third got brown fat cells. All those cells came from the same human donor.

At the end of the study, the researchers weighed each mouse. Obese mice given HUMBLE or brown cells now weighed 20 percent more. Obese animals given extra white fat cells weighed 30 percent more. (In the normal mice, the body weight difference between the three groups was smaller than in the obese ones.)

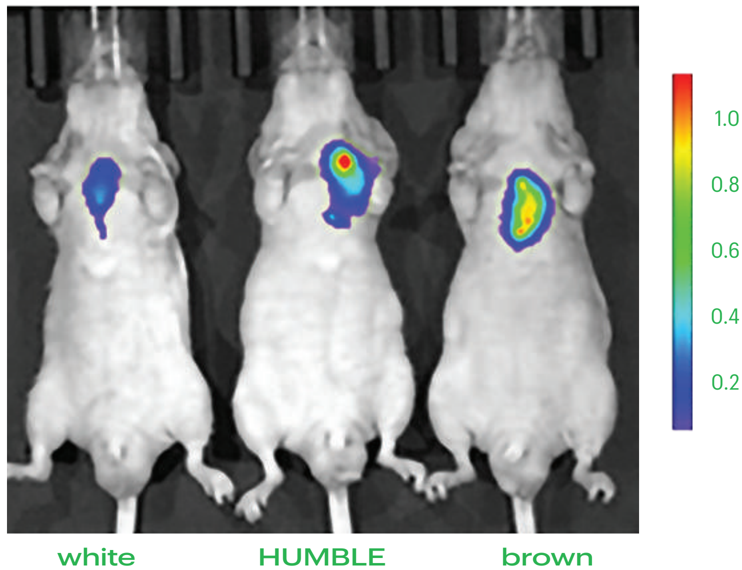
The researchers also measured how much blood sugar, or glucose, the different cells took up in the mice. "To our surprise, it was not the transplanted HUMBLE cells that took up the most glucose," says Tseng. "It was the brown fat the mice already had."

Tseng was thrilled to see this. It means HUMBLE cells communicate with the existing brown fat. The transplanted cells released chemical signals. And those told the mouse's own tissue to take up more blood sugar. These changes made the mice healthier.

Creating cells that signal as in real people — while in another species — "is impressive," says Wouter van Marken Lichtenbelt. He's a physiologist who co-discovered adult human brown fat in 2009. He works at Maastricht University in the Netherlands.

Could this fight disease?

Tseng hopes this innovative use of CRISPR tech will one day treat obese people with diabetes. She can imagine doctors removing a patient's fat cells and editing their DNA. The doctors would then return the cells to that person (without firing up an immune attack). She says it would be "almost like waking up your own fat cells to boost your glucose metabolism." Glucose metabolism is the body's uptake and use of blood sugar. That process no longer works normally in diabetes.



The color shows activity levels of the UCP1 gene (blue: low, red: high). A molecular switch boosted the activity of this gene in mice that had received HUMBLE or brown fat cells. The gene stayed inactive in mice that received white fat cells.

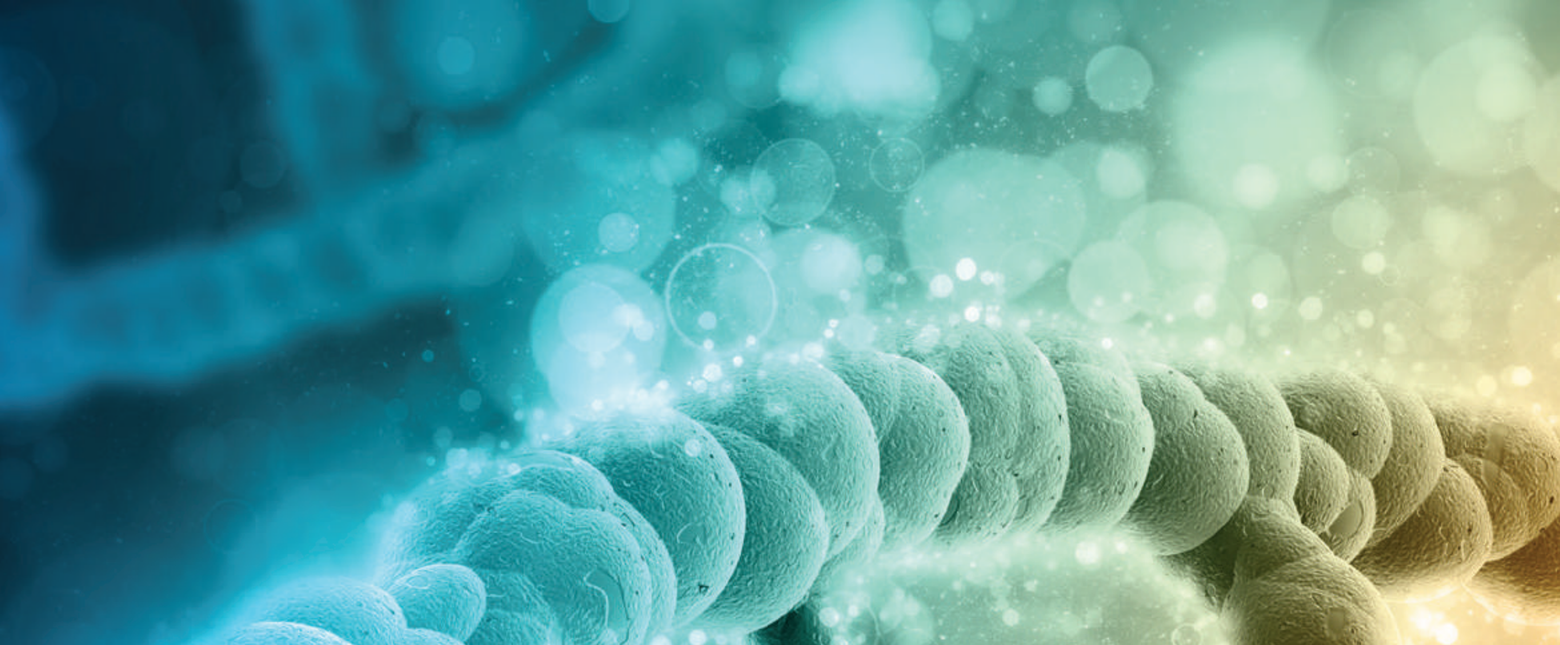
For now, the researchers need to look for any side-effects. We don't know whether it's safe for adults to have as much brown fat as babies, points out van Marken Lichtenbelt.

Silvia Corvera is a molecular biologist at the University of Massachusetts Medical School in Worcester. In 2016, her group used a chemical method to turn on human beige fat. It, too, improved glucose uptake in mice. But before Tseng's study, it wasn't clear whether the increased UCP1 gene activity alone caused this benefit. Showing that here, Corvera says, is a major advance.

Corvera is now testing her approach in monkeys. Obese monkeys and people develop diabetes at similar rates. If the method works in monkeys, testing it in people will be next.

"Current drugs don't control diabetes well enough in all patients," says Corvera. "I think this [method] could soon become a phenomenal new treatment." ✖

GRAFIKAZPAZUREM/ISTOCK/GETTY IMAGES PLUS; JOSLIN DIABETES CENTER, HARVARD MEDICAL SCHOOL



Explainer

How CRISPR works

Scientists usually shy away from using the word miracle. Unless they're talking about the gene-editing tool called CRISPR, that is. "You can do anything with CRISPR," some say. Others just call it amazing.

Indeed, it amazed so many people and so swiftly that just eight years after they discovered it, Jennifer Doudna and Emmanuelle Charpentier took home the 2020 Nobel Prize in chemistry.

CRISPR stands for "clustered regularly interspaced short palindromic repeats." Those repeats are found in bacteria's DNA. They are actually copies of small pieces of viruses. Bacteria use them like collections of mug shots to identify bad viruses. Cas9 is an enzyme that can cut apart DNA. Bacteria fight off viruses by sending the Cas9 enzyme to chop up viruses that have a mug shot in the collection. Scientists recently figured out how bacteria do this. Now, in the lab, researchers use a similar approach to turn the microbe's virus-fighting system into the hottest new lab tool.

This CRISPR/Cas9 tool was first described in 2012 and 2013. Science labs around the world soon started using it to alter an organism's genome — the entire set of its DNA instructions.

This tool can quickly and efficiently tweak almost any gene in any plant or animal. Researchers already have used it to fix genetic diseases in animals, to combat viruses and to sterilize mosquitoes. They have also used it to prepare pig organs for human transplants and to beef up the muscles in beagles.

So far CRISPR's biggest impact has been felt in basic biology labs. This low-cost gene editor is easy to use. That has made it possible for researchers to delve into the basic mysteries of life. And they can do it in ways that used to be difficult if not impossible.

Robert Reed is a developmental biologist at Cornell University in Ithaca, N.Y. He likens CRISPR to a computer mouse. "You can just point it at a place in the genome and you can do anything you want at that spot."

At first, that meant anything that involved cutting DNA. CRISPR/Cas9 in its original form is a homing device (the CRISPR part) that guides molecular scissors (the Cas9 enzyme) to a target section of DNA. Together, they work as a genetic-engineering cruise missile that disables or repairs a gene, or inserts something new where the Cas9 scissors has made some cuts. Newer versions of CRISPR are called "base editors." These can edit genetic material one base at a time, without cutting. They're more like a pencil than like scissors.

KIRSTYPARGETER/ISTOCKPHOTO

Here's how it works
Scientists start with RNA. That's a molecule that can read the genetic information in DNA. The RNA finds the spot in the nucleus of a cell where some editing activity should take place. (The nucleus is a compartment in a cell where most of the genetic material is stored.) This guide RNA shepherds Cas9 to the precise spot on DNA where a cut is called for. Cas9 then locks onto the double-stranded DNA and unzips it.

This allows the guide RNA to pair up with some region of the DNA it has targeted. Cas9 snips the DNA at this spot. This creates a break in both strands of the DNA molecule. The cell, sensing a problem, repairs the break.

Fixing the break might disable a gene (the easiest thing to do). Alternatively, this repair might fix a mistake or even insert a new gene (a much more difficult process).

Cells usually repair a break in their DNA by gluing the loose ends back together. That's a sloppy process. It often results in a mistake that disables some gene. That may not sound useful — but sometimes it is.

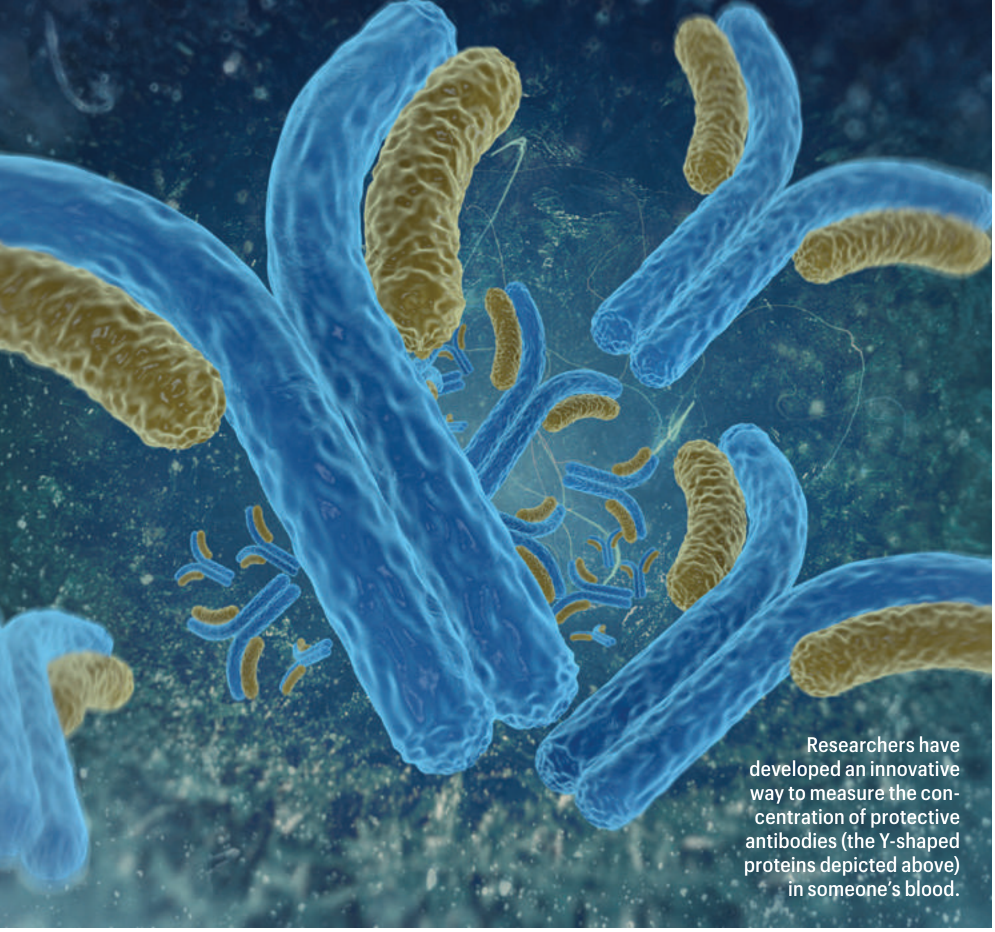
Scientists cut DNA with CRISPR/Cas9 to make gene changes, or mutations. By comparing cells with and without the mutation, scientists can sometimes figure out what a protein's normal role is. Or a new mutation may help them understand genetic diseases. CRISPR/Cas9 also can be useful in human cells by disabling certain genes — ones, for instance, that play a role in inherited diseases.

"The original Cas9 is like a Swiss army knife with only one application: It's a knife," says Gene Yeo. He is an RNA biologist at the University of California, San Diego. But Yeo and others have bolted other proteins and chemicals to the dulled blades. That has transformed that knife into a multifunctional tool.

CRISPR/Cas9 and related tools can now be used in new ways, such as changing a single nucleotide base — a single letter in the genetic code — or adding a fluorescent protein to tag a spot in the DNA that scientists want to track. Scientists also can use this genetic cut-and-paste technology to turn genes on or off.

This explosion of new ways to use CRISPR hasn't ended. Feng Zhang is a molecular biologist at the Massachusetts Institute of Technology in Cambridge. He was one of the first scientists to wield the Cas9 scissors. "The field is advancing so rapidly," he says. "Just looking at how far we have come … I think what we'll see coming in the next few years will just be amazing."

— Tina Hesman Saey



Researchers have developed an innovative way to measure the concentration of protective antibodies (the Y-shaped proteins depicted above) in someone's blood.

A new way to measure antibodies

Technique uses luminescent substances and needs only a small drop of blood

By Sid Perkins

An international team of researchers has come up with a five-minute, on-the-spot way to measure antibodies to several important diseases. This can tell health officials if someone has been exposed to a certain disease. Tracking antibody levels over time might also help doctors figure out the best treatment plan for a patient.

When the body senses some invading bacteria or viruses have arrived, it calls out germ-fighting troops: antibodies. These special proteins can fight infections. Later they can work as sentinels that scout for more of the disease-causing germs.

Many antibody tests today must be processed using a lab full of expensive equipment, notes Maarten Merkx. He works at Eindhoven University of Technology in the Netherlands. Often, a trained technician also is needed to perform antibody tests, he notes. That can make them rather costly. One added challenge: So much blood may be needed, he says, that the technician must first pull out a syringe and draw a vial of blood.

Merkx and his colleagues wanted to avoid these problems. But they didn't want to start from scratch. Instead, they decided to adapt a system they created a few years ago. It worked but needed more blood than a pinprick would deliver.

Their newest version doesn't. It takes just a drop of blood to trigger a glow on test strips. The color, which indicates whether certain antibodies are there, lasts about a half-hour. That should give doctors plenty of time to read the findings.

Also novel, this method can test for signs of more than one type of infection at once — from flu to AIDS. Because its proteins can be designed to detect any type of antibody, this method might even be useful to tell whether someone has antibodies to the coronavirus that causes COVID-19.

Researchers described their innovation on May 22, 2020 in *ACS Sensors*.

Know by the glow

The test relies on two types of glowing substances. One is luciferin. It glows blue when it reacts with oxygen. An enzyme called luciferase helps speed that reaction. The second glowing chemical in their test is called luminescent antibody-sensing protein, or LASP.

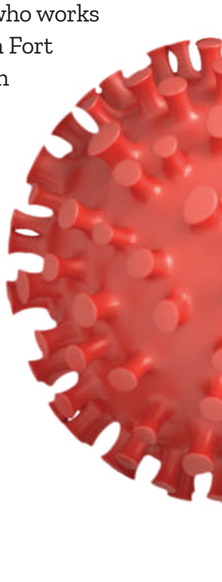
The LASP protein is tailored to detect a particular antibody, such as the one the human body makes to kill an influenza virus. Another part of LASP's chemical recipe includes luciferase. A third part is something called GFP. That's short for green fluorescent protein, which in fact glows green.

The older version of this test, which used a layer of paper, needed at least 30 microliters (a thousandth of an ounce) of blood. To use far less blood, Merkx's team figured the reacting chemicals must start out closer together. The gap between the layers of paper had just been too wide.

Their thinner alternative? Thread. They treat one strand of it with luciferin. A second gets the LASP. When twisted together, the strands stay in tight contact. As before, there is no reaction or glow when the strands are dry. But add a bit of blood and the chemicals mix. Then the telltale green or blue glow emerges.

The new test can detect and measure three antibodies at once.

Charles Henry is a chemist who works at Colorado State University, in Fort Collins. He wasn't involved with the new test, but really likes its ability to measure the color of the blue-green glow with a smartphone's camera. Such information can help doctors figure out the stage of someone's disease, says Henry. Any change in antibody levels over time, he adds, could serve as a sign of that patient's progress. ✖



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Explainer

What are Antibodies?

A world of germs is vying to invade your body and make you sick. Luckily, your immune system can assemble a mighty army to protect you. Think of this system as your own personal team of superheroes. They are dedicated to keeping you safe.

And antibodies are among their strongest ammunition. Also called immunoglobulins, or Ig's, these are a family of proteins.

The job of these antibodies is to locate and attack "foreign" proteins — that is, proteins that don't appear to belong in the body.

These foreign invaders contain substances the body doesn't recognize. Known as antigens, these can be parts of bacteria, viruses or other microbes. Pollen and other things that cause allergies can have antigens, too. If someone is given blood that doesn't match their blood type — during surgery, for instance — those blood cells can host antigens.

Antigens attach to the outside of certain white blood cells. These cells are known as B cells (short for B lymphocytes). The antigen's binding triggers the B cells to divide. This causes them to transform into plasma cells. Plasma cells then secrete millions of antibodies. Those antibodies travel through the body's blood and lymph systems, hunting for the source of those antigens.

Oveta Fuller is an infectious disease expert at the University of Michigan in Ann Arbor. When an antibody spots an antigen, it latches onto it, Fuller explains. This alerts the immune system to crank out more antibodies to destroy the invading virus, bacteria or other foreign cell.

There are four main types of antibodies. Each has a different job:

IgM antibodies are made as soon as the immune cells recognize an antigen. They are the first to go to the site of infection and offer some protection. They don't hang around long, though. Instead, they trigger the body to make a new type: IgG antibodies.

IgG antibodies "stick around," says Fuller. "These are the ones that circulate in the blood and continue to fight off the infection."

IgA antibodies are found in body fluids, such as sweat, saliva and tears. They grab antigens to stop invaders before they cause illness.

IgE antibodies are stimulated by antigens or allergens. (Allergens are substances that trigger the immune system to inappropriately go into overdrive. Certain proteins in pollen, shellfish, peanuts — all sorts of things — can be allergens.) IgE antibodies act quickly. They trigger the immune system to go into what Fuller calls "turbocharge" mode. These substances are what make your nose run or your skin itch when you have an allergic reaction.

Memory cells are a special part of the immune system. They make antibodies and remember specific antigens. When activated, they set off a new cycle of antibody production. And they remember how they did it. So once you've had something like chicken pox or mumps or measles, you'll always have some memory cells ready to make more antibodies if they see that infection again.

Vaccines make this process quicker by giving you a weakened version of some virus or bacterium (often part of a germ that lacks the harmful parts). In this way, vaccines help your immune system learn to recognize the invader before you're exposed to it in a form that can cause disease. Researchers are even treating some people with the antibodies another person had already made to fight off COVID-19. Scientists think this could prevent disease in some people, or perhaps help treat those already sick with the coronavirus that causes COVID-19.

Like all superheroes, immune cells will have to deal with super-villains. And some immune cells might not be up to the task. Certain microbes have tricky ways of fooling antibodies. Shape-shifting viruses, like influenza, change so often the immune system can't keep up. That's why scientists have to develop a new flu vaccine each year. But in most cases, your immune system is very good at spotting and destroying germs and other antigen-makers that invade your body and threaten to make you sick. — *Avery Elizabeth Hurt*

New device tells smiles from frowns — even through a mask

It analyzes someone's cheeks for telltale clues to expressions

By Kathryn Hulick

Tuochao Chen gapes. Then he sneers. Then he grimaces. As he makes faces, he wears a device that looks like a pair of headphones. But instead of playing sound, it points cameras toward his cheeks. The cameras only see the sides of his face. Surprisingly, that's enough facial real estate to tell a sneer from a smile, or a laugh from a frown. A computer system connected to the headphones can figure out what Chen's eyes and mouth look like without seeing them directly.

It works even if Chen wears a face mask. The system can tell if he's smiling or frowning behind it.

Chen studies computer science in the lab of Cheng Zhang at Cornell University in Ithaca, N.Y. Zhang came up with the idea for this system. He calls it C-face. That "C" stands for facial contours. The C also is a pun because the device can "see" your face.

His team's goal is to create technology that can better understand people. Right now, our devices are mostly clueless about how we're feeling or what we need. But over time, more devices will understand us. Zhang hopes that "everything will be smart in the future." For example, your phone might recognize when your face looks upset and suggest calming music. For your phone to know you're upset, however, it has to somehow capture that information from you. Such as from a camera.

But it's not convenient to always have a camera in front of your face. What if you're exercising, cooking or shopping? Meanwhile, the sides — or contours — of someone's cheeks change as they make different faces. These shapes tend to match specific expressions. Deep learning, an artificial-intelligence technique, can detect patterns like this. It just needs lots of practice, known as training.

To train C-face, Chen and other team members made funny faces. Meanwhile, headphone cameras captured how the contours of their cheeks changed with each expression. And a camera in front of the face captured the locations of important "landmarks" around the eyebrows, eyes and mouth. The researchers then fed those landmark positions into a computer. It created a matching virtual version of the face that looked happy, sad, puzzled, surprised or something else entirely.

Zhang's group unveiled its new system in October 2020. The researchers shared details about it at a virtual conference of the Association for Computing Machinery Symposium on User Interface Software and Technology.

The pandemic shaped this research.

Everyone's face is unique. So each person who uses the C-face device has to train and test it on their own expressions. But in spring 2020, when they wanted to test this, the coronavirus pandemic had sent most of the world into lockdown. So the team "got approval to conduct the study with our roommates," says Benjamin Steeper, another Cornell student. The situation wasn't ideal. Steeper converted one room of his apartment into "the science room," complete with a desk, chair, cameras and everything else he needed.

Chen set up his bedroom to also use for the study. He also stars in the video that the team used for training and testing C-face.

The pandemic had another important impact on the team's research. Face masks suddenly became part of

When you wear a mask, other people often can't tell if you're smiling or frowning. But a new device called C-face can. It learns our facial expressions by watching the motion of our cheeks.

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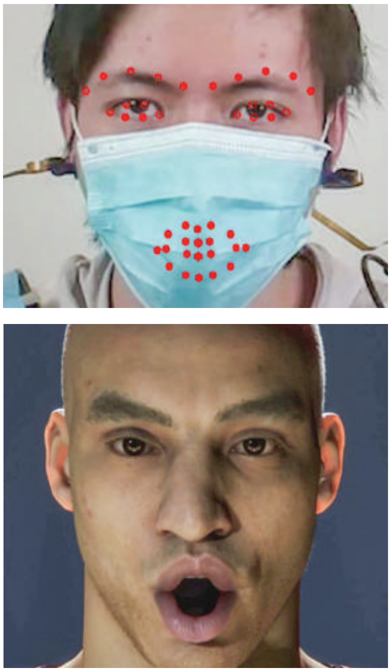

As Tuochao Chen (top) makes a face behind a mask, a virtual character (bottom) copies that expression. The system controlling the virtual face can't see Chen's eyebrows, eyes or mouth. It only watches his cheeks. The device doesn't look directly at someone's mouth and nose, yet it can reveal expressions hidden by a mask.

daily life. Other software designed to recognize people's faces — like FaceID on an iPhone — doesn't work when someone wears a mask. "I keep seeing everyone opening their mask for iPhone unlock," says Ilke Demir. "Looking at the contours is a very nice solution." Demir, who wasn't involved in the research, is a research scientist at Intel in Los Angeles, Calif.

The team showed that C-face could reveal people's expressions even when wearing masks. This device could help you communicate more easily with friends while you wear a mask. It would do this by mapping your hidden expression onto the face of a virtual avatar. This digital version of you would match your expressions as you talk, smile or perhaps gasp.

You can't buy C-face, at least not yet. It needs a bit more work. Yet Steeper is among those who looks forward to someday using C-face or something like it daily. ✖

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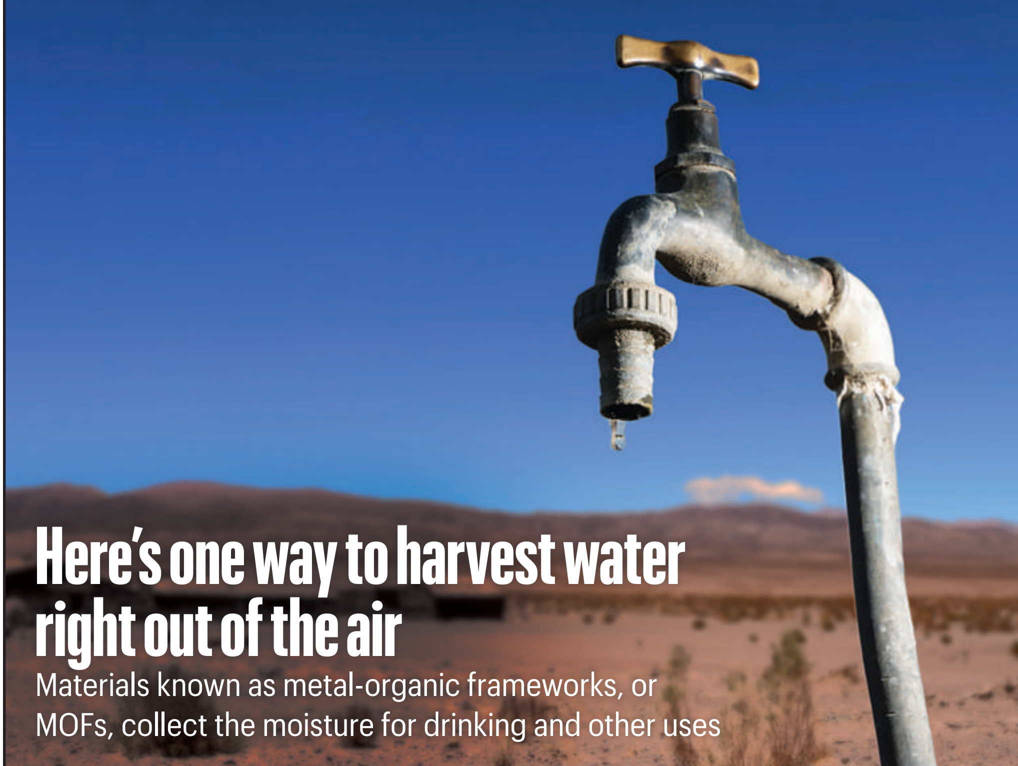


Here's one way to harvest water right out of the air

Materials known as metal-organic frameworks, or MOFs, collect the moisture for drinking and other uses

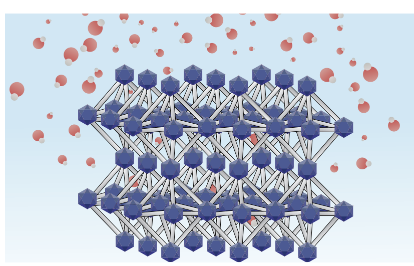
Materials known as metal-organic frameworks can harvest humidity from the air, even when that air is relatively dry.

By Sid Perkins

Need water but you have no access to rain, lakes or groundwater? Materials known as metal-organic frameworks, or MOFs, could be used to slurp that water from the air.

MOFs are a bit like a set of super-tiny Tinkertoys. The hubs are small clusters of metal atoms. Chains of carbon-bearing compounds serve as the "sticks" linking those hubs together. When these components join up, they create an open, honeycomb-like structure.

These materials have a range of useful traits. But communities in arid parts of the world would be most interested in the MOFs that absorb water out of thin air. These materials can capture plenty just from the air, says Zhiyong Xia. This materials scientist works at the Johns Hopkins University Applied Physics Laboratory in Laurel, Md.



By absorbing humidity from cool air and then releasing it at higher temperature, materials called metal-organic frameworks (MOFs) can collect water without using much energy.

Water molecules (H_2O) are the perfect size and shape to pass through pores in the new MOFs. That lets them soak into the material. A second MOF trait is just as important. Its internal arrangement of electrical charges attracts water.

A water molecule is somewhat V-shaped. A negatively charged oxygen atom sits at the bottom of that "V," explains Xia. At the V's upper tips sit two positively charged hydrogen atoms.

Not all water-collecting MOFs are equally useful. Some attract and latch onto water molecules too well. Later, you'd need a lot of energy to release any water collected by them. Xia's solution: Find a MOF that doesn't hold onto water molecules so aggressively.

After testing nine different types, one zirconium-based MOF stood out. The test sample was small. But if its weight had been 1 kilogram (2.2 pounds), the material would have absorbed and then released more than 8 liters (2.1 gallons) each day. That beats any previous MOF-based water-collection system.

Xia and his teammates described their findings January 30, 2020 in *Scientific Reports*. ✖

Explainer

All Earth's water connects in one vast cycle

It's a summer day at the lake. Creeks spill into the clear water. Puffy clouds roll across the sky. On the horizon, a grey curtain of rain sweeps across distant snow-capped peaks.

This is Earth's water cycle in action. Water, shape-shifting through three phases — liquid, vapor and ice — is on the move 24/7. As it moves, it connects every environment and living thing on the planet. Without the water cycle to replenish, clean and transport water, life on Earth could not exist.

The water cycle is driven by a series of linked processes in an endless loop.

Let's start with evaporation. Heat from the sun causes liquid water from oceans, rivers and lakes to evaporate into an invisible vapor. Because vapor is lighter than air, it rises into the atmosphere.

Water vapor also enters the water cycle through transpiration. This is the process of water moving through plants and being released from plant leaves as vapor into the atmosphere. Transpiration accounts for about 10 percent of the water vapor in the atmosphere.

Next up is condensation. As water vapor rises, it cools. Cooling causes the vapor to condense, or re-organize, into tiny droplets. We see those droplets as clouds. Condensation and evaporation constantly shape and reshape clouds. Watch a cloud, and you will see that even as some parts of it evaporate and disappear, other parts grow where condensation is occurring.

Transportation of water occurs as water vapor is moved from place to place with wind, stream currents and clouds.

Precipitation happens when cloud droplets merge into bigger drops. They may collect around particles such as ice, dust or smoke, or they may freeze into ice crystals. When the drops are heavy enough, down they come as rain, hail, sleet or snow. Not all precipitation reaches the ground. Some evaporates instead, or is transported back up by air currents, even as other drops fall.

When precipitation does reach the ground, several things can happen. Water may infiltrate, or soak into, the soil, and percolate deeper into the ground. It may run off right away, collecting in trickles and torrents as it flows downhill across the surface. Or, it may be intercepted by plants, collecting in leaves or taken up by their roots.

Then, there may be a lull in the action, called storage. Water may collect in lakes, ice, snow or underground (as groundwater). But eventually, snow melts, lakes drain or evaporate, and ice changes back to liquid or vapor. Even groundwater moves, ever so slowly, as it makes its way back to the surface.

Then the water cycle repeats, starting with evaporation once again.

The water cycle is as old as life itself. Yet scientists are still working out important details of the roles these different processes play, says Patrick Keys. Keys is a sustainability scientist at Colorado State University in Fort Collins. And, he adds, people can play a big role in that water cycle.

"What we do to the land around us — like cutting down a lot of trees or planting crops in dry places — can lead to enormous changes in evaporation and transpiration, the invisible parts of the water cycle," he says. "These changes to the land can sometimes lead to big changes in the amount of rain a location downwind may receive."

— Beth Geiger

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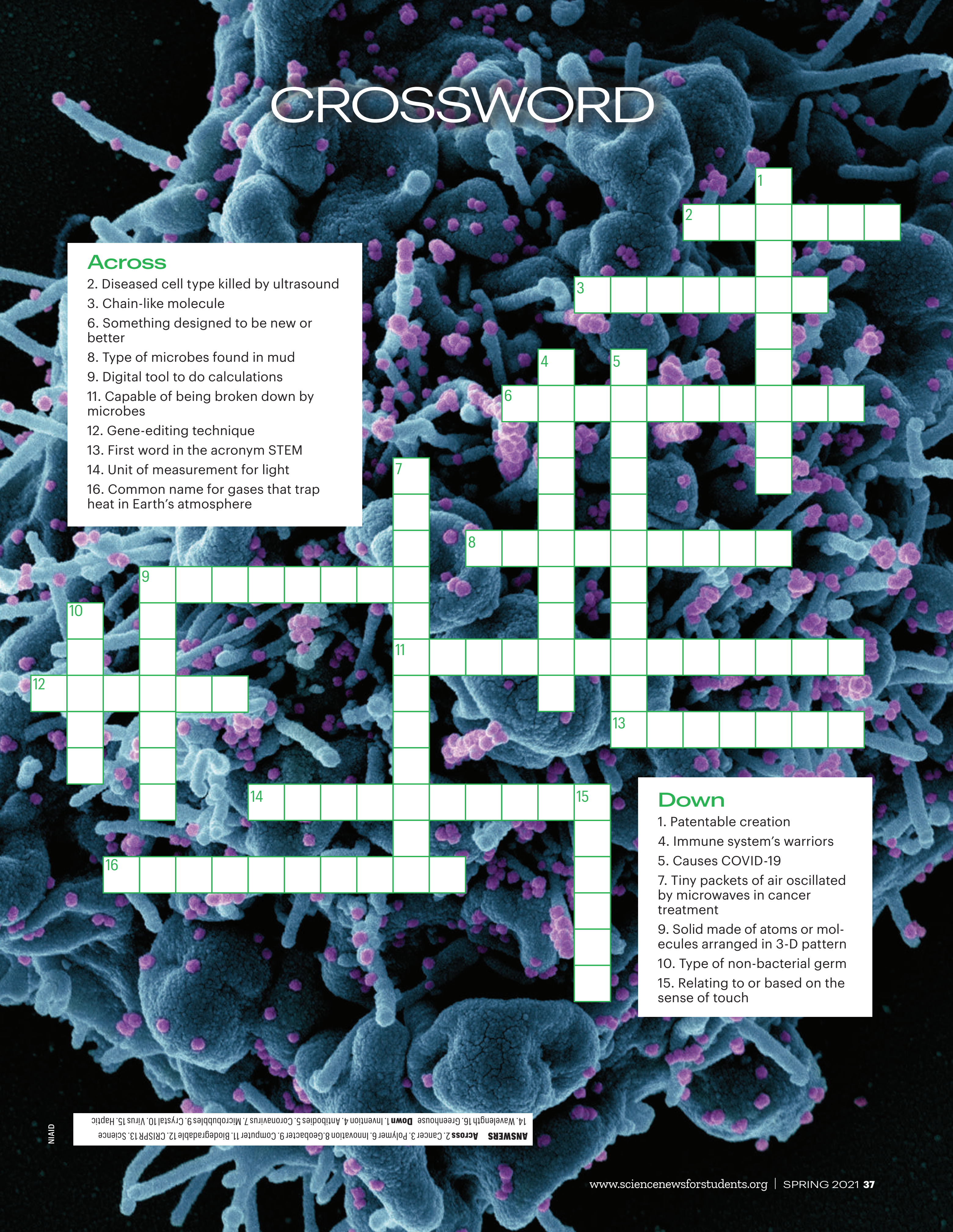

Across

2. Diseased cell type killed by ultrasound
3. Chain-like molecule
6. Something designed to be new or better
8. Type of microbes found in mud
9. Digital tool to do calculations
11. Capable of being broken down by microbes
12. Gene-editing technique
13. First word in the acronym STEM
14. Unit of measurement for light
16. Common name for gases that trap heat in Earth's atmosphere

Down

1. Patentable creation
4. Immune system's warriors
5. Causes COVID-19
7. Tiny packets of air oscillated by microwaves in cancer treatment
9. Solid made of atoms or molecules arranged in 3-D pattern
10. Type of non-bacterial germ
15. Relating to or based on the sense of touch

NIAID

ANSWERS **Across** 2. Cancer 3. Polymer 6. Innovation 8. Geobacter 9. Computer 11. Biodegradable 12. CRISPR 13. Science 14. Wavelength 16. Greenhouse **Down** 1. Invention 4. Antibodies 5. Coronavirus 7. Microbubbles 9. Crystal 10. Virus 15. Haptic

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