Science News for Students
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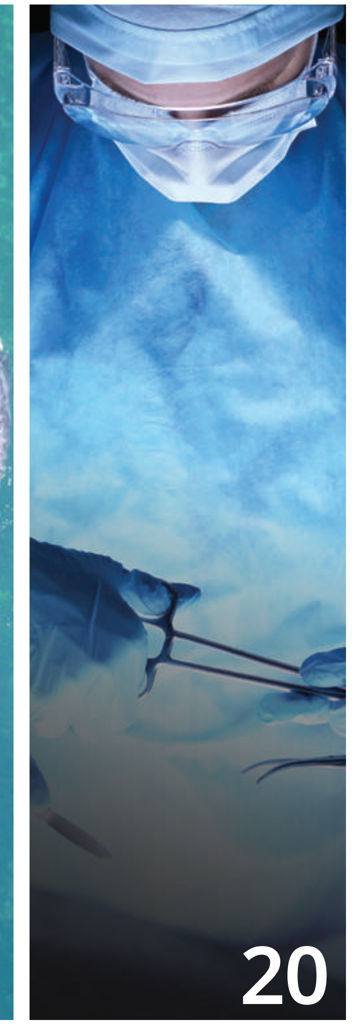
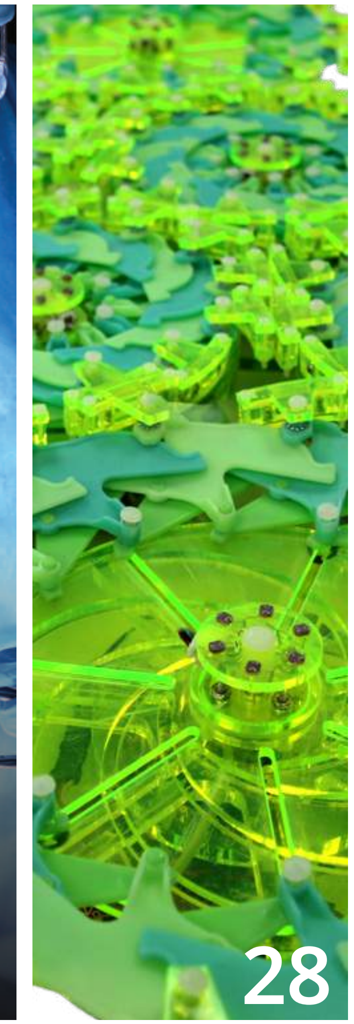
Science News for Students





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COVER A collage of concepts presented in this book was designed for us by Robyn Williams

JIM WEBB

Innovation brings the world better options

From landmine detectors to drones that can gauge a whale's weight while hovering above, each year researchers harness science in clever ways to tackle real-world problems. With generous support from the Lemelson Foundation, *Science News for Students* reported on 18 of these advances in 2019.

Several projects work on a very small scale. There are tiny capsules that can safely move through the blood, releasing toxic cancer drugs once they reach a tumor. Another project uses nano-scale building blocks to protect plants from the harmful effects of the sun. Graphene is a nanomaterial with lots of uses. One group is using that graphene to fashion super-thin fabrics that can keep mosquitoes from biting us.

Like robots? When new plastic, magnet-studded disks collect into a group, they turn into a "smart" robot that now can move on its own, responding to its environment.

Mother Nature inspired plenty of inventions. A sunflower-like solar cell automatically follows the sun to maximize its collection of energy. New super suction cups are based on the weird clingfish. Snail goo pointed researchers to a better superglue that holds when it needs to—and lets go when you want it to.

A new bionic mushroom can make small amounts of electricity. Larger electrical zaps can now in minutes perform painless surgery on the ears, nose and possibly eyes. These stories and more than a half-dozen others showed readers the impacts that an inventive mindset can deliver.

And for even more cool research daily, all delivered free on our mobile-friendly site, visit www.sciencenewsforstudents.org. —*Janet Raloff*

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Magnetic-field generators, like this one, are already used for physical therapy. A similar device that directs the field to a specific area of the body could be used to activate the nanoparticles.

KLUBOVY/ISTOCK/GETTY IMAGES PLUS

Remote-controlled nanoparticles could fight cancer

Sealing toxic drugs inside nanoparticles could reduce their harmful side effects

By Caroline Seydel

Cancer drugs need to be powerfully toxic to kill tumor cells. But they also can kill healthy cells, sometimes with brutal side effects. Now, scientists have designed a way to seal cancer drugs inside tiny capsules so the drugs won't harm the healthy cells while traveling through the bloodstream. They hold that medicine securely until they reach a tumor and a remote control "switch" finally triggers the drug's release.

Smaller than bacteria, the capsules are called *nanoparticles* because their size is measured in nanometers. (A nanometer is equal to one billionth of a meter, or 3 billionths of a foot.)

A magnetic field is the invisible force generated by a magnet. Researchers use a magnetic field to work as that remote control switch. Focusing that field on the cancer site ensures that the medicine is released only where it's needed.

"The drug is not toxic while it's inside the particle," explains Carlos Rinaldi. He's a biomedical engineer at the University of Florida in Gainesville. He led the team that designed the remotely activated particles.

The nanoparticles don't seek tumors out. They do, however, tend to collect at tumor sites. And here's how. Tumors tend to grow so fast that the blood vessels inside them can't keep up. This causes holes to form in the blood vessels. For a nano-package carrying the medicine, those leaky spots become a doorway from the bloodstream into the tumor. The nanoparticles slip in through those leaks, then accumulate in the tumor.

Nanoparticles also can pile up in unwanted places. One such unhelpful collection point is the liver. This organ acts as a filter, snagging poisons out of the blood. It will also net some nanoparticles. Those caught in the liver could damage that organ if they shed too much of an anti-cancer drug.

For many years, researchers have studied how to make nanoparticles that won't drop their drug cargo at such unwanted sites. Sometimes they relied on a chemical trait of the tumor — or the enzymes it produces — to unlock the particles. But not all cancers have the same chemistry. So the medicine might still leak out to poison cells outside the tumor. The new innovation by Rinaldi's team is the creation of a a nanoparticle that won't release its medicine anywhere until it gets very warm. And that warming occurs when the particle is exposed to a magnetic field.

The team published its findings January 9, 2019 in *ACS Applied Polymer Materials*.

Hot idea

The nano-package contains two types of particles inside a thin wall, or membrane. Picture something like a gumball machine, with two types of gumballs inside. The first gumball is a nanoparticle made of iron oxide. This metal responds to magnetic fields. Think of a paper clip that jumps to meet a refrigerator magnet. These particles also react when zapped with a certain type of magnetic field. Here, instead of jumping, they warm up.

The second type of gumball is a polymer. This type of molecule is made from long chains of the same building blocks. The researchers figured out how to lock this polymer onto a molecule of a cancer-fighting drug. They're linked using a type of chemical bond that breaks when it gets hot.

Next, Rinaldi's team wrapped each gumball pair in a water-friendly jacket. This allows the nanoparticles to travel through the blood, which is water-based. The coating also acts as a disguise. It hides the nanoparticles from the body's immune system. Each two-"gumball" package measures about 100 nanometers (0.0000039 inch) across. For perspective, a red blood cell is about 70 times that size.

When exposed to a specific type of magnetic field, the iron-oxide "gumball" in each package heats up. That breaks the bonds holding the medicine inside and sends it flooding out into the tumor.

For this new treatment, Rinaldi and his colleagues use a special machine that restricts where the field contacts the body. They can target that field to the tumor site. Nanoparticles in the liver or any other healthy organ won't be exposed to the magnetic field. And that means any particles in them won't release the drug.

Because the drug will be released only at the tumor, patients now can take higher doses of toxic cancer drugs without poisoning healthy parts of the body.

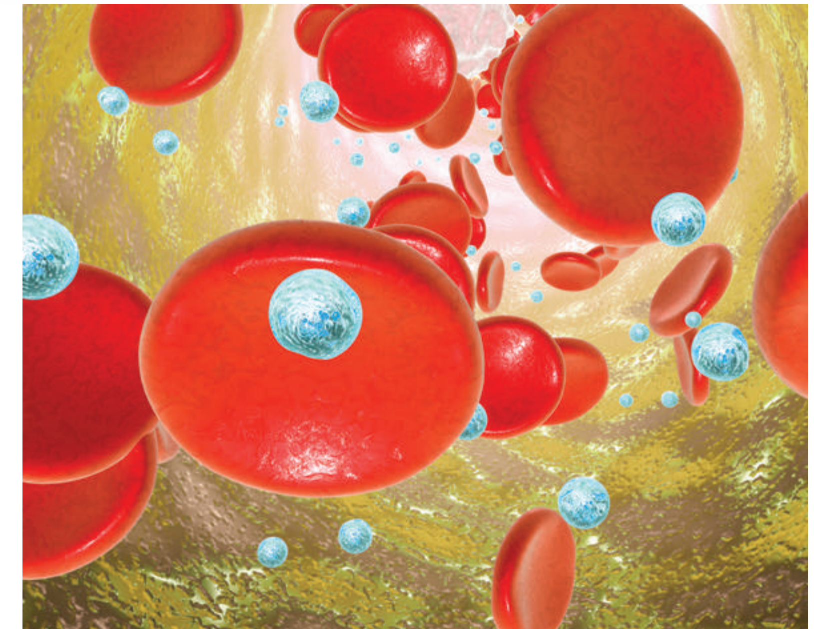
Not yet ready for the clinic

Chemotherapy using the new particles is still a ways off. The current work is a "proof of principle," Rinaldi says. That means that he and his team have not yet tested the system on living cells, much less in animals. In fact, they still haven't packed their particles with real drugs yet. In place of a drug, the researchers attached a glowing fluorescent molecule to the iron-oxide "gumballs." That made it easy to track where and when the chemical was released in response to the magnetic field.

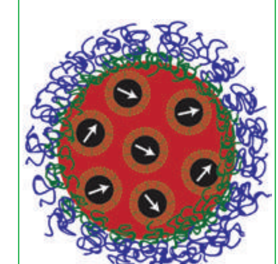
It would be "a major advance if they can really guarantee that these particles do not release [a] drug without [a] magnetic field," says Amit Joshi. He's a biomedical engineer at the Medical College of Wisconsin in Milwaukee. He works on nanoparticles but was not involved in this study. However, he cautions, without animal testing, "we don't know how stable it is." Even if nanoparticles work well in the lab, there is no guarantee they would work equally well inside the body.

The new nanoparticles do have features that make them look promising for medicine, Joshi says. The U.S. Food and Drug Administration has already approved iron-oxide nanoparticles for use in the body, he points out. And the magnetic fields used to trigger drug release by the new particles can reach tumors deep inside the body without surgery, he explains. That should make their use easier on patients.

"This is really, I would argue, for us, a small step," Rinaldi says. "There's a lot of things we don't understand very well." But every small step brings the technology closer to real-world use. In the end, he concludes: "It's an exciting field with a lot of potential applications." ■



This artist's drawing shows nanoparticles (in blue) are far tinier than red blood cells. The nanoparticles use the bloodstream to bring anti-cancer medicine to tumors.



Iron oxide nanoparticles (black) react to a magnetic field and heat up. The heat breaks chemical bonds holding the particle together, unleashing a dose of cancer-killing drugs.

FROM TOP: DR_MICROBE/ISTOCK/GETTY IMAGES PLUS; ERIC FULLER AND CARLOS RINALDI/UNIV. OF FLORIDA

How crops may survive space

Nanoparticles help plants build a super-sunscreen

By Tyler Berrigan

Plants typically endure long, blazing-hot days to produce the fruits and vegetables that growers desire. The incoming sun's ultraviolet (UV) rays can be intense — enough to damage some crops. Such plants might benefit from a built-in sunscreen. Now a team of scientists in Australia has stepped in to lend a helping hand.

A family of nanoparticles known as metal-organic frameworks, or MOFs, can absorb harmful UV radiation. Joseph Richardson is a nano-engineer. He works in Melbourne at the Australian Research Council Centre of Excellence in Bio-Nano Science and Technology. Some MOFs, he knew, can turn UV rays into other wavelengths — ones that plants could use for photosynthesis. That's the process by which plants produce food from light.

In theory, he could "feed" MOFs to the plants. The problem is, MOFs are too big for plant roots to take up. And cutting open the plants to load them with nanoparticles would damage their stems. So that was not an option.

Instead, he's leading a research team working to make plants take up the building blocks of MOFs. Their goal: to help plants make their own MOFs. If those MOFs can capture the tissue-damaging UV rays, they might help crops survive tougher climates, both on Earth and in space.

It all began when Richardson realized the building blocks used to make MOFs are really small. They are so small that plant roots could slurp them up. His brainstorm: figure out a way to make these building blocks come together *inside* the plant and grow, on-site, into complete MOFs.

With that in mind, his team dissolved the starting materials — metal atoms and special carbon compounds — in water. They then placed plant cuttings into this solution.


Plants loaded up with metal-organic frameworks, or MOFs, may be key to growing crops in the harshest environments, including space.

"To our amazement, these simple materials were taken up by the plant, and grew into full-formed MOFs," Richardson reports.

The scientists engineered these MOFs to fluoresce. They emit an intense green light when irradiated with UV light. This helped confirm the plants built the MOFs on-board. Under UV light, the entire plant fluoresced. Says Richardson, this showed that "MOFs formed in the roots, stems, leaves and other parts of plants."

High-tech plants for tough conditions

The bigger question was whether this innovative way to seed the plant with MOFs would work as a sunscreen. To test that, the researchers covered clippings of two plant species with MOFs. They then exposed the plants to UV light for three hours. Compared to uncoated clippings, the treated plants wilted less. Wilting is one indicator of plant damage, such as water loss due to the sun's heat.

The new findings might boost the prospect of being able to grow food crops in space, Richardson says. (That would likely be necessary for long-term human missions.) The sun's UV rays bombard the surface of Mars, for instance. But Mars lacks Earth's thick, protective atmosphere to filter out dangerous amounts of that UV. So any plants there would likely shrivel and die.

MOF-carrying plants, however, should be able to withstand the UV onslaught. In fact, they should be able to use the MOFs' altering of light wavelengths — both to make more food and for the plants' protection.

Richardson and his team now plan to study the effects of MOFs on plant growth. "So far we haven't seen any damage to the plants. But all of our experiments were pretty short term," he admits. "Now we're looking [for possible] long-term damage — although we think it's unlikely."

Another big question relates to the safety of eating MOF-enriched plants. "MOFs can be toxic to humans, depending on what metal they are built around," says Richardson. "But the ones we used have proven to be non-toxic to human cells, yeast and bacteria in lab tests." Richardson also highlighted the fact that many labs around the world are looking to MOFs as a means for drug delivery in humans.

C. Michael McGuirk is more concerned about the long-term durability of MOFs. He's a materials chemist at the Colorado School of Mines, in Golden. "Many MOFs break down over time and lose their unique structure and properties," he explains, "especially in water." Because water is vital for plant growth, MOF breakdown could pose a risk for crop production.

Even so, Richardson hopes MOF-embedded plants will one day help to feed people in hostile outposts, including space. "The plants that we are trying to create — plants that can withstand severe, high-UV environments — are certainly promising," he says.

Richardson presented his team's work at a meeting in April 2019 of the American Chemical Society in Orlando, Fla. ■

GORODENKOFF/ISTOCK/GETTY IMAGES PLUS

MATERIALS SCIENCE

Glass keeps itself clean underwater

Microscopic pancakes on its surface stop dirt from sticking

By Tyler Berrigan

Imagine a surface you never had to clean — because it never gets dirty. It stays spotless, resisting dirt and oil. New research finds that the secret to such a long-lasting, scrub-free shine might be microscopic pancakes.

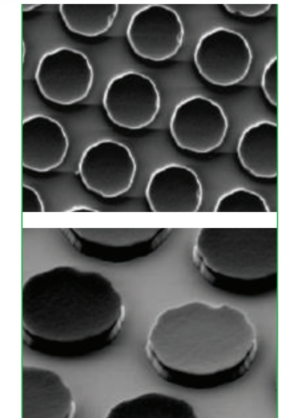
Some self-cleaning surfaces already exist. Stores don't yet sell these self-cleaning clothes, kitchen utensils and windows, to name a few. But scientists are working on them. Up close, you'd see that microscopic pillars or columns cover the surface of many of these. A material coating those tiny structures repels oil and dirt. The narrow pillar tops also give grime less area on which to stick. That helps gunk slide off.

But micro-pillars are far from ideal. The tall, thin columns easily bend, snap and topple. Over time, dirt and oil can collect around damaged pillars. That buildup is hard to dislodge without some form of cleaning. And if the surface is glass, those busted pillars cause even more trouble. Bent and broken bits — and stuck gunk — interfere with light passing through the glass. That can blur or distort images viewed through them.

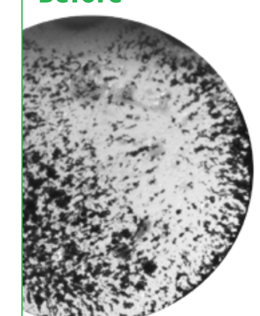
To address these issues, scientists in Norway took a new approach. Instead of pillars, they used shorter, squatter pancake shapes. And so far, those pancakes seem to do the trick. A window tested in the ocean has stayed clean and clear for more than a year.

"Unlike pillars, water moves freely between our pancake microstructures," says Bodil Holst. She's a physicist at the University of Bergen in Norway. With taller pillars, more water molecules get slowed down as they try to pass the structures. Water flows more easily around the shorter structures. Underwater, that liquid flow keeps dirt from sticking. In fact, that provides the self-cleaning, meaning the surface doesn't need a dirt-repelling coating.

Their stout shape also makes the pancakes more durable. Imagine two pieces of chalk: one long and thin, the other short and flat, Holst says. "It would require a lot more effort to break a short piece of chalk," she points out. "In the same way, it takes a lot more effort to break microscopic pancakes compared to pillars."


Scanning electron microscope images show the microscopic "pancakes" on the self-cleaning glass surface. Each pancake is roughly five micrometers across. That's about the size of one red blood cell, or one-twentieth the width of a human hair.

Before



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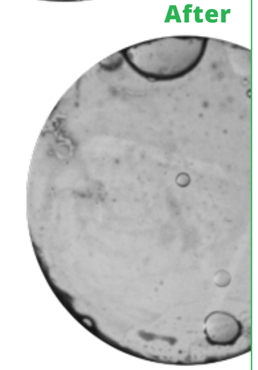

Sitting in an oily mixture left the glass on top gunky and clouded. But the self-cleaning window on bottom stayed completely clean, even after 46 hours.

BOTH: AKHTAR *ET AL*./AMERICAN CHEMICAL SOCIETY (ACS)

In her team's tests, those pancakes have remained firmly in place and held their shape. Holst's group described its findings December 12, 2018, in *Nano Letters*.

A clear problem

The pancake project arose from a real-world problem. "The company we work with uses light-detecting sensors to test water quality," explains Naureen Akhtar. She is a physicist who works with Holst at the University of Bergen. "The problem is, the sensor sits behind a window that gets dirty far too quickly. Sometimes it's soiled after only one week."

Cleaning the window so often takes a lot of costly time and effort. So the company wanted a long-lasting, self-cleaning window. That's when Akhtar and Holst's team came up with their innovation: pancaking the surface.

Once they'd created their new glass, they were ready to test it in the ocean. To do that, they replaced the old, easily soiled glass in front of the sensors with the pancake-studded glass.

The researchers — and the company — have been pleased with the results. In some cases, the pancakes extended the time between window cleanings from weekly to yearly, Akhtar says.

Their glass also performed well in the lab. In one test, a clean glass window was dunked in an oily mixture for 46 hours. It ended up absolutely covered in gunk. The researchers repeated the test on a glass window whose surface was coated with micropancakes. That one stayed completely clean.

"Something like this would be extremely useful in areas that are remote or hard to access," says Gareth McKinley at the Massachusetts Institute of Technology in Cambridge. He's a mechanical engineer who did not work on the new glass. "It's simply too hard," he notes, "to send a window cleaner into some locations underground or underwater — human or robot."

Akhtar thinks the new technology could be useful for self-cleaning windows on ships and ocean-exploration vessels. It might even keep algae or bacteria from growing on the glass lenses of underwater cameras and sensors. This kind of buildup, called biofouling, can interfere with how the lenses work.

The micropancakes still have room for improvement, though. McKinley notes that the new surface slowed down the dirtying of the glass but didn't prevent it completely. Holst's team hopes that future versions of their product will work even better. ■

The mosquito *Aedes aegypti* (seen on human skin) transmits several dangerous diseases, including Zika. Researchers have shown that these bloodsuckers can't bite through a fabric made of graphene.

NECHAEV-KON/ISTOCK/GETTY IMAGES PLUS

Mosquitoes can't bite through this material

Atom-thick fabric keeps mosquitoes from our skin

By Silke Schmidt

Mosquito bites aren't just a nuisance on summer hikes or backyard patios. For millions of people around the world, they can bring deadly diseases. Now, researchers have proposed a new strategy to keep our skin bite-free: Add a layer of graphene to your outerwear.

Graphene is a single layer of carbon atoms. Identified in 2004, graphene earned its two discoverers the 2010 Nobel Prize in physics. Millions of graphene layers form the graphite in school pencils. Attaching oxygen atoms to graphene produces a film known as graphene oxide (GO). And that's the basis of the new fabric.

Cintia Castilho is a graduate student in engineering at Brown University. That's in Providence, R.I. She was intrigued when Robert Hurt, her advisor, mentioned mosquito protection at a team meeting. "Our group had used GO in clothing that protects against chemical vapors," Castilho recalled. "From that and other applications, we knew it's an extremely versatile material." Yet, could it keep a mosquito from biting?

This project showed Castilho that any idea may be worth trying, even when some of your colleagues are skeptical. Her team described its success in the September 10, 2019 *Proceedings of the National Academy of Sciences*.

The mosquito's unique piercing toolkit

Castilho learned that a mosquito's mouth consists of more than a straw to slurp up blood. In fact, there are six mouthparts. They are, in some ways, like dinnerware. "A mosquito holds your skin with two mouthparts that act as a fork," she explains. Another four parts have knife-like serrated edges. They cut into your skin.

Only a female needs a blood meal. It will nourish her eggs. The mouthparts of males can't penetrate skin. Some biting flies have mouthparts similar to those of a female mosquito. But none are as unique and powerful as hers.

Some female mosquitoes strongly prefer human blood. A prime example is *Aedes aegypti*, which transmits many dangerous diseases. They include Zika, dengue fever, yellow fever and chikungunya.

"We think that *Aedes aegypti* comes from Africa and reached other continents with our ancestors," says Laura Harrington. People likely transported it in human-made water containers, she says. "It's basically a domesticated animal that can't survive without people."

Harrington is an insect scientist, or entomologist, who wasn't involved in the new project. She works at Cornell University in Ithaca, N.Y. The mosquito *A. aegypti* can feed on many mammals, she's found. But it prefers people 98 percent of the time. During millions of years of evolution, 3,500 mosquito species have developed different body adaptations and behaviors. These help them feed on whatever animal they prefer.

Female mosquitoes transmit diseases through a channel formed by their mouthparts. They inject their saliva (spit) before pumping the host's blood out. The mosquito's saliva contains molecules that stimulate blood flow and prevent clotting. But sometimes that spit carries viruses from a blood source on which the insect previously fed.

We try to prevent mosquito-borne disease with protective clothing, chemical repellents, bed nets — even some drugs. But those drugs are too expensive for most people in poor countries. The same is true for vaccines. They are difficult and costly to develop. And for many diseases, they don't even exist.

Harrington is excited about the new study because graphene-based materials are a new idea. "We're losing the battle against infectious diseases," she says. "Any promising new technology for mosquito protection is something we should pursue."

Graphene oxide vs. mosquito

To test graphene oxide's prowess, Castilho's group needed human recruits willing to expose their arms to mosquitoes. The researchers covered a volunteer's skin with cheesecloth, a light, airy fabric. Then they let 100 mosquitoes loose on the volunteer for five minutes. (The researchers made sure those mosquitoes were free of dangerous viruses.) A volunteer would end up with about 10 bites per square inch of exposed skin.

Then the researchers ran the test again. This time they used some cheesecloth to hold the GO film in place. After another five minutes with the insects, the volunteer would have no mosquito bites.

The researchers thought the film would be a mechanical barrier — like a wall. In that case, mosquitoes should still land on the arm. In fact, almost no mosquitoes landed on a GO-protected arm.

To better understand why, the researchers added water to the film. That simulates human sweat, which is known to attract mosquitoes. And now mosquitoes did land on the arm. They also were able to bite. So while dry GO was fully protective, wet GO was not. (Mosquito bites were still less frequent with wet GO than with cheesecloth alone.)

FROM TOP: FRANK600/ISTOCK/GETTY IMAGES PLUS; C. CASTILHO AND R. HURT/BROWN UNIV.

For five minutes, the researchers gave 100 mosquitoes access to a human arm. The insects did not bite when the arm was protected by dry graphene oxide (GO) film plus cheesecloth. With the cheesecloth only, there were plenty of itchy bites.

A microscope showed what happened. Wet GO has a mushy structure that makes it a less effective shield. To restore its original protection, the researchers changed GO's chemistry. They applied a vapor to the film. That removed most of the oxygen molecules. It was now what chemists call reduced graphene oxide (rGO). Wet rGO doesn't get mushy. And the wet rGO film kept mosquitoes from biting, even when they landed.

These results showed that wet rGO was the mechanical barrier the researchers had expected to find. Dry GO, on the other hand, blocks some (smelly) chemicals that our skin emits with sweat. These chemicals help mosquitoes find nearby people to bite. Other attractants include heat, humidity, carbon dioxide and visual cues.

Castilho is confident that rGO will work for other kinds of mosquitoes, too. The size of the mouthparts and the sensing system are very similar in all species.

Two kinds of barriers to explore

Matthew Daly is a materials engineer who studies graphene at the University of Illinois at Chicago. He was not involved in the project but is impressed by its findings. "The science is excellent," Daly says. "And the use of graphene for mosquito control is new and timely."

The Brown University researchers know that rGO is not a breathable material. That's why they plan to test if other chemical changes can keep GO fully protective in moist conditions. Daly notes that one of the challenges will be finding the right chemical recipe. The ideal material needs to stick together while remaining breathable.

Rakesh Joshi is also impressed with the work, especially the potential of rGO. He is a materials scientist at the University of New South Wales. That's in Sydney, Australia. "I think it's possible to make composite fabrics with an rGO coating," Joshi says. Composite materials contain two or more components with different properties.

Joshi thinks teaming up with textile companies would be a great next step. More research might show which graphene-based material is the best barrier. The company could help get it into clothing that's comfortable to wear and easy to clean.

The goal is durable and affordable clothing that deters mosquitoes and protects against diseases. Future studies of the technology also may lead to products that work directly on the skin. ■

Sunflower-like rods could boost collection of sun's energy

They keep bending toward the sun to soak up maximum energy

By Sofie Bates

The stems of sunflowers move throughout the day so that their flowery heads always squarely face the sun, wherever it is in the sky. This phototropism helps the plants soak up maximum amounts of sunlight. Scientists had trouble copying this ability with synthetic materials. Until now.

Rods of a new solar-energy-collection material seen at front of this drawing were inspired by sunflowers.

Researchers at the University of California, Los Angeles have just developed a material with the same type of sun-tracking ability. They describe it as the first synthetic phototropic material.

When shaped into rods, their so-called SunBOTs can move and bend like mini sunflower stems. This allows them to capture about 90 percent of the sun's available light energy (when the sun is shining on them at a 75-degree angle). That's more than triple the energy collection of today's best solar systems.

YUSEN ZHAO, YOUSIF ALSAID AND XIMIN HE

People have often been inspired by the world around them. Scientists, too, may look to plants and animals for clues to new discoveries. Ximin He is a materials scientist. She and her team found the idea for their new material in sunflowers.

Other scientists have made substances that can bend toward light. But those materials stop at a random spot. They don't move into the best position to catch the sun's rays and then stay there until it's time to move again. The new SunBOTs do. The whole process happens almost at once.

In tests, the scientists pointed light at the rods from different angles and from a range of directions. They also used different light sources, such as a laser pointer and a machine that simulates sunlight. No matter what they did, the SunBOTs followed the light. They bent toward the light, then stopped when the light stopped moving — all on their own.

On November 4, 2019, He's team described how these SunBOTs work in *Nature Nanotechnology*.

How SunBOTs are made

SunBOTs are made from two main parts. One is a type of nanomaterial. It's made from billionth-of-a-meter size pieces of a material that responds to light by heating up. The researchers embedded these nanobits into something known as a polymer. Polymers are materials made from long, bound chains of smaller chemicals. The polymer that He's team chose shrinks as it heats up. Together, the polymer and nanobits form a rod. You might think of it as being something like a cylinder of solid glitter glue.

When He's team beamed light on one of these rods, the side facing the light heated and contracted. This bent the rod toward the beam of light. Once the top of the rod pointed directly at the light, its underside cooled and the bending stopped.

He's team made its first version of the SunBOT using tiny pieces of gold and a hydrogel — a gel that likes water. But they found that they also could make SunBOTs from many other things. For instance, they substituted tiny pieces of a black material for the gold. And instead of the gel, they used one type of plastic that melts when it gets hot.

This means scientists can now mix and match the two main parts, depending on what they want to use them for. For example, ones made with a hydrogel might work in water. SunBOTs made with the black nanomaterial are less costly than ones made with gold.

This suggests that "scientists can use [SunBOTs] in different environments for different applications," says Seung-Wuk Lee. He's a bioengineer at the University of California, Berkeley, who did not work on the SunBOTs.

Little SunBOTs for a sunnier future

UCLA's He envisions that SunBOTs could be lined up in rows to cover an entire surface, such as a solar panel or window. Such a furry coating would be "like a mini sunflower forest," she says.

Indeed, coating surfaces with SunBOTs might solve one of the biggest problems in solar energy. While the sun moves across the sky, stationary things — such as a wall or rooftop — don't. That's why even today's best solar panels capture only about 22 percent of the sun's light. Some solar panels could be pivoted by day to follow the sun. But moving them requires a lot of energy. SunBOTs, in contrast, can move to face the light all on their own — and they don't need added energy to do it.

By tracking the sun, SunBOTs are able to absorb almost all of the sun's available light, says Lee, at Berkeley. "That is a major thing that they achieved."

Ximin He thinks that unmoving solar panels might one day be upgraded by coating their surfaces with a SunBOT forest. By putting the little hairs on top of the panels, "We don't have to move the solar panel," she says. "These little hairs will do that job." ■

This bandage uses electrical zaps to heal wounds faster

The movements of a patient's body power this setup

By Ilima Loomis

One day, bandages could speed healing by zapping wounds with gentle bursts of electricity. They wouldn't even need a battery pack. A patient's own body movements would power the device. And such a system may not be that far off. Researchers have already produced a working prototype.

"We thought it might work, but we didn't know how good it would be," says Xudong Wang. "Then we saw the result and thought, 'Wow! That's really fascinating.'" Wang is a materials scientist at the University of Wisconsin–Madison. He leads the group working on this new bandage.

His team has been developing a nanogenerator for many years. It uses body movements to generate electricity. These engineers were hoping to use the device to power wearable electronics. Then they realized it might be even more useful as medicine.

Scientists have known for decades that electricity can stimulate wounds to heal. For instance, electricity fosters cells on the skin's surface to grow. This "electrotherapy" has relied on bulky devices that need a power source. That's why it's usually used only in hospitals for treating serious injuries.

The Wisconsin engineers have now created a bandage with small electrodes. "Our device is very simple," Wang says. "It's a flexible, wearable device." Its electrodes connect to nanogenerators inside the bandage. Those nanogenerators turn movement into electricity. That power then travels through the electrodes into the skin as mild electrical pulses.

Wang's group tested the bandage on more than 10 injured rats. As these "patients" breathed in and out, their wounds received tiny electrical shocks. Another group of injured rats served as controls. That means they received no treatment.

The wounds of rats in the control group took about two weeks to heal. Those on rats treated with the electrified bandages healed in just three days.

Wang's team described its new findings online November 29, 2018 in the journal *ACS Nano*.

No pain, big gain

The new bandage not only is simple, flexible and wearable, but also gentle. Compared to the electrical stimulation delivered by hospital machines, this bandage gives a much smaller electrical pulse. That should help protect healthy tissue from being damaged by the zaps. In fact, Wang says: "Usually, you don't even feel it."

This is "a good first step toward an interesting and potentially promising approach to wound care," says Tyler Ray.

SAM MILLION-WEAVER/UNIV. OF WISCONSIN–MADISON

A new bandage uses electrical pulses to help wounds heal faster. It's powered by the patient's natural body motions.

He says you might think of it as a "smart Band-Aid." Ray is a mechanical engineer at the University of Hawaii at Manoa who had no role in creating the new system. He said he'd like to see the bandage tested on larger animals or people, and lots of them.

Wearable technology has been around for several years. Usually these are fairly stiff devices, like a Fitbit, Ray notes. Researchers across many fields are now working on building soft, flexible devices for people to wear on their skin.

Wang next wants to design a nanogenerator that's even more sensitive. His goal is to build one that can generate electricity from the tiniest movements — like blood moving under your skin. That way, the bandage could be powered by something as small as someone's pulse. ■

Heat signatures help track down deadly land mines

A drone-mounted infrared camera could aid in locating old explosives so they can be removed

By Sid Perkins

Even when a war is over, the killing can continue. Land mines left behind in former conflict zones can still claim casualties. Now, researchers have developed a technique that can help spot one type of plastic-based mine. It's a type that is very hard to spot. One day, this new technique might be used to locate and eliminate those explosives — especially in fields where children now play.

In late 1979, troops from the Soviet Union invaded Afghanistan, a nation in south-central Asia. In the more than nine years the Soviet troops were there, they spread a lot of land mines, says Alex Nikulin. He's a geophysicist at Binghamton University in New York. These weren't big explosives, the types designed to target tanks. Instead, the soldiers' intent was to hurt or kill people. Made largely of plastic, these mines can be quite difficult to find the usual way — walking around with metal detectors.

Soviet helicopters dropped millions of these mines, each small enough to fit into the palm of an adult's hand. Their official name is the PFM-1 mine. But owing to their shape, people often call them "butterfly mines," notes Jasper Baur. He's a geology student at Binghamton University. Baur was part of a team — one that included Nikulin — that developed the new mine-spotting technique.

The Soviets often painted the butterfly mines with colors that helped them blend into the background. That helps the human eye miss them, explains Baur. His team's innovation relies on thermal inertia, a trait that many materials have. Inertia is the tendency of an object to remain in place, even if something is pushing on it. Thermal inertia is the tendency of an object to remain at a constant temperature even as its environment is warming or cooling down. So when air temperatures are changing fairly rapidly, an object lying on the ground may tend to retain its temperature longer than the rocks and soil around it. And a special camera that senses heat — or infrared wavelengths — should be able to highlight objects that are cooler or warmer than the ground around them.

To test the idea, the team mounted an infrared camera on a drone. Then they flew the robotic craft back and forth over an area. They had already placed a few faux mines at the site — ones with no explosives. They also added a few of the small metal racks used to hold such mines before they are dropped from a copter. Finally, the researchers used computer software to create video images from the drone's camera data.

When the team analyzed the infrared images, it was often easy to eyeball the mines. They had been cooler than the surrounding rocks, making them show up as a different color on the image. That color difference was often stark in images taken some 30 minutes to 2 hours after sunrise. That's when the land was warming quickly. The technique also worked well when data had been collected soon after sunset, as the land was cooling. These are times when the temperature difference between the mines and the rocks was typically greatest.

This sign in English and Arabic warns pedestrians that live land mines still litter this field in Afghanistan.

MANXMAN/ISTOCK/GETTY IMAGES PLUS

PFM-1 "butterfly" mines (a non-explosive example at bottom right) were dropped from helicopters in Afghanistan by the millions. A metallic rack (top) is filled with such mines. It was used to dispense the mines from helicopters.

In tests, the researchers could detect about eight out of every 10 faux mines. And they picked out the metallic racks in those images each and every time. Baur's group shared its new findings in Washington, D.C., in December 2018 at the annual meeting of the American Geophysical Union.

Speeding the search for mines

Based on these data, the team estimates that its drone-based camera system can scan an area about 20 meters (66 feet) long and 10 meters (33 feet) wide in 10 minutes or less. That would greatly speed up the search for mines, Baur and Nikulin say. To carefully look for mines on foot in an area that size (about one-third the size of the infield of a baseball field) could easily take hours, they note.

Sayed Agha Atiq is a technical advisor to the United Nations' de-mining operations in northeastern Afghanistan. There, he works out of the city of Kunduz. The Binghamton team's technique is "interesting and somewhat promising," Atiq says. Still, he cautions that it might be challenging to use in the mountainous areas where he works.

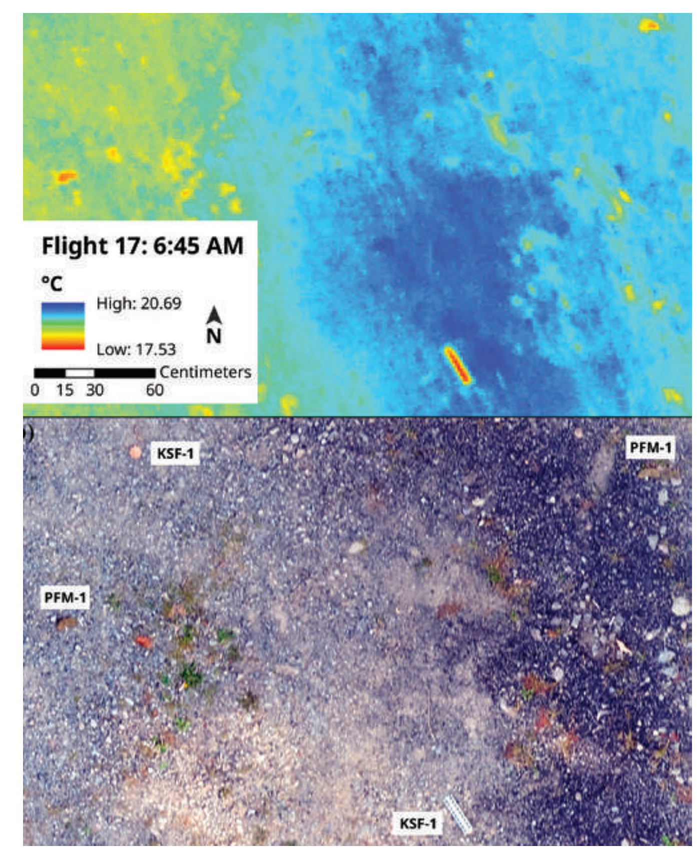
Mohammad Wakil Jamshidi agrees and explains why. Based in Kabul, Afghanistan's capital, he and his boss supervise United Nations de-mining efforts throughout Afghanistan. They also provide technical support for the country's program to locate and remove mines. And here's one potential problem, Jamshidi says: Sunlight may reach the valley floor for only a short time each day. Plus, trees and bushes may shade the ground. Such conditions would limit the amount of sunlight reaching the surface to heat it up. So many northeastern Afghan sites may not experience the rapid ground heating and cooling on which this technique relies. Jamshidi would expect, therefore, to see less thermal inertia of mines there than in regions where the terrain is flat. Vegetation would also make it difficult for a drone-mounted camera to see the ground.

Also, for much of the year snow covers the ground. That blanket, Jamshidi points out, will block the view of any mines it covers. Finally, mines on steep slopes can become buried over time. In that case, soil would block the view.

All of these factors might prevent detection of mines by the new technique, he suspects.

Fazel Rahman works in Kabul for Afghanistan's de-mining agency, the National Mine Action Authority. He says that a field trial of the team's mine-finding technique would help determine how useful this novel technology might be. ■

In the infrared image at top, PFM-1 "butterfly" mines and metallic racks used to disperse them stand out clearly (red blobs and rectangles), but in the visible-light image at bottom the munitions (labeled) are largely invisible.



FROM TOP: T. DESMET *ET AL*/*JOURNAL OF CONVENTIONAL WEAPONS DESTRUCTION* 2018; A. NIKULIN *ET AL*/*REMOTE SENSING* (2018)

Ultrasound might become a new way to manage diabetes

At least in mice, the energy releases insulin to help control blood sugar

By Silke Schmidt

During pregnancy, parents love to take a first peek at the baby developing inside mom's body. Special sound waves, with a frequency too high for the human ear to hear, make this imaging possible. But these ultrasound waves can do much more. Researchers are now investigating how well this type of energy can control diabetes before the disease damages the body.

In most people with diabetes, the body doesn't respond normally to the hormone insulin. In some people, the body doesn't make insulin at all. Insulin's job is to move a simple sugar (glucose) circulating in our blood into cells throughout the body. Glucose fuels the growth and activity of those cells. If insulin can't do its job, glucose builds up in the blood. Over time, that can damage organs.

Vesna Zderic is a biomedical engineer at George Washington University. That's in Washington, D.C. Zderic uses her engineering knowledge to solve medical problems. In one of her projects, she has focused on the cells that make and release insulin. These cells, called beta cells, live in the pancreas. This organ, which sits behind the stomach, is about 15 centimeters (6 inches) long.

Other researchers had shown that ultrasound could prompt brain cells to release certain signaling chemicals. Zderic and her colleagues wondered if ultrasound might similarly trigger beta cells to release insulin. Many diabetes drugs affect beta cells this way. But those drugs can be costly, especially for lifelong treatments. And diabetes drugs often have unpleasant side effects.

If ultrasound could trigger beta cells to release insulin, it might halt the common form of diabetes in its tracks. That would be important, Zderic reasoned. People with advanced diabetes can develop serious damage to the heart and kidneys. They may even become blind. At that point, many of their beta cells will have died. Their body will no longer be able to make much insulin, if any.

So Zderic's team figured out a way to treat cells inside the pancreas with ultrasound. And in new tests, the researchers confirm that the technique works—at least in mice.

"Common diabetes drugs often upset the digestive system or harm the kidneys," observes Tania Singh. She's a biomedical engineer who worked in Zderic's lab as a student. Like her mentor, she hopes the ultrasound treatment might one day offer a way to avoid these drugs' side effects.

The need to manage glucose

Every time you eat a meal, your digestive system breaks down food into its chemical building blocks. One of these is glucose. Once released in the gut, glucose will travel through the blood to body parts that need energy to function. The heart pumping at 60 beats per minute, for instance, requires a regular supply of energy from food sources.

Throughout the body, cells need to take up glucose to turn its chemical energy into a usable form. The hormone insulin is a glucose sensor. As blood glucose levels rise, insulin acts as a key to unlock the cells and let glucose in. That removes the sugar from the circulating blood.

But that system is broken in diabetes.

In type 1 diabetes, the body's own immune system kills the insulin-making beta cells. That means the body doesn't have the key for managing glucose. In type 2 diabetes, the body makes insulin, but cells don't respond to it as they should. The key is broken.

People with diabetes monitor their blood sugar to avoid organ damage. Many take drugs that affect insulin, a hormone that controls blood sugar. Researchers are exploring ultrasound as an alternative to those drugs.

AZMANJAKA/E+/GETTY IMAGES PLUS; ADAPTED BY L. STEENBLIK HWANG

When the key for removing glucose is missing or broken, sugar levels in the blood can rise to dangerous levels. Very high levels can damage tissues. (Doctors diagnose diabetes when blood glucose levels exceed 125 milligrams per deciliter after fasting. Normal levels are 100 or less.)

Earlier, Zderic's team had zapped beta cells growing in a dish with a five-minute beam of continuous ultrasound. That boosted the cells' insulin release. The researchers reported the findings two years ago. Singh tackled the next step: testing to see if beta cells would do the same thing in the pancreas of healthy mice. The team chose this animal because its pancreas is similar to the human organ.

For the test, they treated one group of mice with ultrasound and left a second group untreated. (Such untreated groups are known as controls.) After numbing the mice, Singh measured the insulin levels in each animal's blood. Then she put both groups of mice on small stretchers and placed an ultrasound probe on their bellies. She then turned on the ultrasound in the treatment group for five minutes. Afterward, she again measured blood insulin levels in both groups.

Treatment upped insulin levels by about 20 percent. That increase was similar to the results for beta cells tested in a dish. At the same time, insulin levels fell in the control animals. The ultrasound increased the temperature of the surrounding tissue. But it didn't cause any skin burns in the mice. And the pancreas and nearby organs weren't injured.

Singh described her team's findings at a meeting of the Acoustical Society of America in May 2019. The meeting took place in Louisville, Ky.

New method needs more testing

These results are intriguing, says Gabriela Da Silva Xavier. She works at the University of Birmingham, in England. There, she studies how diabetes disturbs the normal response of cells to glucose and insulin. Still, as promising as the data appear, Da Silva Xavier thinks the researchers will need to answer many more questions.

For one, beta cells make up only 1 to 2 percent of cells in the pancreas. "It's really important to check if ultrasound triggers the release of chemicals from any other cells," Da Silva Xavier says. After all, those other cells perform important tasks. Some digest food. Some produce other hormones.

That release of other chemicals could happen if ultrasound affects the cells' outer membrane. If the cell were a soap bubble, the membrane would be the soap layer that surrounds the pocket of air. Beta cells may release insulin because the ultrasound vibrations make their membranes leaky. If that happens to membranes of other cells in the pancreas, their contents may spill out, too.

Ultrasound is used to image a baby in the womb (shown). But it may have therapeutic uses, too, such as to control blood sugar in people with diabetes.

RAWPIXEL/ISTOCK/GETTY IMAGES PLUS

> ... Zderic's team figured out a way to treat cells inside the pancreas with ultrasound. And in new tests, the researchers confirm that the technique works — at least in mice.

But a different mechanism might also explain the effect of ultrasound on insulin, says Julianna Simon. She is an acoustics expert at Pennsylvania State University, in State College. She was not involved in the project.

"I think the treatment basically massages the pancreas," she says. "It sends energy, in the form of a pressure wave, into the body." There, she says, it likely "compresses and expands the tissue." This pancreas massage might cause the release of insulin without changing the cell membrane.

Zderic's team is testing several theories for the effect of sound waves on the cells in the pancreas. The researchers also will study how to target only the beta cells. They'll also gauge how long they need to zap them to lower blood glucose levels.

They plan to test the method repeatedly on mice that are already obese or diabetic. That will better mimic treating people recently diagnosed with diabetes. Next, the researchers hope to study larger animals, such as pigs. If all those tests go well, Zderic's team may begin safety studies in human volunteers.

What's the team's long-term vision? "It may be possible to implant a device on the pancreas that's linked to a blood glucose monitor," Singh says. "When the sensor detects high glucose levels, the device would apply ultrasound to release insulin. When glucose levels are back to normal, it would stop."

Says Da Silva Xavier, being able to do that "would be brilliant." ■

Weird little fish inspires the development of super-grippers

One version can hold a 5-kilogram (11-pound) rock or firmly adhere to whale skin

By Sid Perkins

Suction cups are pretty handy. They can hold up a shaving mirror in the shower or hang a small picture on a living-room wall. But these devices don't work on all surfaces or hold heavy objects. At least they didn't until now. Researchers report having built super-suction devices modeled on the rock-grabbing tricks of the aptly named clingfish.

The finger-sized northern clingfish (*Gobiesox maeandricus*) lives along the Pacific coast of North America. It ranges from southern Alaska to just south of the U.S.-Mexico border, notes Petra Ditsche. As a biomechanicist, she studies how living things move. She investigated the clingfish's gripping prowess while working at the University of Washington in Friday Harbor.

Northern clingfish tend to live in intertidal zones. Such coastal areas are submerged during high tide but dry out at low tide. That can make them tough places to hang out. Currents can swish back and forth powerfully between rocks there, Ditsche notes. And the pounding surf can easily wash away anything that isn't firmly affixed to the rocks. Over many generations, clingfish developed the ability to hold onto the rocks, despite buffeting from waves and strong currents. A fish's pectoral fins and pelvic fins form a suction cup of sorts under its belly. (Pectoral fins project from the side of a fish, just behind its head. Pelvic fins project underneath a fish.)

The fins' hold is powerful, Ditsche's tests show. Even when a rock's surface is rough and slick, these fish can withstand a pulling force equal to more than 150 times their weight!

Biomimicry is the creation of new designs or technologies based on those seen in living organisms. For their biomimicry, Ditsche and Adam Summers took a lesson from this odd little creature. They found the key to the clingfish's super grip in the fringe of the cup-like structure formed by its belly fins. That fringe formed a good seal at the edge of the cup. A small leak there would allow gases or liquids to flow out. That would ruin the pressure difference between the underside of the cup and the world outside of it. It's that pressure difference that ultimately holds the fish to a surface.

Tiny structures called papillae cover the edges of the fish's fins. Each papilla measures about 150 micrometers (6 one-thousandths of an inch) across. The papillae are covered with small rods. Even tinier filaments cover the rods. This ever-branching pattern allows the edge of the suction cup to flex easily. That means it can even mold to fit rough surfaces — such as your average rock.

An ever-branching pattern would be difficult to manufacture, Ditsche and Summers realized. So instead, they chose to make their suction cup out of a super-flexible material. This had a downside, however. A suction cup made from it would warp if anyone tried to pull it off a surface. And that would break the seal needed for the cup to work. To solve this problem, Ditsche and Summers took yet another hint from the clingfish.

Nature has reinforced fins of this fish with bones. This prevents warping of the super-flexible fin tissue. To serve the same reinforcing role, the researchers added an outer layer of stiff material to their device. It prevents almost all the warping that could jeopardize the device's ability to grip. To help limit slippage in their flexible material, they mixed in some tiny bits of a tough material. It ups the friction exerted against the surface to which it's attached.

Ditsche and Summers described their innovative device September 9, 2019 in *Philosophical Transactions of the Royal Society B*.

Long-lasting suction

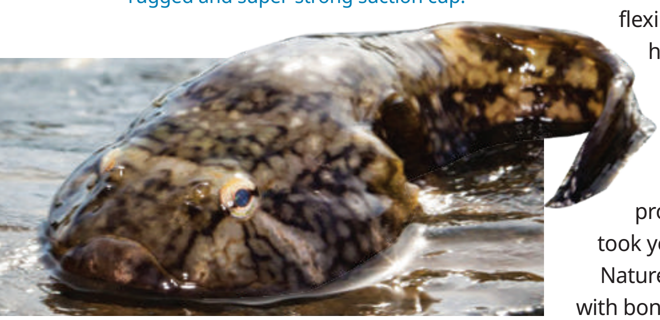
The new device can adhere to rough surfaces so long as any existing bumps are smaller than 270 micrometers (0.01 inch) across. Once attached, the cup's grip can be quite long-lasting. One suction cup held its grip on a rock underwater for three weeks, Ditsche notes. "We only stopped that test because someone else needed the tank," she explains.

In a more informal test, one of the suction cups remained stuck to Ditsche's office wall for months. She only took it down when she moved out of that office.

"I'm amazed at how well the design works," says Takashi Maie. He's a vertebrate anatomist at the University of Lynchburg in Virginia. He has studied other fish with similar suction-cup-like fins. Those fish, however, use their oddly arranged fins to help them climb waterfalls in Hawaii.

Ditsche and Summers can imagine lots of uses for their new grippers. In addition to handling jobs around the house, they could help strap down cargo in trucks. Or, they could attach sensors to ships or other underwater surfaces. The suction cups might even be used to attach migration-tracking sensors to whales, the researchers propose. That means that scientists wouldn't need to pierce the animal's skin to attach a tag.

The team has written "a really neat paper, from start to finish," says Heiko Schoenfuss. He's an anatomist at St. Cloud State University in Minnesota. "It's great to see the translation of basic research to something that could be immediately applicable to the real world." ■



This finger-sized northern clingfish was the inspiration for the new technology. Its rock-grabbing abilities led to the creation of a rugged and super-strong suction cup.

PETRA DITSCHE

Tiny vest could help sick babies breathe easier

It works by gently pulling on baby's belly to draw in air

By Sharon Oosthoek

Babies that are born sick or prematurely often have lung problems. Many need help just to take a breath. There are machines to help these infants. But using them can come at a cost. "[Their] masks and tubes often leave babies with deformed noses," notes Doug Campbell. And, he adds, "The wires and machinery mean their mothers can't hold or breast-feed them."

Campbell is a pediatrician in charge of an intensive care unit for babies at St. Michael's Hospital in Toronto, Canada. He thought there must be a better way to bring life-saving support to these babies. His team has just begun testing one promising alternative.

Called NeoVest, it looks a bit like a tiny lifejacket. Campbell's team fits the vest around a baby's belly. The vest is airtight, so when it pulls away from the baby, it creates a vacuum. That, in turn, gently pulls on the belly. This motion draws air into the baby's lungs.

Elsewhere, such babies would be hooked up to another type of mechanical ventilator. Such machines push air into a baby's tiny body. The air enters through a tube attached to a mask that is sealed over the nose. These devices continue to breathe for the infants until they are strong enough to do it themselves.

NeoVest avoids the mask and all those tubes and wires that can get in the way of a baby bonding with its mother. In June 2019, the team tested the vest on the first baby. It worked well. The researchers now plan to start testing the vest on more babies.

Ventilation — a special problem for preemies

Ordinarily, a newborn figures out how to breathe at birth. But in babies born prematurely, the lungs may not be fully developed at birth. Many newborns also develop lung diseases, such as an infection, that impairs their ability to breathe well. To help these children, hospitals often use mechanical ventilators.

These have proven to be life-savers. But they can have side effects. Besides the mask, tubes and wires, a traditional ventilator is unlikely to match the precise rhythm of air intake and exhalations that a baby's body would normally develop. To compensate, doctors need to sedate babies as a way to help them deal with the severe discomfort of the ventilator being out of sync with their natural breathing rhythms.

NeoVest's co-creator is Jennifer Beck. She works at St. Michael's Keenan Research Centre for Biomedical Science. As a physiologist, she studies how the body functions. Her specialty is the science of breathing.

In healthy people, explains Beck, the brain sends a signal to a muscular wall just below the lungs. It's known as the diaphragm. Signals from the brain tell the diaphragm to contract, bringing in a breath. Other signals tell it when to relax, releasing a breath. When patients are very sick, however, the diaphragm may not respond properly to those brain signals about when to breathe.

Working with her research partner and husband, Christer Sinderby, Beck came up with a solution. A sensor attached to the baby's feeding tube picks up the brain's breathing signals. These signals match the NeoVest's rhythms of expansion and contraction to the baby's natural breath.

Adults on ventilators may have the same problem with mismatched ventilator breaths. However, the problem is bigger in babies. Why? They breathe faster and tend to have a less regular rhythm. This makes it even harder for a ventilator to match what would be their natural breathing patterns. Beck and Sinderby's invention solves that problem.

Still a work in progress

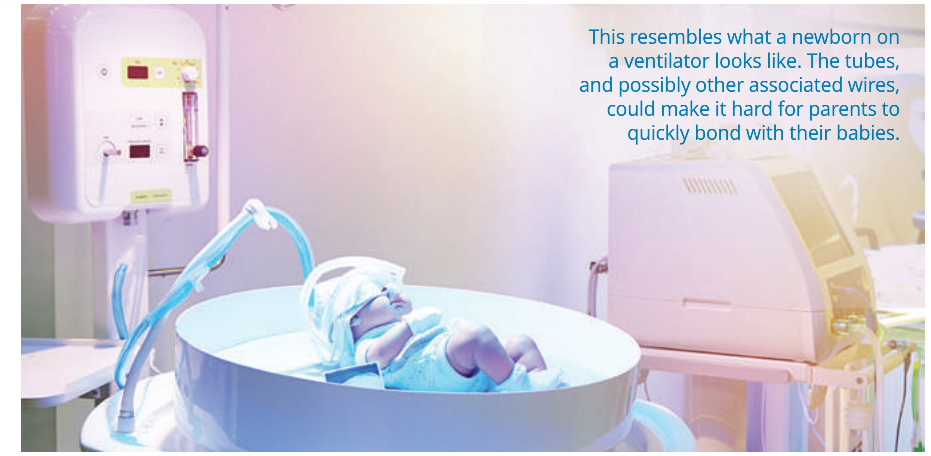
The new vest also solves another important problem with traditional forced-breath ventilators, says Michael Dunn. He's a pediatrician at nearby Sunnybrook Health Sciences Center in Toronto.

"Pushing gas in is not natural and carries a risk of injury to the lungs," he explains. "Drawing a breath in is more natural," he says. By encouraging the body to draw air in, he says, "NeoVest has great potential as a way of protecting the lung from injury."

Still, there are potential drawbacks, he notes. Babies, especially premature ones, have very sensitive skin. The rhythmic pulling on the skin might injure the skin underneath the vest.

That is one of the things Beck will be watching for closely in the St. Michael's tests. She also will be watching to make sure the vests are properly sealed so they do in fact create a vacuum when they pull away from the baby's belly.

"We don't usually think about breathing," says Beck. "It's an automatic process. But what happens when you can't breathe? I want to help the oldest patients down to the tiniest, most vulnerable ones." ■



This resembles what a newborn on a ventilator looks like. The tubes, and possibly other associated wires, could make it hard for parents to quickly bond with their babies.

SERGEYRYZHOV/ISTOCK/GETTY IMAGES PLUS

This bionic mushroom makes electricity

Scientists had to figure out how to 3-D print bacteria onto a curved home of fungus

By Dan Garisto

Some bacteria have a superpower that scientists would love to harness. These microbes capture energy from light, just as plants do. Scientists have wanted to tap these bacteria to make electricity. But in previous research, the bacteria didn't survive long on artificial surfaces. Researchers have now moved them to a living surface — a mushroom. Their creation is the first mushroom to make electricity.

Sudeep Joshi is an applied physicist. He works at the Stevens Institute of Technology in Hoboken, N.J. He and his colleagues turned that mushroom — a fungus — into a mini energy farm. This bionic mushroom combines 3-D printing, conductive ink and bacteria to generate electricity. Its design could lead to new ways of combining nature with electronics.

Cyanobacteria (sometimes called blue-green algae) make their own food from sunlight. Like plants, they do this using photosynthesis — a process that splits water molecules, releasing electrons. The bacteria spit out many of these stray electrons. When enough electrons build up in one place, they can create an electrical current.

The researchers needed to clump a lot of these bacteria together. They decided to use 3-D printing to deposit them precisely onto a surface. Joshi's team chose mushrooms for that surface. After all, they realized, mushrooms naturally host communities of bacteria and other microbes. Finding test subjects for their tests was easy. Joshi simply went to the grocery store and picked up white button mushrooms.

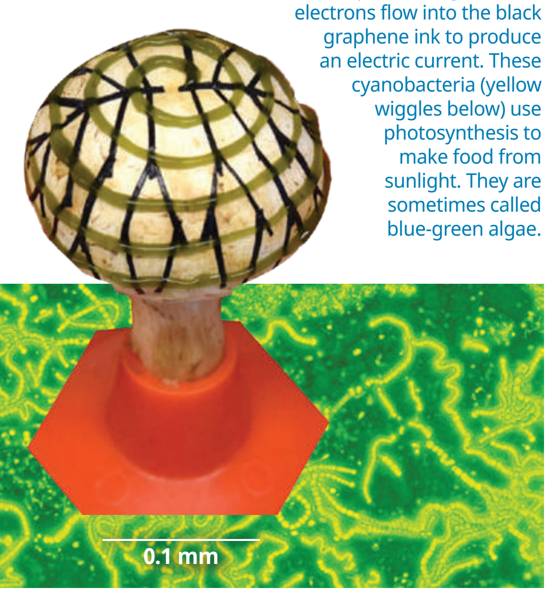
Printing on those mushrooms, though, turned out to be a real challenge. 3-D printers have been designed to print on flat surfaces. Mushroom caps are curved. The researchers spent months writing computer code to solve the problem. Eventually, they came up with a program to 3-D print their ink onto the curved mushroom tops.

The researchers printed two "inks" onto their mushrooms. One was a green ink made of cyanobacteria. They used this to make a spiral pattern on the cap. They also used a black ink made of graphene. Graphene is a thin sheet of carbon atoms that's great at conducting electricity. They printed this ink in a branching pattern across the mushroom top.

Then it was time to shine.

"Cyanobacteria are the real hero[es] here," says Joshi. When his team shone light on the mushrooms, the microbes spit out electrons. Those electrons flowed into the graphene and created an electric current.

The team published its results November 7, 2018, in *Nano Letters*.



Researchers 3-D print a green spiral of cyanobacteria onto a mushroom. The microbes give off electrons when exposed to light. Those electrons flow into the black graphene ink to produce an electric current. These cyanobacteria (yellow wiggles below) use photosynthesis to make food from sunlight. They are sometimes called blue-green algae.

Current thinking

Experiments like this are called "proof of concept." They confirm an idea is possible. The researchers showed their idea worked, even if it's not yet ready for practical use. Achieving even this much took a few clever innovations. The first was getting the microbes to accept being rehoused on a mushroom. A second biggie: figuring out how to print them on a curved surface.

To date, Joshi's group has generated a roughly 70 nanoamp current. That's small. *Really small*. It's about a 7-millionth the current needed to power a 60-watt light bulb. So clearly, bionic mushrooms won't be powering our electronics right away.

Still, Joshi says, the results show the promise in combining living things (such as bacteria and mushrooms) with non-living materials (such as graphene).

It's noteworthy that the researchers have convinced the microbes and mushrooms to cooperate for a short while, says Marin Sawa. She's a chemical engineer at Imperial College London in England. Although she works with cyanobacteria, she was not part of the new study.

Pairing two life forms together is an exciting area of research in green electronics, she says. By green, she's referring to an eco-friendly technology that limits waste.

The researchers printed cyanobacteria on two other surfaces: dead mushrooms and silicone. In each case, the microbes died out within about a day. They survived more than twice that long on the live mushrooms. Joshi thinks the microbes' long life on the living mushroom is proof of symbiosis. That's when two organisms coexist in a way that helps at least one of them.

But Sawa isn't so sure. To be called symbiosis, she says the mushrooms and bacteria would have to live together a lot longer — at least a week.

Whatever you call it, Joshi thinks it's worth tweaking. He thinks this system can be greatly improved. He's been gathering ideas from other researchers. Some have suggested working with different mushrooms. Others have advised tweaking the genes of the cyanobacteria so that they make more electrons.

"Nature gives you lots of inspiration," Joshi says. Common parts can work together to produce surprising results. Mushrooms and cyanobacteria grow in many places, and even graphene is just carbon, he notes. "You observe it, you come to the lab and start experiments. And then," he says, if you're really lucky "the light bulb will go off." ■

FROM TOP: AMERICAN CHEMICAL SOCIETY; JOSEF REISCHIG/WIKIMEDIA COMMONS (CC BY SA 3.0)

Drones help scientists weigh whales

This may help evaluate the animals' health without disturbing them

A drone outfitted with a camera and laser rangefinder captured these images of southern right whales. Scientists used the images to develop a computer program for estimating a whale's weight. (Images/videos taken after getting a research permit.)

By Carolyn Wilke

Weighing a whale is a beast of a challenge. Scientists who study these majestic mammals can't just hoist them out of the water and plop them onto some scale. But researchers now have a method to estimate a whale's weight without disturbing it. The approach uses drone imagery of the animals at sea.

The team's members described how they did it October 1, 2019 in *Methods in Ecology and Evolution*.

This shows what you can do with technology, says Fredrik Christiansen. A marine biologist, he studies sea life. Christiansen works at the Aarhus Institute of Advanced Studies in Denmark. His team estimated a whale's weight by determining its length and width from a photo. A whale's body mass — a measure of how heavy it is for its size — can reveal if it's underfed. Being underweight can hurt its chances of reproducing and surviving at sea. "By photographing [whales] you can get a snapshot of the … health status," he says.

His team's new study provides a "really rigorous" method to calculate a whale's size, says Jeremy Goldbogen. Goldbogen was not part of the work. A comparative physiologist, he investigates how bodies work by comparing animals. He works at Stanford University's Hopkins Marine Station. That's in Pacific Grove, Calif.

Filter-feeding baleen whales can fluctuate in body mass "tremendously," says Goldbogen. At the beginning of their feeding season, whales start out thin. But they fatten up by feasting on tiny ocean animals such as zooplankton and crustaceans. As they eat, their girth — the distance around their midsection — grows. "Some species, they get impressively girthy," Goldbogen says.

The whales need those fat stores to survive and reproduce. So sizing up whales is important for conserving these species, he notes. And comparing the weights of whales over multiple years can help scientists track their health.

Whale watchers

Christiansen and his team observed southern right whales (*Eubalaena australis*) for about three months in Península Valdés. That's in Argentina. Southern right whales come to this South American spot to breed. The scientists used a drone to photograph 86 different whales. Some were mothers, others were juveniles and calves. The drone carried a laser rangefinder. This tool uses a laser to determine the distance between itself and some other object (here, the whale). With this tool, the researchers were able to convert the photos' pixels to measurements. The team could then size up the whales' body length, width and height.

A drone hovering above the whales could easily capture length and width. But height was not so easy. The researchers had to wait patiently until some animals showed their sides. "It's really quite rare that they roll on their side," says marine biologist Patrick Miller. He works at the University of St. Andrews in Scotland.

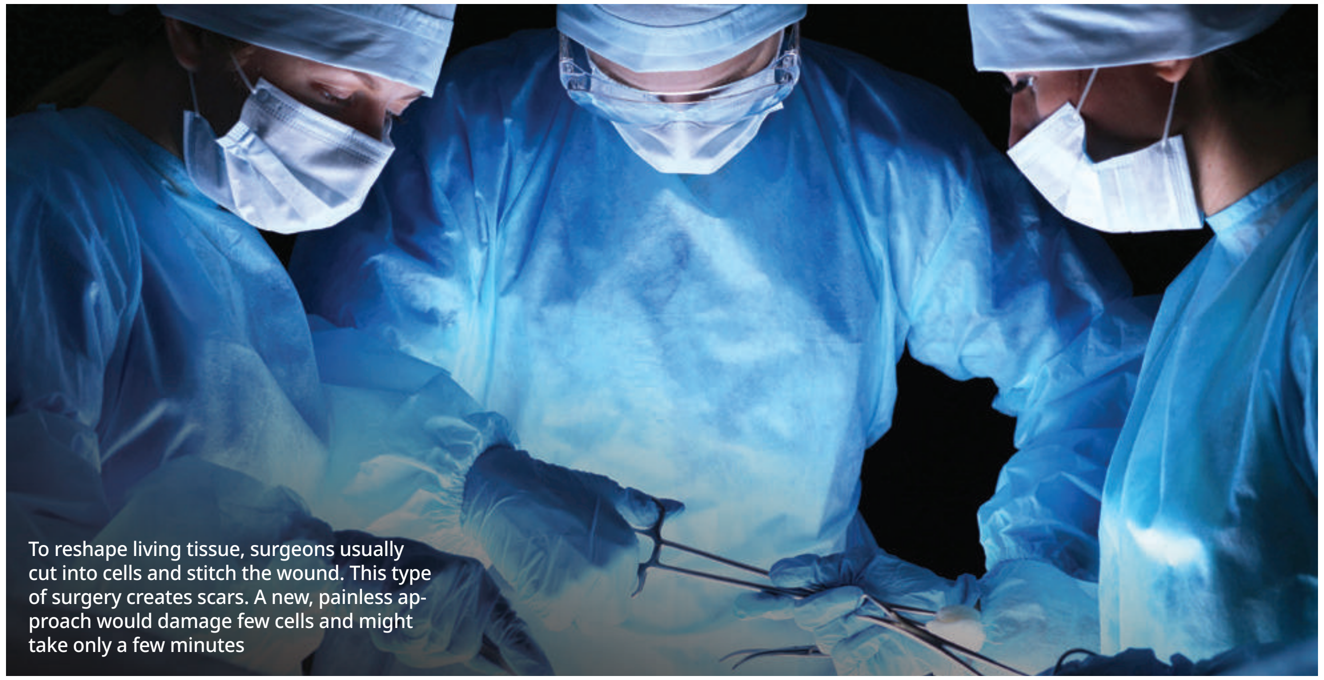
Height turned out to be important for figuring out the shape of these whales. Until now, scientists' best guess was that whale bodies are roughly cylindrical. A cylinder is basically a stack of circles. But the drone pictures revealed that some parts of whale bodies are more like a smooshed cylinder. If you took cross-sections through a whale, starting at the head and moving to the tail, many of them would look oval. The scientists used this information to estimate a whale's volume — the amount of space within its body.

The team next turned to historical data to help complete the picture. They looked at records from eight whales captured and killed for research in the 1960s. Those whales had been measured and weighed. The scientists calculated the density (weight divided by volume) of the long-dead whales. This information helped the team relate size to mass in living whales.

Knowing the body mass can help biologists better understand whales. It plays a role in how they swim and float. It's even linked to their social interactions, such as mating.

"To suddenly have this breakthrough to be able to measure their body mass, it's a game changer," says Miller. "These researchers came up with an ingenious way to do something that until now hasn't been possible." He says it shows the power of creative thinking. ■

FREDRIK CHRISTIANSEN AT AARHUS INSTITUTE OF ADVANCED STUDIES



To reshape living tissue, surgeons usually cut into cells and stitch the wound. This type of surgery creates scars. A new, painless approach would damage few cells and might take only a few minutes

ANDREI_R/ISTOCK/GETTY IMAGES PLUS

New electric tool may fix noses, ears and eyes

Painless 'surgery' reshapes tissues and might one day correct vision problems

By Silke Schmidt

Our ears and noses contain a special tissue that's softer than bone but stiffer than muscle. Reshaping this tissue for medical reasons usually requires "cut-and-sew" surgery. Healing from that type of surgery can be painful and leave scars. Soon, however, surgeons may avoid these problems by using electricity instead of a scalpel.

The special tissue is cartilage. It's difficult to reshape because its inner structure is very strong. It always bounces back into its original shape. The body has different types of cartilage. The form in our ears and nose is less rigid than the type in our joints, tendons and spinal discs.

The cartilage that separates the nostrils inside the nose is known as the septum. In some people, this tissue is off-center or crooked. Such a "deviated" septum can make breathing difficult. Some people might be born with the problem. A sports injury or other trauma might also alter the septum's shape.

Traditional septum surgery is challenging. The area that needs fixing is hard to reach. The space is tiny. Cutting into cells with blades tends to damage or kill the cells, creating scar tissue. The healing can prove painful. And mistakes can be quite visible.

Brian Wong is a surgeon who works at the University of California, Irvine. He's also an engineer who works to solve medical problems.

To avoid some of these problems, Wong had tried heating the cartilage with an infrared laser as a new way to reshape the septum without a scalpel. That's less invasive than cutting into the nose with a knife. And it worked. But the heating still damaged cells. This procedure also was expensive.

Electric current to the rescue

So Wong's team decided to try heating the cartilage with an electric current. They started by working with a sample of cartilage in a lab dish. The current indeed let Wong reshape the tissue — and with hardly any temperature increase.

That was a big surprise.

To figure out what was going on, Wong contacted Michael Hill. He's a chemist at Occidental College in Los Angeles, Calif. Hill studies how electricity affects chemical processes. And when he learned that 75 percent of cartilage consists of water, he had a hunch that the water might explain what happened. An electric current can split water into two atoms of hydrogen and one atom of oxygen. Chemists call this process electrolysis.

Hill's hunch turned out to be right.

That cartilage in our ears and noses is weblike. Its fibers are made from a protein called collagen. Electric bonds between the molecules hold those fibers together. The negatively and positively charged parts of the molecules glom together like the positive and negative poles of two magnets.

So pulling apart the collagen web is like pulling apart two magnets. "If you let go, the molecules snap back together, like the magnets would," explains Hill. "The electric bonds give cartilage the ability to hold its shape. But if we can briefly turn off the bonds, we can change that shape."

The energy to turn off those bonds came from splitting the water in cartilage. Exposing a small region of the tissue to an electric current created hydrogen atoms that were positively charged. They canceled out the tissue's negatively charged molecules. And that broke apart the electric bonds to make the cartilage malleable, like Play-Doh.

Now a surgeon could reshape the tissue. As soon as that doctor turned off the current, the electric bonds would quickly reform. The tissue's new shape also would become permanent.

Bend an ear

Hill and Wong first tested the process on the ear of a rabbit that had died. Their goal was to permanently bend the ear 90 degrees from its normal, upright shape. To do this, they made a 3-D image of the ear. Then they printed a 3-D mold of the new shape they wanted to give that ear.

Their software showed them the best place in the ear to place two tiny needles. Pulsing an electric current through these needles softened the tissue there. The software also figured out how long to send the current pulsing through those needles.

While delivering the current, the researchers bent the softened tissue into the new shape and then held it in place with the 3-D mold. Turning off the electricity allowed the cartilage to harden.

"The chemistry couldn't be simpler," Hill says. "Not so simple," he notes, "was figuring out how to zoom in on the small region we want to treat."

The researchers first described this process four years ago in the journal *Angewandte Chemie: International Edition*. It took much longer to develop the computer software and test the reshaping of cartilage in live rabbits. The process killed very few cartilage cells, which proved a big advantage over traditional surgery. Hill reported his team's new test data in April 2019 at the American Chemical Society spring annual meeting in Orlando, Fla.

Those animal tests were really important, says Taylor Lawson, who was not involved with the research. He works at Boston University in Massachusetts, where he studies knee and hip cartilage.

"You want to avoid injuries around the needle-insertion site," he says. "You also need to know how much voltage to apply for a desired new shape. And you have to learn how to limit the electric current to just the area of interest."

These are some of the things the researchers will now test in larger animals. Eventually, Hill and Wong hope to extend their team's tests to humans. First, they have to ensure the new method will be safe to use in people. New medical procedures require many rounds of tests. Some are known as clinical trials.

"The electric bonds give cartilage the ability to hold its shape. But if we can briefly turn off the bonds, we can change that shape."

If approved for humans, the new technique might be used to fix a deviated septum and other nose problems. It also could adjust ears that stick out. (This would help kids who get teased about "Dumbo" ears, says Hill.)

Eyes on the future

Hill and Wong wonder if their molecular surgery might have even broader uses, such as fixing vision problems. If it also works in people, Hill and Wong think their technique could help millions of people who are nearsighted, farsighted or have trouble reading as they get older.

Eyeballs aren't made of cartilage. But like cartilage, the transparent layer on top of the eyeball — the cornea — is made from a web of collagen fibers. In nearsighted people, the eyeball has grown too long, so the cornea is overly curved. That makes far-away objects appear blurry. Flattening the cornea fixes this problem. And electrolysis may be one way to do this.

So far, working in a lab dish, the researchers have only tried the technique on a rabbit's cornea. They printed a mold for a contact lens and then painted electrodes onto it. After they put the mold onto the cornea, the researchers applied an electric current. This succeeded in changing the cornea's shape.

The researchers have yet to try this on living animals. That means it will take many years to assess whether it is safe enough for people. But if it is, it one day might replace glasses and contact lenses in those who choose to have the procedure. The researchers think their method might pose fewer risks and side effects for correcting vision problems than laser surgery now does. That surgery "shaves off" thin layers of the cornea, instead of reshaping its tissue.

Hill and Wong are also working toward their original goal. Wong hopes he can soon fix ear and nose problems in a five-minute, low-cost procedure that can be done in a doctor's office without causing pain or scars.

Chemist Stefanie Sydlik, who was not involved in the work, thinks that is a realistic goal. She studies cartilage and other body tissues at Carnegie Mellon University in Pittsburgh, Penn. This new technique should have great potential, she says, if the researchers can prove that it's safe.

"The science behind it is really cool because it's such a simple concept," Sydlik says. "You use the water inside your own tissue to create the energy for changing its shape." ■

Microcrystals give magnets superpower over living cells

These iron-rich protein crystals could be the future of how scientists study nerve cells

By Jeremy Rehm

Imagine if you could control someone by using a magnet. It would be a bit like Magneto, the supervillain in X-Men. He can control anything magnetic. Even the iron inside someone's body.

Controlling people with magnets sounds a little, well, wacky. But scientists have now done something close to that. They have engineered cells to make long, needle-like crystals rich in iron. Researchers can then use magnets to control cells containing these crystals.

Video recordings show these iron-rich crystals moving toward a strong magnet. The crystals pull the entire cell along with them.

"It's almost alien," says Bianxiao Cui. She's a chemist at Stanford University in California.

Cui and her colleagues didn't set out to give scientists superpowers like Magneto's. Instead, their new protein crystals were designed to help scientists study which neurons control an animal's movements and senses. The crystals provide something inside a cell that magnets can attract. This innovation fills a gap in the budding field of magnetogenetics.

Scientists in this field genetically engineer cells so that they will respond to magnetic fields. Now researchers can remotely control specific neurons in the body using magnets. Those neurons could be ones that control how hungry an animal gets. Or they could be neurons that control leg muscles so a mouse starts running when a magnet is nearby.

A crystal is a solid made of atoms or molecules arranged in a three-dimensional, repeating pattern.

JOPELKA/ISTOCK/GETTY IMAGES PLUS

Gaining magnetic control

A magnetic field can turn on neurons that contain proteins rich in iron. The field does this by heating or giving a mechanical push to those proteins.

Researchers had already been able to control neurons with light. That process is called optogenetics. To use it, scientists insert light-sensitive molecules into the neurons of living animals. The researchers can then turn the neurons on or off simply by shining a light on them. With this technique, neuroscientists have done some incredible things. They've made mice run in circles. They've even restored movement to an animal's paralyzed leg.

But optogenetics has its downsides. Light, for example, can't penetrate deeply into the body. There's just too much bone, muscle and other tissue in the way. So researchers may implant optical fibers into the animal to deliver light to deep neurons. That makes the method cumbersome and even potentially dangerous.

The whole idea behind magnetogenetics is that you don't have to implant anything, explains Jacob Robinson, who was not involved in the study. He's a neuroengineer who works at Rice University in Houston, Texas.

Cells deep inside the body could be switched on with just a magnetic field. No fibers or surgery would be needed.

But there's a snag. The only protein found naturally inside animal cells that's even remotely magnetic is ferritin. Each molecule can have as many as 4,500 atoms of iron. That may sound like a lot, but it's not. The force that a magnet acting on ferritin generated would be only a billionth as strong as would be needed to turn on a neuron. So Cui's team developed protein crystals that could carry enough iron to make their cells responsive to magnets.

Giant crystals with an iron heart

The team first extracted the gene to make ferritin from a microbe. They then made a circular piece of DNA that contained two human genes. Those genes make long, hollow crystals called inka-PAK4 (short for Inkabox-PAK4cat). The team introduced these circular pieces of DNA into human kidney cells that were growing in a petri dish. A day later, the first crystals appeared.

"When I first saw those crystals assemble in the cells by themselves, it was just amazing," Cui recalls.

The crystals grew for three days until they were 45 millionths of a meter long. That's about half the average thickness of a human hair. They're the largest iron-containing protein crystals ever made in the lab — or in nature, Cui says. They were even longer than the cells they grew in. But the cells in which they formed never ripped. They just stretched to accommodate the crystals.

The researchers pried open the cells and removed the crystals. Then they loaded these with iron. The team estimates that it packed some 8 billion iron atoms into each crystal before inserting those crystals into human cells growing in a dish. Now they exposed the cells to a magnetic field and waited to see what would happen.

And the cells moved.

"The first time I actually saw [the cells] move toward the magnet, I was like, 'Wow!'" Cui says.

Crystals started collecting close to the magnet. And the crystals pulled their cells with them. The team described this online September 25, 2019 in *Nano Letters*.

Robinson expressed excitement over this. "It's an excellent step," he said, "toward engineering cells to create their own magnetic nanoparticles."

Scientists aren't sure what will happen to the crystals afterward. But the cells have the genes for the crystals. So every cell reproduced from the original cells should be able to make the crystals, Cui says.

Iron not included

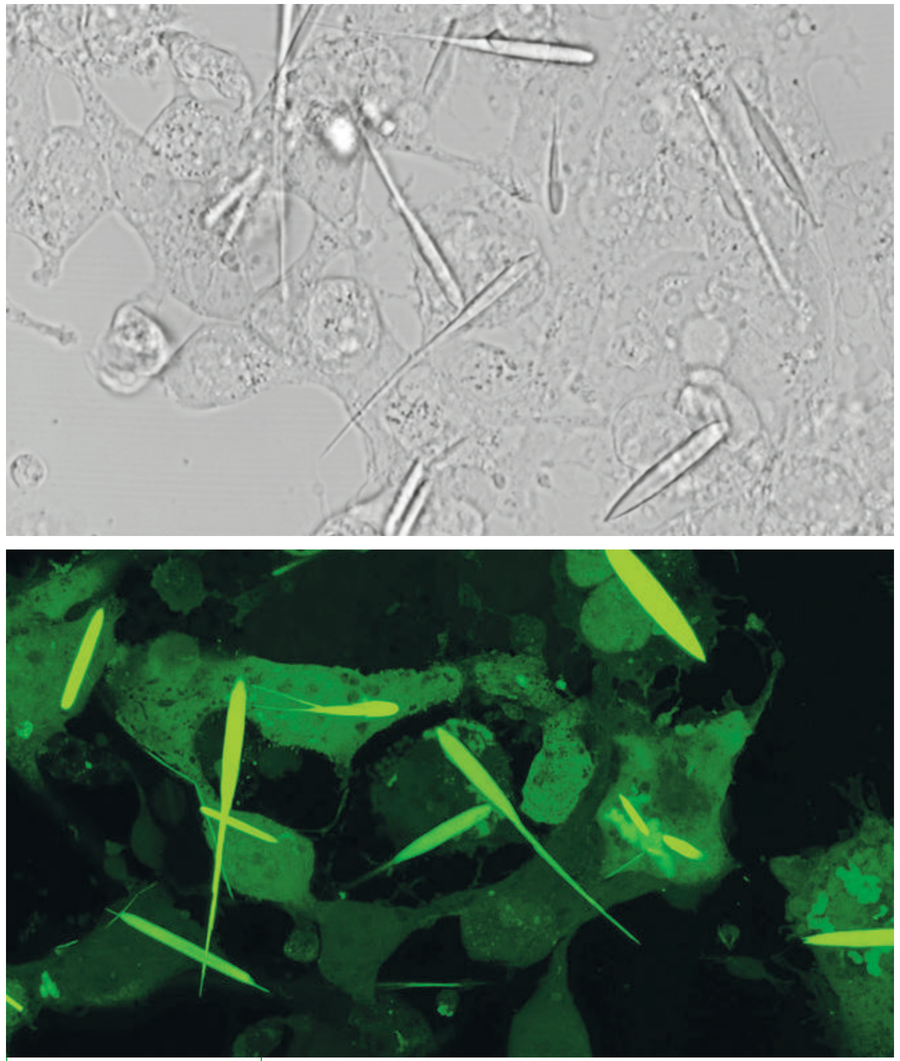
As promising as the results are, both Cui and Robinson emphasized that this isn't the end.

"We still haven't reached the goal," Cui says.

Ideally, researchers would not need to first remove newly grown crystals to pack them full of the metal atoms. Instead, cells would enrich the crystals with iron as it built them. In fact, Cui's group tried three different ways to get iron into its cells. They even drenched the cells in an iron-rich solution. Nothing worked.

Cells typically keep their iron levels low, Cui's team notes. It's estimated that cells naturally contain only 3 percent as much iron as the crystals would need to be effective.

We probably need to alter the cell's outer membranes, Cui suspects. Then, she says, they might be able to transport more iron into a cell. Still, these magnetic crystals are a major leap forward in the young field of magnetogenetics. And the researchers are confident additional studies will overcome this iron-enrichment obstacle. ■



BOTH: BIANXIAO CUI

Top image: Scientists engineered spine-like crystals that are the longest iron-containing crystals ever made in the lab or in nature. Many, including those in this microscopic image, are larger than the cells in which they grew. Bottom image: Labeled with a protein that gives them an eerie green glow, these needle-like protein crystals are jammed full of iron. That lets scientists control the crystals — and the cells they're inside of — with a magnet.

When not on the move, snails use mucus to stick to plants and other objects.

GABRIEL PACCE/ISTOCK/GETTY IMAGES PLUS

Reversible superglue mimics snail slime

This super-strong adhesive can be undone by adding water

By Alison Pearce Stevens

Makers like to combine unusual items to create new things. To do so, they need super-strong adhesives — tapes and glues — to hold it all together. But sometimes they want to be able to take the items apart again. That's been a problem, because reversible adhesives usually are not very strong. Sticky stuff can be super-strong and permanent — like superglue. Or it can be less sticky but easily removed — think of a sticky note. Now, though, researchers have created an adhesive that's both reusable and super-strong.

Shu Yang works at the University of Pennsylvania in Philadelphia. Her team described its new superglue July 9, 2019 in the *Proceedings of the National Academy of Sciences*.

As a materials scientist, Yang uses physics, chemistry and engineering to create new types of items. In her work, Yang often finds inspiration for new materials based on structures that exist in nature.

For years, she has been working to create an adhesive that not only holds well but also can be undone and reused. Earlier work mimicked the tiny hairs on gecko feet. Although the material came unstuck easily, it didn't have a strong grip. So the scientists in Yang's lab kept searching for something better.

One day, a student in her lab was playing with a substance known as a hydrogel. A polymer, it's made up of repeating chains of smaller chemicals. This particular gel turns soft when wet — in fact, it's what makes contact lenses so flexible. Yang's lab had been using it to make various structures for about 10 years. The student, Gaoxiang Wu, made patterns with it on a glass slide and then left it there.

When Wu returned, the hydrogel had hardened and was seriously stuck. He pulled, pried and scraped, but nothing separated the gel from the glass slide. Then he added water — and it came right off.

That finding made Yang and her team curious. Why had this dried gel been so hard to remove? They also wondered whether anything in nature might also work that way. And before long they discovered that snails make a similarly sticky goo.

During the heat of the day, snails are at risk of drying out. To prevent this, a snail finds a good spot near the ground with plenty of moisture. There, it pumps lots of mucus through the opening on its shell.

The mucus oozes over the ground, filling in any gaps. As it dries, the mucus hardens. This creates a structure that is both protective and adhesive. Called an epiphragm, it seals the moist snail inside its shell, protecting it from predators that would readily munch on it if they could get to the meat inside. When temperatures fall in the evening and humidity rises, the mucus loosens. Now free to move, the snail continues on its way.

A sticky situation

Yang and her team reached out to Anand Jagota. He is a bioengineer at Lehigh University in Bethlehem, Penn. Jagota specializes in soft materials and their adhesive properties. Together, the researchers studied the hydrogel and found that it worked the same way as a snail's slime. When the gel was wet, it oozed into every little nook and cranny, just like snail mucus. When it dried, the material turned hard and glassy. Now it was almost impossible to pull off.

The key, Yang says, is that the gel is very soft when wet. It's a lot like those squishy splat balls that stick to the wall, she says. Almost every surface has tiny imperfections, she observes. So with just a small bit of pressure, the gel can squeeze into all of those the tiny pores and spaces on the surface it's sticking to.

For most adhesives, that surface roughness is a problem. It reduces the amount of contact between the adhesive and surface, she notes. That makes the adhesive less sticky. But the hydrogel fills in those itty-bitty gaps, forming a tight connection.

What's more, the gel doesn't shrink much as it dries. So it doesn't pull away from those rough patches. Instead, it holds its shape as it turns glassy. In fact, that's key to why it sticks so well — it's locked on to the tiny cavities. "We couldn't separate the gel from the substrate," Yang says. No matter what tool they tried, it stuck tight.

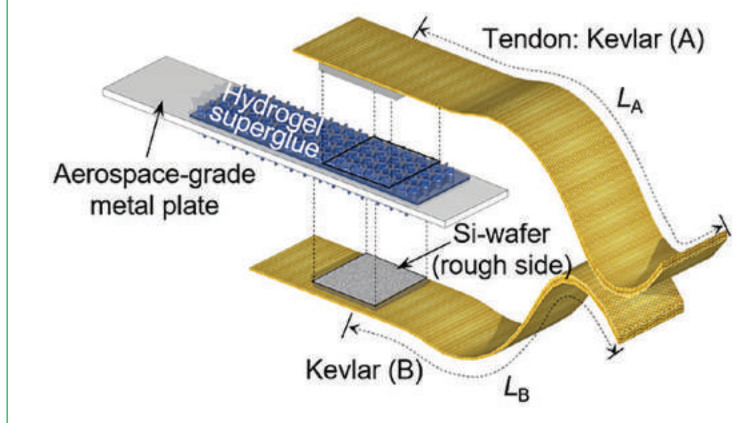
Hanging tight

Strong adhesives are important for making things — building cars or airplanes, for example. So the team wanted to figure out just how strong their new adhesive was.

To find out, they made the gel on one side of a sheet of silicon. They cut the gel-coated silicon into small chips no bigger than a postage stamp. Then they superglued a piece onto each side of a strip of heavy-duty metal. They glued other squares of bare silicon to one end of each of two Kevlar ribbons. (Kevlar is a tough material used to make bulletproof vests. It wouldn't fall apart during testing.)

Finally, the team added water to the hydrogel and pressed the ribbons' bare silicon wafers onto either side of the gel-coated metal strip. When it dried, the Kevlar ribbons were firmly attached to the metal.

FROM TOP: H. CHO *ET AL./PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES* 2019; CHICTYPE/E+/GETTY IMAGES PLUS



Yang's team used the hydrogel superglue to attach Kevlar ribbons (called tendons) to a metal plate. (They used this setup to test how strong the glue is. Si-wafer refers to a chip made of silicon.)

> Why had this dried gel been so hard to remove? They also wondered whether anything in nature might work that way. And before long they discovered that snails make a similarly sticky goo.

The team used the hydrogel to attach the metal strip to the front of a filing cabinet. They then hung a 4-kilogram (8.8-pound) weight from the Kevlar ribbon. It held firmly. Only when the team added water did the hydrogel soften, letting the weight fall to the ground.

The hydrogel was even stronger than the superglue. Sometimes when the weight was added, the superglue used in the setup broke free. But the hydrogel always held fast.

In a final test, the team built a large metal frame and stuck the gel-coated strip with the Kevlar ribbons to the top. They attached the Kevlar to a harness worn by a student in the lab. He carefully lifted his feet off the ground — and waited. The strip held. Just two postage-stamp-sized pieces of gel held up an 87-kilogram (192-pound) man!

The new adhesive "beautifully imitat[es] the reversible bonding mechanism used in the snail's epiphragm," says Diana Kay Hohl. She is a materials scientist at the University of Fribourg in Switzerland. Water is a good choice to make the new adhesive non-toxic, she says. But water is slow to dry. The hydrogel takes longer to dry than many other strong glues, Hohl notes. And water won't work in many types of manufacturing, she points out.

"It will be interesting to see if, in next-generation materials, the adhesion can be tuned by triggers other than water," she says. Heat or light, she suggests, might make the super-adhesive more suitable for manufacturing. ■

Shape-shifting chemical is key to new solar battery

It can absorb and hold energy until needed hours to months later

By Alison Pearce Stevens

What powers the computers you use? Electricity, obviously. But where did *that* come from? Two thirds of the electricity used in the United States comes from power plants fueled by fossil fuels — coal, oil or natural gas. Solar energy produces just 1.3 percent of the electricity. Yet energy from the sun could easily power our every need if it could be stored for use when the sun doesn't shine (such as at night). Researchers in Sweden now think they might have a way to do just that.

As a chemical engineer, Kasper Moth-Poulsen uses chemistry and physics to design solutions to problems. He works at Chalmers University of Technology in Gothenburg, Sweden. He teamed up with other researchers in Sweden and Spain to tackle the problem of storing energy from the sun. Their solution: Store that energy inside the bonds of molecules that have been suspended in a liquid.

Molecules consist of two or more atoms. Those atoms share electrons through bonds that hold them together.

Different types of molecules have distinct 3-D shapes. For example, methane is shaped like a three-sided pyramid called a tetrahedron. Other molecules have different shapes. Adding energy to a molecule can alter its shape. New bonds may now form between its atoms — ones that may hold different amounts of energy. When a molecule later absorbs energy, that energy can become trapped within those new bonds.

That's the key to the new solar-energy battery.

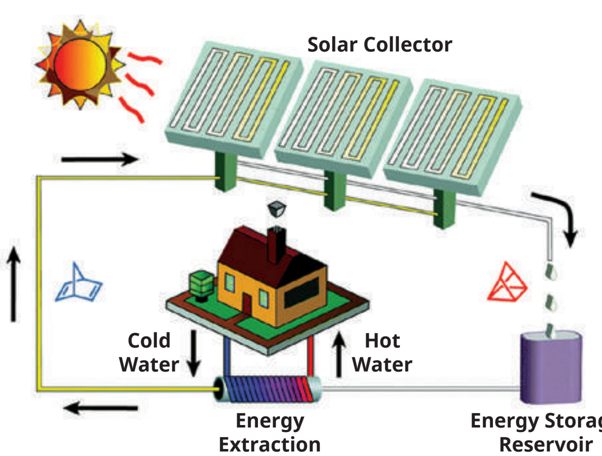
Using bonds inside a molecule to store solar energy isn't new. Moth-Poulsen's group had been working on that for years. They found a low cost candidate made mostly of carbon and hydrogen. But it could absorb only ultraviolet (UV) light — a small part of the sun's light. To make this molecule more useful, the researchers tweaked it in such a way that it would absorb more wavelengths (colors) of sunlight.

One end of the molecule reacts to this light and snaps into a new shape. New bonds between its atoms trap that energy. And they hold it tight, even after the molecule cools to room temperature.

But storing energy isn't useful unless you can release that energy when you need it. So Moth-Poulsen's team found a way to get its molecule to release the stored energy as heat. Researchers pass the liquid over a type of salt. The salt causes the molecule to change back into its original shape. When it does so, the molecule releases the energy stored in its bonds. That raises the temperature of the liquid by 63.4 degrees Celsius (114 degrees Fahrenheit) — enough to heat a home.

The team published its findings in the January 2019 issue of *Energy & Environmental Science*.

The liquid battery created by Moth-Poulsen's team would become part of a system (illustrated) that the team designed to heat a home.



Z. WANG ET AL/ENERGY & ENVIRONMENTAL SCIENCE 2019 (CC BY 3.0)

Solar-powered future

A liquid battery made with these molecules can store solar energy for days, months or even years, Moth-Poulsen says. So energy absorbed during long summer days can be held for use at night or during the winter, when days are short.

The team has tested its system in a rooftop experiment at their lab in Sweden. The system works well — but not yet well enough to put in every home. First, the team needs to increase how much of the sun's energy the molecule can absorb. "We are aiming at reaching 5 to 10 percent" of that energy, Moth-Poulsen says.

Storing more energy in the molecule's bonds means these could later release more heat. And while the system doesn't make electricity, the heat it releases could be used to drive a turbine that does, Moth-Poulsen says. One day, such a system might both heat and power buildings without any connection to outside sources of electric power. Those buildings also could stay warm without a need for energy from fossil fuels.

"We have discovered some new tricks recently," Moth-Poulsen says. He hopes these will help the home-heating system work even better. That should increase its affordability and attractiveness.

Jeffrey Grossman finds the new data exciting. This study, he explains, "demonstrates real world use of this technology." Grossman is a materials scientist at the Massachusetts Institute of Technology in Cambridge. He was not involved with the study.

Deepa Khushalani is less excited about the new technology's prospects for making electricity. She's a chemist at the Tata Institute of Fundamental Research in Mumbai, India. To drive a turbine or other engine, she notes, such a molecule must release enough heat to turn water into steam. That means the system would need to heat water to more than 100° Celsius (212° Fahrenheit). Batteries that store electricity are a more practical way to harness the sun's energy, she suspects.

But Moth-Poulsen plans to get the extra heat needed from the new energy-storage molecule. His team is working to make it absorb energy from yellow and orange light, too. ■

Trees may become the key to 'greener' foam

It's as strong as Styrofoam and works even better at keeping things cold

By Alison Pearce Stevens

If you're heading to the beach on a hot summer day, you don't want to forget the cooler full of drinks. You might load that cooler with ice. However, ice on its own won't keep things cold for long. That's why a cooler packs insulation in its walls. The best insulators have long been plastic-based foams, such as Styrofoam. But a new type of foam made from wood pulp works even better. And it's friendlier to the environment.

Plastic foam is both incredibly useful and popular. Filled with millions of tiny air pockets, its frothy structure is both lightweight and strong. This material protects fragile packages during shipping. And when used as an insulator, plastic foam's tiny bubbles help keep heat in — or out — for hours. That's why people have relied on it for everything from cups and coolers to packaging and home insulation.

These foams have a few drawbacks, however. They are made from petroleum, a non-renewable material. And when someone has finished using these foam-based products, they're difficult to recycle. Plastic foam doesn't biodegrade (break down naturally). Instead, it tends to break apart into tiny little beads that can scatter on the wind, spreading pollution near and far.

That's why researchers have been trying to find an alternative. They want something that's "green" — better for the environment, both in how it's made and how we get rid of it. Xiao Zhang and Amir Ameli are materials scientists who work at Washington State University in Richland. And they think the answer may lie in trees.

Turning to trees

Cellulose is the very sturdy material that makes up a plant's cell walls. Other scientists had found ways to make foam from the cellulose in trees. They liked that the starting ingredient not only is a renewable resource, but also can break down completely in the environment.

However, straight from the plant, cellulose isn't foamable. Earlier researchers had found they needed to first dissolve wood pulp with acid and then filter it. What remained would be tiny crystals of cellulose. They are so small that you need 500 of the crystals, side-by-side, to match the width of a human hair. These nanocrystals are the reason tree trunks are so strong.

To turn them into a foam, researchers dissolved the nanocrystals in harsh solvents. (Solvents are liquids that dissolve other substances.) Then they froze this liquid to create a foam and dried it out to remove the solvent. But the resulting material was weak, didn't insulate as well as Styrofoam and broke down in hot and humid conditions.

This wood-based foam works better than plastic foams. It's also friendlier to the environment.

AMIR AMELI/WASHINGTON STATE UNIVERSITY

Zhang and Ameli wanted to make something that not only worked better than plastic foams but also was friendlier to the environment. For instance, Ameli explains, "We wanted to avoid any harmful or expensive solvents."

"Cellulose is soluble in water," he notes. His team then chose other ingredients that would dissolve in water. Now, when they removed water from the solution, the team hoped to end up with a strong cellulose foam.

The researchers prepared different recipes. Some were just a mix of cellulose nanocrystals and water. For stretchiness, other recipes contained a polymer known as polyvinyl alcohol. Still others used all of those ingredients, plus an acid. That acid helped the molecules of cellulose and polyvinyl alcohol bond. Those bonds "hold the nanoscale ingredients together and make the material stronger," Ameli explains. Stronger materials create smaller bubbles inside the foam, he adds, which should produce a higher-quality foam.

Next, the researchers poured each mix into a tube and froze it for six hours. That kept the nanocrystals in place. Once each mixture was good and solid, they freeze-dried it. This removed the water, leaving behind just the foam.

Pulp power

The team then compared how well each foam performed. They also looked at a thin slice of each foam under a scanning electron microscope to see its tiny air pockets. Air spaces in the cellulose-only foam were big — more than 0.2 millimeter (0.008 inch) across. The polyvinyl alcohol and acid recipe left much smaller pockets. These bubbles were less than half as big. They also were evenly distributed in the foam. That suggested this foam should be stronger.

Sure enough, when the researchers tested the foams by putting weights atop them, the acid foam stood up to much more pressure than either the cellulose-only or the cellulose-and-alcohol foams. The acid foam should therefore work well for packaging.

Finally, the researchers tested how well the foams kept heat in (or out). Once again, the acid recipe proved the clear winner. This foam prevented heat from moving through it much better than the other types they'd made. It also insulated better than Styrofoam. And that's because it had so many tiny bubbles, Ameli says. "As the bubbles get smaller and smaller, air cannot freely move inside the bubble, and cannot transfer heat as quickly."

The researchers describe their findings in the August 15, 2019 issue of *Carbohydrate Polymers*.

The team has not yet studied how well the foam will break down in the environment. But Ameli expects it should degrade quickly. ■

This robot's parts are helpless alone, but smart as they team up

A new system called particle robotics is expanding what it means to be a robot

By Stephen Ornes

When you imagine a robot, you might picture R2-D2 in *Star Wars*, the Omnidroid from *The Incredibles* or the big-armed machines that build cars on an assembly line. But there's a new robotic system that doesn't resemble any of these. Instead, it looks like some kids forgot to pick up their toys.

The robot is a collection of plastic, neon-green disks. Each is about 15 centimeters (6 inches) across. Alone, a single disk can't do much of anything. It can only expand and contract.

But when a bunch of disks huddle together, things change. Tiny magnets on the disks' outer rims make them stick together. When one disk expands or shrinks, it pushes or pulls on its neighbors. All of those small pushes and pulls add up. Suddenly the entire blob starts to move — very slowly.

The designers refer to each individual disk as a "particle." When working as a system, they become what the designers call a "particle robot." The researchers described their invention March 20, 2019 in *Nature*. In the new study, they also showed how such a particle robot can accomplish simple tasks, like shuffling toward a light.

"It's an innovative mechanism," says Katia Sycara. She's a computer scientist at Carnegie Mellon University in Pittsburgh, Penn., who designs multi-robot systems. She did not work on the new invention. But she says it illustrates the wild variety of ways that people can build robotic systems.

At one end of the spectrum of robots you find single-bodied devices. Think R2-D2. These are robots contained in just one body. At the other end of the spectrum are modular robots. These are groups of individual robots that each have their own job but together work on some common task. They include "swarm" robots, which talk to each other and share information about where and how they're moving.

The new system, says Sycara, is somewhere in between. The disks are individual units, but they bunch together to form a unified team. Their behavior results from their interactions and the laws of physics, not someone telling them what to do.

Natural inspiration

"We wanted to make robots that are very simple and that can respond to changes in the environment," says Richa Batra. She's a graduate student at Columbia University in New York City and part of the team behind the new particle-robotics system.

Scientists behind the project were inspired by nature, Batra explains. In the human body, for example, individual cells work together as muscle tissue. Many other types of cells also move together as a group.

The motion of the robot also reminds Batra of something else in the living world. The blob shuffles along "like a caterpillar moves," she says. "It bunches up a little, then stretches out."

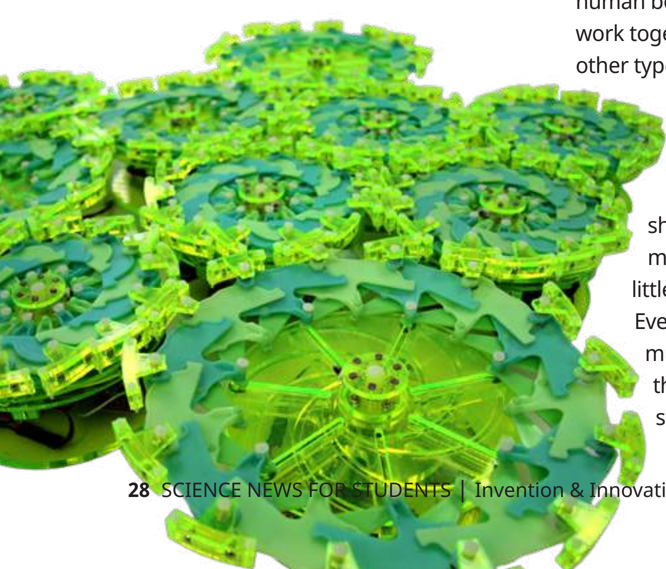
Even though the disks don't communicate directly with each other, they can respond as a group to some signal. The scientists showed this by installing sensors on each disk that could detect light. Then they programmed the disks to expand and contract faster or slower, depending on how intense the light was. When the researchers shone a bright light, their robot crept toward it — the result of all those individual expansions and contractions.

To make sure the group of particles would not get stuck, the researchers had to consider how friction would affect the disks. Friction is the resistance between two surfaces rubbing together. The disks had to push hard enough to overcome friction. But they couldn't push each other so far away that their magnets stopped working.

Another challenge the researchers faced was deciding what the disks should look like. For help, they turned to Chuck Hoberman at Harvard University in Cambridge, Mass. He had created what are known as Hoberman Spheres. The clever plastic toys are made of interconnected arms that expand into giant spheres when thrown in the air, and then collapse back into small spheres when caught. The new robotics team recruited Hoberman to design the disks that would become their "particles." Like his spheres, these, too, get bigger and smaller with minimal effort.

Finally, the scientists had to create a system that could work at different scales. So far, they have built physical robots with more than two dozen disks. But they wanted to show what would happen with groups of hundreds, or even thousands, of particles. That's where Batra came in. For two years, she wrote computer programs that could predict the behavior of big groups. She showed how a system with 100,000 particles would move. Her software also predicted what would happen if individual disks in the group stopped working.

"That was one of the really beautiful things we were able to look at," she says. "How many of these particles could be killed off and still have it move?" Right now, the robot only moves across a flat surface. The researchers don't know yet how their flat system might be used. Still, that's normal for robotics, says Sycara. Each new approach adds to the toolbox that other researchers can later use. ■



Individually, each of these disks can only expand and contract in place. But together, when loosely connected by magnets, they can complete a task like moving toward a light.

SHUGUANG LI/COLUMBIA ENGINEERING