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SEPTEMBER 15, 2018

Quantum Switch Has Superpowers

Video Fakery

How Elephants Dodge Cancer

Supersmooth Desalination

Off to the Sun

The Parker Solar Probe is headed for its stellar close-up

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Science News

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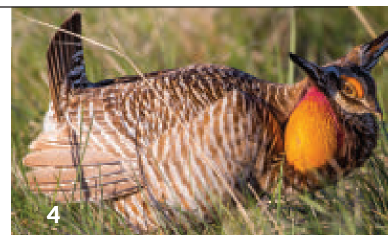

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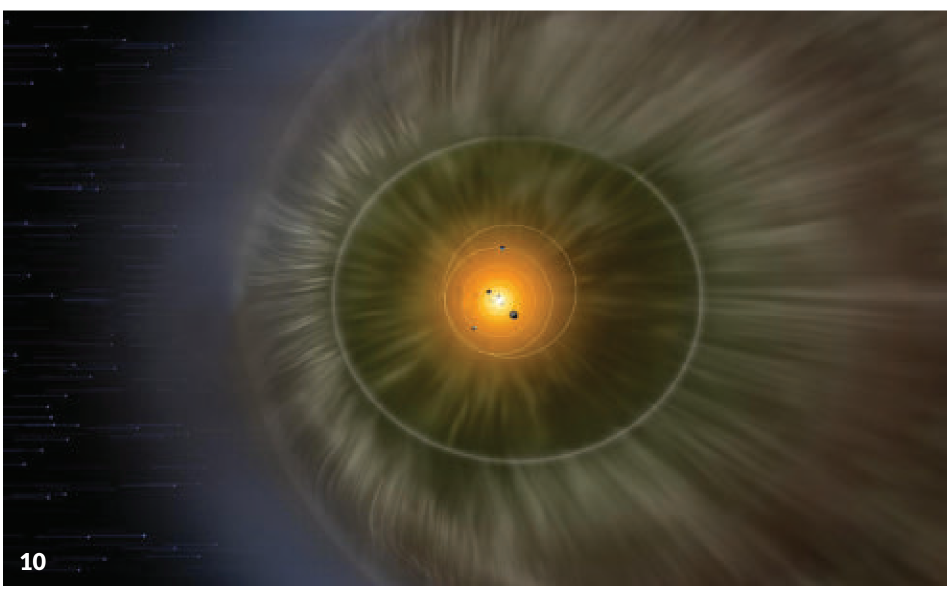

COVER Launching from Cape Canaveral, Fla., on August 12, the Parker Solar Probe sits inside the white nose cone at top. *United Launch Alliance*

FROM TOP: CHANG/ISTOCKPHOTO; JACKVANDENHEUVEL/ISTOCKPHOTO; ADLER PLANETARIUM, IBEX, NASA

To boldly go where no robot explorer has gone before

Space travel still sounds like just about the coolest thing ever, even though we have learned that it brings with it nausea, sleeplessness, radiation exposure, muscle loss, vision changes, cranky fellow explorers and the challenge of going to the bathroom in zero gravity. And that's just with the "easy" stuff, like living on the International Space Station. Let's not even get started on a possible mission to Mars (*SN: 11/29/14, p. 22*).

Fortunately, we have robot friends out exploring the cosmos for us.

Right now, the Parker Solar Probe is winging its way to the sun's corona. Once it arrives in November, the probe will study electric and magnetic fields as well as solar wind, the charged particles that flow from the sun. Astronomy writer Lisa Grossman talked to the scientists who figured out how to sling the spacecraft through the sizzling corona without frying it like a crouton (Page 16). That required plenty of clever engineering and some surprising work-arounds for testing antennas and other gear. Who knew that IMAX movie projectors would be the perfect stand-in for intense sunlight?

Parker joins other recent explorers, including the TESS space telescope, which launched April 18 on a hunt for exoplanets. Then there's InSight, a lander due to reach Mars in November that will try to probe the planet's internal activity. OSIRIS-REx is en route to asteroid 101955 Bennu, where it will use a robotic arm to snuffle up rocks and bring them back to Earth in 2023. The goal there is to glean clues to the origins of our solar system.

And those are just some of the newcomers. The Hubble Space Telescope has been beaming down images of space since 1990, while Gaia has mapped more than a billion stars since 2013 (*SN Online: 5/9/18*). The Opportunity rover has been testing minerals on the surface of the Red Planet since 2004, far beyond its planned three-month mission. New Horizons, which launched in 2006, may have just spotted an ultraviolet glow near the edge of the solar system (Page 10).

My childhood dreams of rocketing into space will never die, but I'm delighted that these competent, dogged extraterrestrial explorers are also out there, working away in the service of science. *— Nancy Shute, Editor in Chief*

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SSP

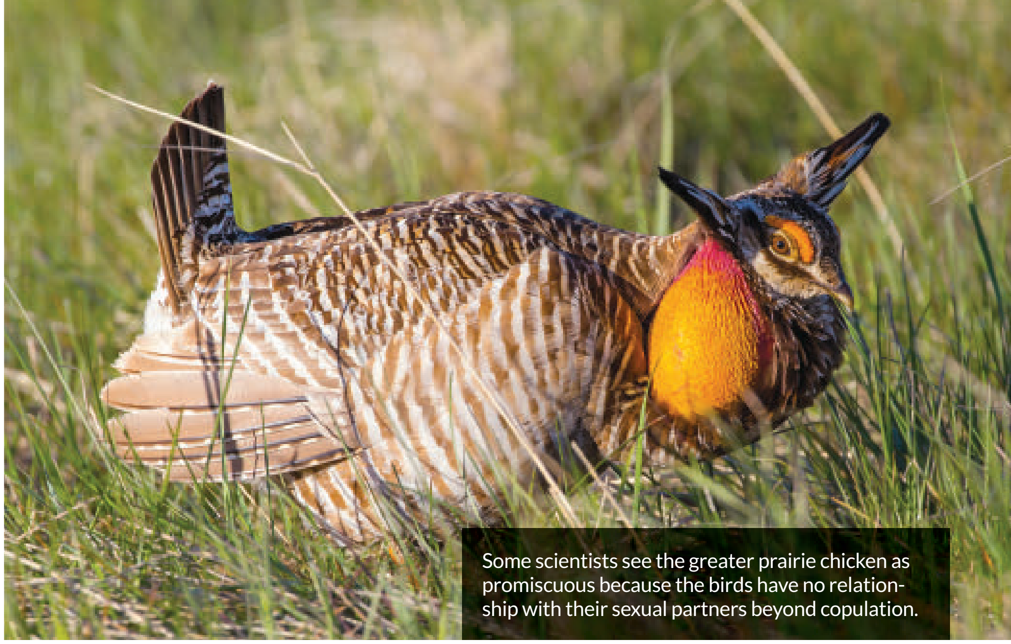
Excerpt from the September 14, 1968 issue of *Science News*

50 YEARS AGO

Transplanted hearts will be shortlived

Now that heart recipients can realistically look forward to leaving the hospital and taking up a semblance of normal life, the question arises, what kind of semblance, and for how long? South Africa's Dr. Christiaan Barnard, performer of the first heart transplant, has a sobering view.... "A transplanted heart will last only five years — if we're lucky."

UPDATE: Barnard didn't need to be so disheartening. Advances in drugs that suppress the immune system and keep blood pressure down have helped to pump up life expectancy after a heart transplant. Now, more than half of patients who receive a donated ticker are alive 10 years later. A 2015 study found 21 percent of recipients still alive 20 years post-transplant. In 2017, nearly 7,000 people across 46 countries got a new heart, according to the Global Observatory on Donation and Transplantation.



Some scientists see the greater prairie chicken as promiscuous because the birds have no relationship with their sexual partners beyond copulation.

JACKVANDENHEUVEL/ISTOCKPHOTO

SOAPBOX

In the animal kingdom, what is promiscuous?

MILWAUKEE — When it comes to the sex lives of animals, scientists have a slate of explicit terms to describe the proclivities of species. But researchers may be playing a little fast and loose with one of those words: promiscuous.

In a review of almost 350 studies regarding animal mating published in 2015 and 2016, the label was applied to a surprisingly wide range of mating behaviors in animals, including humans. "This idea of promiscuity seems to mean different things to different people," says behavioral neurobiologist Sarah Jane Alger of the University of Wisconsin–Stevens Point.

Promiscuity was referenced in about half of the studies, Alger reported August 3 at the annual Animal Behavior Society conference. The term was used to describe various scenarios, such as rats that mate with any rat of the opposite sex they encounter, kingbirds that pair up for several years and share parental duties but also mate with other birds, and even some populations of lagoon triggerfish that don't encounter enough potential mates to be choosy.

Lumping all of these under one term "misses the potential to explore some really interesting and complicated patterns in animal mating systems," says behavioral ecologist Brent Burt of Stephen F. Austin State University in Nacogdoches, Texas.

The sheer variety and fluidity of behaviors seen in the animal kingdom may be behind some of the confusion. Some species, and even some individuals, change sexual strategy based on things like relative abundance of food, potential mates or predators.

How promiscuity is defined also may depend on the species being scrutinized, Burt says. The vast majority of bird species are considered monogamous because they form long-term bonds and share parental duties with one mate. Even if those partners are getting some side action, they are labeled "socially monogamous." Truly faithful species like the Florida scrub jay are said to be "genetically monogamous."

Bird researchers generally use promiscuity to describe only the relatively rare bird that has no relationship with its sexual partners beyond the deed itself, like the greater prairie chicken, Burt says.

Animals that appear to mate at random and others that have too few potential mates to be selective are both sometimes described as promiscuous. It's even possible to label a species as monogamous, because individuals have only one partner, as well as promiscuous, because there's little or no choice in mates.

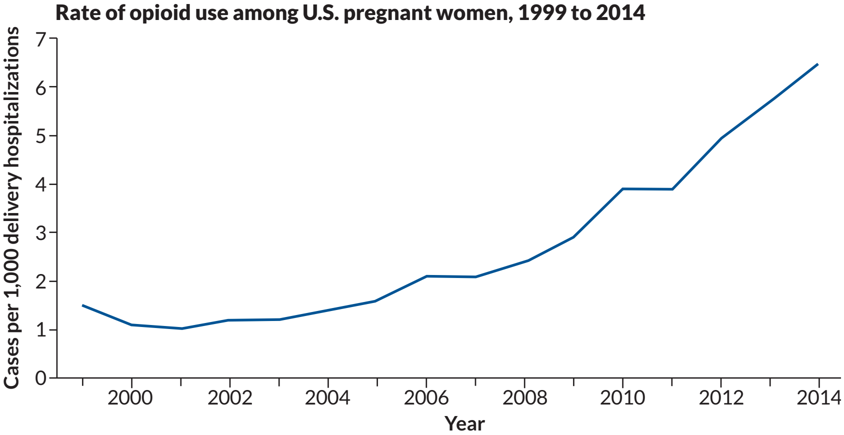
Behavioral ecologist David McDonald of the University of Wyoming in Laramie suggests that researchers avoid using "promiscuity" altogether. Other scientific terms are more precise and don't have the same negative connotations, he says. There's polyandry (females have multiple mates), polygyny (males have multiple mates) and polygynandry (both sexes have multiple mates). *— Betsy Mason*

SCIENCE STATS

Pregnant women's use of opioids is on the rise

The rate of opioid use among pregnant women more than quadrupled, from 1.5 to 6.5 per 1,000 women, from 1999 to 2014, according to records on hospital deliveries in 27 states and the District of Columbia. That's about 5,461 women versus 24,715 women, the U.S. Centers for Disease Control and Prevention reports in the first study to look at opioid use in pregnant women by state. Vermont had the highest rate in 2014: 48.6 per 1,000 women. Washington, D.C., had the lowest rate at 0.7 per 1,000 women, CDC researchers report in the Aug. 10 *Morbidity and Mortality Weekly Report*. Taking opioids during pregnancy, especially in the last trimester, increases the risk of preterm birth, stillbirth and infant opioid withdrawal (*SN: 6/10/17, p. 16*). "This analysis is a stark reminder that the U.S. opioid crisis is taking a tremendous toll on families," says study coauthor and epidemiologist Jean Ko. — *Leah Rosenbaum*

Rate of opioid use among U.S. pregnant women, 1999 to 2014



SOURCE: S.C. HAIGHT *ET AL/MMWR* 2018

THE –EST

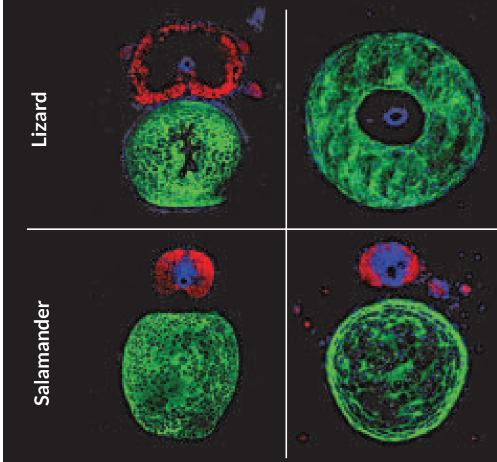
Egyptian tomb held 3,200-year-old cheese

What may be the oldest known slab of solid cheese, dated to roughly 3,200 years ago, has been found in an ancient Egyptian tomb.

Made from a mixture of cow milk and either sheep or goat milk, the cheese filled a broken clay jar unearthed from a 13th century B.C. tomb for Ptahmes, mayor of the ancient city of Memphis, researchers report in the Aug. 21 *Analytical Chemistry*.

Chemist Enrico Greco and colleagues used mass spectrometry to analyze the antique cheese — now a white, soapy lump weighing several hundred grams. Besides milk and whey proteins, the cheese contains remnants of bacteria that cause brucellosis infections, adding to evidence that ancient Egyptians grappled with the disease, says Greco, who did the work while at the University of Catania in Italy. Cheese making predates the new find by more than 4,000 years (*SN: 1/26/13, p. 16*). Archaeologists in 2014 reported finding 3,600-year-old curds draped around the necks of Bronze Age mummies in China. "There are other samples of dairy products in the literature, but not solid cheeses in the strict sense," Greco says. — *Cassie Martin*

This preserved solid cheese, found in an ancient Egyptian tomb, shows signs of contamination with bacteria that cause the disease brucellosis.



No nerve In lizard and salamander tail cross sections (left column), cartilage is shown as green and a spinal cord with nerve cells is red. A lizard's regenerated tail (right column) is mostly cartilage, but a salamander's is cartilage and new nerve cells.

MYSTERY SOLVED

Tail trouble for lizards

Salamanders and lizards can regrow their tails but not to equal perfection.

While a regenerated salamander tail closely mimics the original, bone and all, a lizard's replacement is filled with cartilage and lacks nerve cells, or neurons. That contrast is due to differences between stem cells in the animals' spinal cords, researchers report online August 13 in the *Proceedings of the National Academy of Sciences*. When a salamander loses its tail, its neural stem cells can develop into any type of nervous system cell. But through evolution, lizard neural stem cells "have lost this ability," says Thomas Lozito, a biologist at the University of Pittsburgh.

Lozito and colleagues wondered if something about the biology of the lizard's tail was keeping its stem cells from becoming neurons. So the team implanted neural stem cells from an axolotl salamander (*Ambystoma mexicanum*) into the tail stumps of five mourning geckos (*Lepidodactylus lugubris*). Some of the salamander cells became neurons in the regrown tails, showing that the problem is with the lizard stem cells. The finding suggests that scientists would have to alter only the lizard stem cells, instead of other parts of the tail, to regrow a more complete appendage.

Lozito is using lizards as "a stepping stone" to one day coax stem cells in mammals to regenerate body parts.
— *Leah Rosenbaum*

CELLS: T.P. LOZITO; CHEESE: UNIV. OF CATANIA, CAIRO UNIV.

News

BODY & BRAIN

Gene-silencing drug approved

New treatment is the first based on RNA interference

BY LAUREL HAMERS

A Nobel Prize–winning discovery — that small double-stranded RNA molecules can silence genes by interrupting the translation of DNA's instructions into proteins — is finally delivering on its medical promise.

On August 10, the U.S. Food and Drug Administration approved the first drug that takes advantage of this natural biological process, called RNA interference. The drug, called patisiran, targets a rare hereditary disease that causes misshapen proteins to build up in patients' nerves, tissues and organs, causing loss of sensation, organ failure and even death.

Hereditary transthyretin amyloidosis, also known as hATTR, affects about 50,000 people worldwide. Patisiran will help the subset of patients who have neurological impairments.

The drug uses specially designed pieces of RNA to silence a mutated gene that, when active in the liver, is responsible for patients' symptoms. In an 18-month clinical trial, patients who received patisiran injections every three weeks showed a slight decrease in neurological symptoms; patients on the placebo worsened overall. It's not a cure, but the treatment prevents peripheral nerve disease from progressing.

This approval is "just the beginning," says Craig Mello of the University of Massachusetts Medical School in Worcester, who codiscovered the process of RNA interference, or RNAi (*SN: 10/7/06, p. 229*). Other drugs using the same approach, for diseases ranging from hemophilia to HIV, are winding through clinical trials.

As a medical treatment, "what makes RNA interference so special is that it's biology, tested by 3 billion years of evolution," says Phillip Zamore, a biologist at UMass Medical School. He is also a cofounder of Alnylam Pharmaceuticals, the Cambridge, Mass.–based company that makes patisiran.

RNA interference helps control when and where genes are active. When a gene is turned on, the information that it contains is transcribed into single-stranded messenger RNA, or mRNA, which translates DNA's instructions into proteins. Small pieces of double-stranded RNA that don't carry protein-making instructions can target and bind to specific mRNA molecules and flag them for destruction, heading them off before they make proteins.

Patisiran and other RNAi-based therapies in development use specially crafted snippets of synthetic RNA to artificially manipulate genes' activity.

But translating the RNAi discovery into clinical applications has been challenging. "The thing about RNA interference that made it really attractive is the theoretical simplicity of it," says biologist John Burnett of City of Hope National Medical Center in Duarte, Calif., who has been working on using RNA interference to target HIV. "Of course, nothing is as simple as we anticipate." It took years to figure out how to deliver such drugs to the right place in the body to reduce harmful off-target side effects and how to design synthetic RNA molecules that don't degrade before they do their job.

Once there's a way to safely and effectively deliver a small piece of RNA to a specific organ, it's easy to switch up the RNA molecule to target a different gene in the same organ, Mello says. He predicts that a wave of similar RNAi-based drugs, especially ones like patisiran that target genes in the liver, will soon be available.

"What an amazing process it's been to uncover the mysteries of these mechanisms that are shared by plants and yeasts and worms," Mello says. "To go from the basic biology to a drug in 20 years is kind of amazing." ■

LIFE & EVOLUTION

Fossil shakes up lemur evolution

Primates reached Madagascar in two waves, study suggests

BY BRUCE BOWER

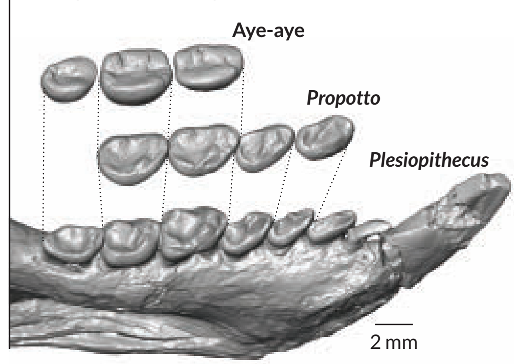
In one published swoop, an ancient fossilized fruit bat has turned into a lemur. If the finding holds, it suggests that lemur ancestors made two tricky sea crossings from Africa to Madagascar, not one as scientists have assumed.

A new fossil analysis finds that the species *Propotto leakeyi*, which lived in East Africa between 23 million and 16 million years ago, was not a bat, as scientists thought, but a primate closely related to modern aye-ayes. These strange-looking lemurs are found only on Madagascar along with another closely related lemur lineage.

What's more, *Propotto* teeth and jaws display key similarities with fossils of a roughly 34-million-year-old primate, *Plesiopithecus teras*, previously found in Egypt, researchers say. *Plesiopithecus* was an ancestor of *Propotto* and aye-ayes, the researchers conclude. Together, the findings, published August 21 in *Nature Communications*, may help rewrite lemurs' evolutionary history.

The work challenges a long-standing view that all modern lemurs, including aye-ayes, evolved from a single population of African ancestors that somehow

These digital reconstructions show tooth similarities between modern aye-ayes, which are found only in Madagascar, and two proposed aye-aye ancestors from mainland Africa (*Propotto* and *Plesiopithecus*).



G. GUNNELL *ET AL*/*NATURE COMMUNICATIONS* 2018 reached Madagascar at least 54 million years ago. That estimate rests largely on genetic studies of modern lemurs and other primates. Destruction of ancient lemurs' African habitats by global cooling around 34 million years ago left their kind isolated on Madagascar, according to this scenario.

But the survival of aye-aye ancestors in Africa millions of years after that, as suggested in the new study, raises the possibility that *Propotto* reached Madagascar on its own — separate from the other lemur lineage found on the island — and gave rise to present-day aye-ayes. No *Propotto* fossils have been found on Madagascar.

"Our identification of both *Propotto* and *Plesiopithecus* as African relatives of the aye-aye implies that [these] lemurs weren't present on Madagascar until 30 million years or more later than previously thought," says study coauthor and paleontologist Erik Seiffert of the University of Southern California in Los Angeles.

Ancestors of modern lemurs other than aye-ayes traveled to Madagascar sometime between around 41 million and 20 million years ago, Seiffert and colleagues estimate. During that period, ancestors of the only other mammal groups now inhabiting Madagascar — rodents, Malagasy mongooses and insect-eating creatures called tenrecs — also reached the island from Africa. Previous computer simulations indicated that ocean currents at that time could have carried animals stranded on storm-uprooted trees and vegetation mats from East Africa to Madagascar.

The team, which included Duke University's Gregg Gunnell (who died in 2017), created digital reconstructions of *Plesiopithecus* and *Propotto* fossils for comparison with fossilized and living primates, including aye-ayes, and closely related mammals called colugos. Evolutionary trees based on tooth and jaw analyses and available DNA data pointed to a link between the two ancient species and aye-ayes.

Plesiopithecus and *Propotto* might have used enlarged teeth projecting from the front of their mouths to gouge holes in trees and expose grubs' nests, as modern aye-ayes do. Aye-ayes also poke through tree holes with long, skinny middle fingers to extract grubs. But no hand fossils from either ancient creature have been found, so it's a mystery whether they shared aye-ayes' taste for finger food.

The ancestors of aye-ayes, which gouge holes in trees and extract grubs with elongated middle fingers, arrived in Madagascar separately from other lemurs, fossil evidence suggests.

DAVID HARING

The discoverer of three *Propotto* tooth-bearing lower jaws in Kenya reported in 1967 that the finds belonged to a new primate species, possibly an ancestor of relatives of lemurs called lorises. But within the next two years, the same scientist accepted another researcher's proposal that *Propotto*'s jaws and teeth more closely resembled those of a fruit bat. A 1984 report describing several more *Propotto* teeth unearthed in Kenya also concluded that they came from a fruit bat.

The new identification of a line of ancient African lemurs that ran from *Plesiopithecus* through *Propotto* "is an interesting discovery," says paleoanthropologist Marc Godinot of the National Museum of Natural History in Paris. "I have thought for years that *Propotto* was more likely a primate than a fruit bat."

Godinot also argued in a 2006 study that the shape and positioning of teeth at the front of *Plesiopithecus*' mouth pegged it as a relative of aye-ayes, consistent with a double colonization of Madagascar by lemur ancestors.

That possibility "merits serious consideration," says evolutionary biologist Anne Yoder of Duke University. But a single African origin for lemurs on Madagascar remains the simplest, most likely scenario, she says. Most African mammals couldn't manage even one colonization of the island, so attributing two of these "highly improbable" events to lemur ancestors alone demands more evidence, Yoder says.

Still, it can't be discounted that several ancient African lines might have evolved in the aye-aye lineage, but only one made it to Madagascar on a sea crossing that occurred independently of other lemurs, Yoder says. Or, in line with her own view, Madagascar may have been colonized by one group of ancient lemurs that gave rise to multiple lines of creatures, one of which was a direct ancestor of modern aye-ayes. Only further fossil discoveries can resolve this mystery, Yoder says. ■

GENES & CELLS

Gene may help elephants avoid cancer

LIF6 tells damaged cells to die before the disease can take hold

BY AIMEE CUNNINGHAM

Elephants rarely succumb to cancer. That's surprising given how large the animals grow and how long they can live, which should provide more opportunities for cells to morph into cancer cells. A newly described gene that was brought back from the dead may take part in protecting the animals from the disease.

A deep dive into elephants' evolutionary history revealed a defunct gene called *LIF6* that was somehow reawakened roughly 59 million years ago, around the time that elephants' ancestors began to develop larger body sizes. Found today only in elephants, *LIF6* is triggered by another gene, *TP53*, to put cells out of commission at the first sign of damage before they turn cancerous, researchers report in the Aug. 14 *Cell Reports*.

Previous work on elephants' cancer-fighting powers has focused on *TP53*.

Learning how elephants resist cancer could lead to improved treatments for humans.

That gene encodes a protein that detects DNA damage and signals for a cell to repair itself or self-destruct, which helps stop damaged cells from becoming cancerous. In 2015, researchers found that elephants have 20 copies of *TP53*; other mammals have one (*SN: 11/14/15, p. 5*).

"What's really fascinating to me about the elephant is that it's not one mechanism" that underpins cancer resistance, says Lisa Abegglen, a cell biologist at the University of Utah School of Medicine in Salt Lake City who was part of the 2015 discovery.

The 2015 study also estimated that just 4.8 percent of elephants die of cancer. For humans, that number ranges from 11 to 25 percent. Understanding how elephants resist cancer could provide insights into treating the disease in people.

In the new experiments, Vincent Lynch, an evolutionary biologist at the University of Chicago, and colleagues chemically damaged the DNA of elephant connective tissue cells in a dish. *LIF6* was eight times as active in damaged cells as in undamaged cells. When the team blocked *TP53* from making its protein, nearly all of *LIF6*'s activity was wiped out.

More work is needed to figure out how *TP53* and *LIF6* potentially help elephants fight cancer, Abegglen says. But the animals probably "wouldn't be so large and long-lived if these changes in genes that are unique to the elephant hadn't occurred." ■

BODY & BRAIN

Lab-made lungs implanted in pigs

Feat brings scientists closer to transplants on demand

BY MARIA TEMMING

For the first time, researchers have created lungs in the lab and successfully transplanted them into pigs.

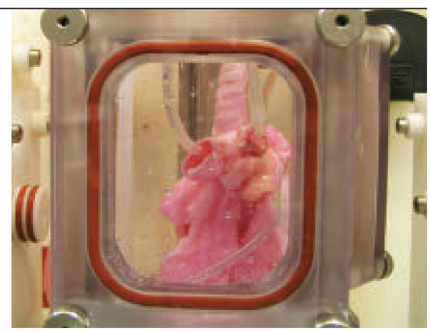
The bioengineered lungs, described in the Aug. 1 *Science Translational Medicine*, developed blood vessels, and the pigs lived for several weeks after surgery. That's a significant improvement from previous efforts: Lab-grown lungs implanted in rodents failed within hours.

If the procedure can be adapted for humans, with lungs grown from a patient's own cells, that could reduce the risk of organ rejection and slash wait times for transplants.

Immunologist Joan Nichols of the University of Texas Medical Branch at Galveston and colleagues built lungs for four pigs by first using sugar and detergent to strip cells from lungs of donor pigs. That left sterilized, lung-shaped scaffolds made of intercellular proteins. (In humans, researchers envision using donated organs or 3-D–printed scaffolding.) The team then repopulated each scaffold with blood vessel and lung cells from the pig destined to receive the organ.

Each lung grew for 30 days inside a bioreactor tank pumped full of nutrients that helped cells stick to the scaffold and multiply in the right spots. The team then replaced the left lung of each pig with the bioengineered version.

The pigs' post-op recovery was "pretty amazing," says Xi "Charlie" Ren, a biomedical engineer at Carnegie Mellon University in Pittsburgh. None of the pigs was given immunosuppressant drugs, and none of the transplants was rejected. One pig that Nichols' team let live for two months after surgery had



Pigs given lab-grown lungs like this one showed no signs of rejection after transplant.

no breathing problems, and its transplanted lung was colonized by bacteria that inhabit normal pig lungs.

But the lungs aren't yet ready for prime time, says Laura Niklason, a biomedical engineer at Yale University. While the lungs linked up with the pigs' circulatory systems, the organs weren't connected with the pulmonary artery, which carries low-oxygen blood for the lungs to replenish with oxygen. That left the pigs to rely on their natural right lungs for air. ■

FROM TOP: MATTHIEU GALLET/SHUTTERSTOCK; J.E. NICHOLS *ET AL*/*SCI. TRANSL. MED*. 2018

EARTH & ENVIRONMENT

CO_2-trapping mineral made in the lab

New technique might one day help combat climate change

BY CAROLYN GRAMLING

Scientists are one step closer to a long-sought way to store carbon dioxide in rocks.

A new technique speeds up the formation of a mineral called magnesite that, in nature, captures and stores large amounts of the greenhouse gas. And the process can be done in the lab at room temperature, scientists reported August 14 at the Goldschmidt geochemistry conference in Boston. If the mineral can be produced in large quantities, the method could one day help fight climate change.

“A lot of carbon on Earth is already stored within carbonate minerals, such as limestone,” says environmental geoscientist Ian Power of Trent University in Peterborough, Canada, who presented the research. “Earth knows how to store carbon naturally and does this over geologic time. But we’re emitting so much CO_2 now that Earth can’t keep up.”

Researchers have been seeking ways to boost the planet’s capacity for CO_2 storage. One possible technique: sequester CO_2 by converting it to carbonate minerals. Magnesite, or magnesium carbonate, is a stable mineral that can hold a lot of CO_2. A metric ton of magnesite can contain about half a metric ton of the greenhouse gas.

But magnesite isn’t quick to make — at least, not at Earth’s surface. Researchers have considered pumping CO_2 deep into Earth’s interior, where high temperatures and pressures can speed up the gas’s reaction with a magnesium-bearing mantle rock called olivine. But many barriers remain to making this idea commercial, including finding the right locations to insert the CO_2 and the costs of transportation and storage for the gas.

One place where magnesite forms naturally at Earth’s surface is in arid basins in northern British Columbia. In previous work, Power and colleagues determined that groundwater circulating through former mantle rocks such as olivine in the region becomes enriched in magnesium and carbonate ions. The ions — atoms that have a charge due to a gain or loss of electrons — eventually react to form magnesite, which settles out of the water. In British Columbia, the process began as far back as 11,000 years ago, Power says.

Under very high temperatures, scientists can quickly create magnesite in the lab, using olivine as a feedstock. But that process uses a lot of energy, Power says, and could be very costly.

Lab scientists can’t quickly make magnesite at room temperature, however, because, as Power’s team found, water gets in the way. When magnesium ions are put into water to create magnesite, the water molecules tend to surround the ions. That “shell” of water molecules hinders the magnesium’s ability to bond with carbonate ions to form magnesite. “It’s difficult to strip away those water molecules,” Power says. “That’s one of the reasons why magnesite forms very slowly.”

To get around this problem, Power and colleagues used thousands of polystyrene microspheres as catalysts to speed up the reaction. The microspheres were coated with carboxyl, molecules with a negative charge that can pull the water molecules away from the magnesium, freeing it up to bond with the carbonate ions. Thanks to these microspheres, Power says, the researchers made magnesite in just about 72 days.

That result doesn’t mean the technique is ready for use, he says. So far, the scientists have made only a microgram or so of magnesite. “We’re very far away from upscaling,” he says, or making the technology commercially viable.

Geochemist Patricia Dove of Virginia Tech in Blacksburg says, “The result really surprised me.” Many questions remain about how cost-effective and energy-efficient the process might be, she says, but it’s “certainly very intriguing.” ■

T. HIGHAM/UNIV. OF OXFORD

HUMANS & SOCIETY

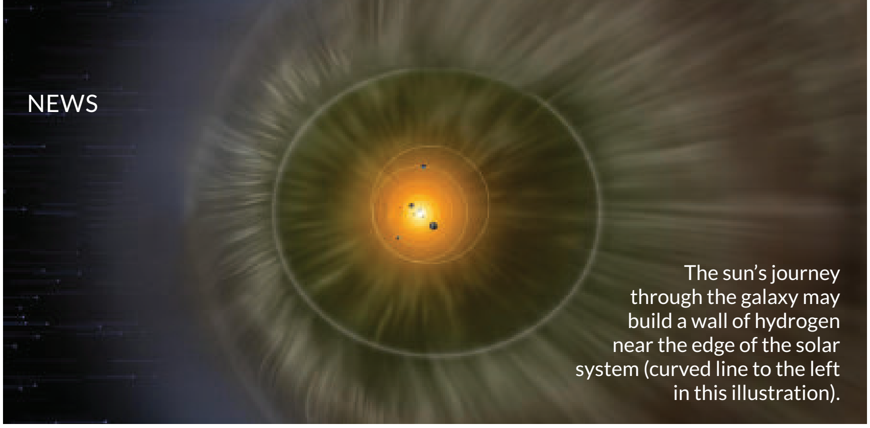
Child had Neandertal mom, Denisovan dad

Talk about blended families. A 13-year-old girl who died about 50,000 years ago was the child of a Neandertal and a Denisovan.

Researchers already knew that the two extinct human cousins interbred (*SN Online: 3/14/16*). But the girl is the only first-generation hybrid ever found. Dubbed Denisova 11, the child is known only from a bone fragment (shown above from multiple views) discovered in Siberia’s Denisova Cave in 2012.

Genetic analyses revealed that the girl inherited roughly equal amounts of DNA from Neandertals and Denisovans — a clue that she was a hybrid. She got at least 38.6 percent of her nuclear DNA, as well as her mitochondrial DNA, from a Neandertal. Because mitochondrial DNA is inherited from the mother, her mother must have been a Neandertal. Her dad was Denisovan, contributing at least 42.3 percent of her nuclear DNA. Viviane Slon of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and colleagues report the parentage online August 22 in *Nature*.

The girl’s father also had Neandertal ancestry but way back in his lineage, about 300 to 600 generations before his birth. *— Tina Hesman Saey*



The sun's journey through the galaxy may build a wall of hydrogen near the edge of the solar system (curved line to the left in this illustration).

ATOM & COSMOS

Spacecraft sees hints of hydrogen wall

New Horizons data may mark where the sun's influence wanes

BY LISA GROSSMAN

The New Horizons spacecraft has spotted an ultraviolet glow that seems to emanate from near the edge of the solar system. That glow may come from a long-sought wall of hydrogen that represents where the sun's influence wanes, the New Horizons team reports online August 7 in *Geophysical Research Letters*.

"We're seeing the threshold between being in the solar neighborhood and being in the galaxy," says team member Leslie Young of the Southwest Research Institute, based in Boulder, Colo.

Even before New Horizons flew past Pluto in 2015 (*SN: 8/8/15, p. 6*), the space was using its ultraviolet telescope to look for signs of the hydrogen wall. As the sun moves through the galaxy, it produces a constant stream of charged particles called the solar wind, which inflates a bubble around the solar system called the heliosphere. Just beyond the edge of that bubble, about 100 times farther from the sun than the Earth is, uncharged hydrogen atoms in interstellar space should slow when they collide with solar wind particles. That buildup, or wall, of hydrogen, should scatter UV light in a distinctive way.

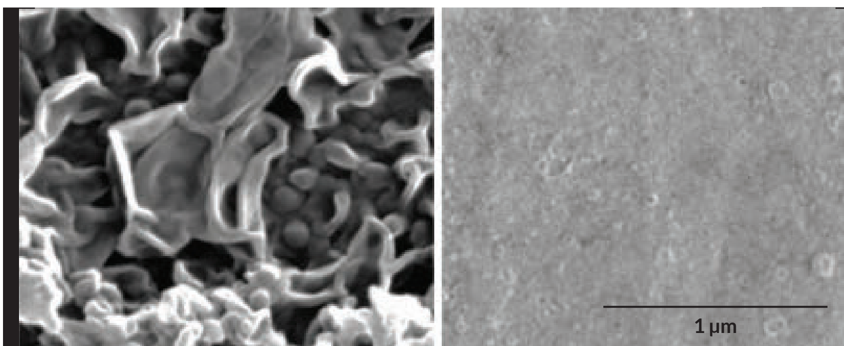
The two Voyager spacecraft saw signs of such light scattering 30 years ago. One of those craft has since exited the heliosphere and punched into interstellar space (*SN: 10/19/13, p. 19*).

New Horizons is the first spacecraft in a position to double-check the Voyagers' observations. It scanned for UV light seven times from 2007 to 2017, space scientist Randy Gladstone of the Southwest Research Institute in San Antonio and colleagues report. As the spacecraft traveled, it saw the UV light change in a way that supports the decades-old observations. All three spacecraft saw more UV light farther from the sun than expected if there's no wall. But the team cautions that the light could also be from an unknown source farther away in the galaxy.

"It's really exciting if these data are able to distinguish the hydrogen wall," says space scientist David McComas of Princeton University. That could help researchers figure out the shape and variability of the solar system's boundary.

After New Horizons flies past the outer solar system object Ultima Thule on New Year's Day 2019, the spacecraft will continue to look for the wall about twice each year until the mission's end, hopefully, Gladstone says, 10 to 15 years from now.

If the UV light drops off at some point, then New Horizons may have left the wall in its rearview mirror. But if the light never fades, then its source could be farther ahead — somewhere deeper in space, says team member Wayne Pryor of Central Arizona College in Coolidge. ■



MATH & TECHNOLOGY

Desalination filter gets an upgrade

Smoothing out the rough patches of a material used to filter saltwater could make desalination more affordable, researchers report in the Aug. 17 *Science*.

Desalination plants typically strain salt out of seawater by pumping the water through polyamide films riddled with pores that allow water molecules to pass through but not sodium ions. Yet, organic matter and some waterborne particles can clog the films' pockmarked surfaces. Operators must replace the membranes frequently or install expensive equipment to remove contaminants.

Now researchers have made a supersmooth membrane without the divots that trap troublesome particles. Manufacturers normally create salt-filtering films by dipping porous plastic sheets into chemical baths containing polyamide ingredients. Molecules glom onto the sheet, building up a thin polymer membrane. But that method doesn't allow for control over texture, says Jeffrey McCutcheon, a chemical engineer at the University of Connecticut in Storrs.

McCutcheon and colleagues sprayed polyamide building blocks, molecular layer by layer, onto aluminum foil sheets. Films (a micrograph of one, above right) were up to 40 times as smooth as their commercial counterparts (left). The team has yet to test how clean the films stay over time. — *Maria Temming*

FROM TOP: ADLER PLANETARIUM, IBEX, NASA; M.R. CHOWDHURY *ET AL*/*SCIENCE* 2018

MATTER & ENERGY

New device defies 'before' and 'after'

Quantum switch makes two orders of events occur at once

BY EMILY CONOVER

One thing leads to another. In the quantum realm, that saying doesn't always ring true. A new quantum device can jumble up a sequence of two events so that they take place in both orders simultaneously, researchers report in a paper to be published in *Physical Review Letters*.

"In everyday life, we are used to thinking of events having a definite order," says physicist Jacqui Romero of the University of Queensland in Brisbane, Australia. In the morning, you might brush your teeth before washing your face, or vice versa. But in the quantum realm, both can be true simultaneously.

The device, called a quantum switch, puts particles of light through a series of two operations — labeled A and B — that alter the shape of the light. These photons can travel along two separate paths to A and B. Along one path, A happens before B; on the other, B happens before A.

Which path the photon takes is determined by its polarization, the direction its electromagnetic waves wiggle: up and down or side to side. Photons that have horizontal polarization experience operation A first, and those with vertical polarization experience B first.

But thanks to the counterintuitive quantum property of superposition, the photon can be both horizontally and vertically polarized at once. In that case, the light simultaneously experiences both A before B, and B before A, Romero and colleagues report.

The results mark "the first steps toward controlling a new regime of quantum physics," says Giulio Chiribella, a physicist at the University of Oxford and the University of Hong Kong, whose team first came up with the quantum switch idea.

Other scientists had built a similar quantum switch, but the new device eliminates an ambiguity. In the earlier switch, if A came before B, the light passed through a slightly different part of the apparatus than if B came before A, making the claim of simultaneously performing two identical operations in both orders less clear-cut. In the new switch, light passes through the same spot regardless of which operation comes first.

The quantum switch could potentially be useful in quantum communication and quantum computing. One new superpower that the quantum switch provides is the ability to communicate through channels where any information that goes in is scrambled, Romero and colleagues report online July 19 at arXiv.org.

Imagine calling a friend on a phone line that completely garbled your voice. If you sent that missive through another noisy phone line, your message would still be nothing but noise. That's not necessarily true with a quantum switch. The scientists showed that, if photons are passed through two noisy channels in a superposition, some info can be extracted.

"This is one of the things that I found the most magical," Chiribella says. ■

GENES & CELLS

Fox genes hold clues to domestication

Scientists ID differences between tame and aggressive animals

BY TINA HESMAN SAEY

For nearly 60 years, scientists in Siberia have bred silver foxes in an attempt to replay how domestication occurred thousands of years ago. Now, researchers have compiled the genome of *Vulpes vulpes*, the red fox species that includes the silver-coated variant. The fox's genetic instruction book may reveal changes that drove the domestication of animals such as cats and dogs, the team reports August 6 in *Nature Ecology & Evolution*.

At the Russian Academy of Sciences' Institute of Cytology and Genetics in Novosibirsk, Russia, scientists bred one group of foxes for ever-tamer behavior and another group for increasing aggressiveness (*SN: 5/13/17, p. 29*). Rif, the silver fox whose DNA now serves as the reference genome for the species, was the son of an aggressive vixen and a tame male.

Geneticist Anna Kukekova of the University of Illinois at Urbana-Champaign and colleagues also conducted less-detailed examinations of 10 foxes each from the tame and aggressive groups and 10 animals from a group that hadn't been bred for friendliness or aggression.

Those genomes are an invaluable resource for studying domestication, behavioral and population genetics and even human disorders such as autism, says Ben Sacks, a canid evolutionary geneticist at the University of California, Davis School of Veterinary Medicine. "It makes all kinds of research possible that weren't before," he says.

Parts of the genome that differ between tame silver foxes and aggressive ones (one shown) include genes involved in brain function.

Domestication researchers want to pinpoint the genes that set tame foxes apart from conventionally bred and aggressive foxes because those genes may be the same ones that were altered in dogs and other domestic animals. Kukekova and colleagues haven't yet identified the precise genetic changes that led to tameness. But the team did find 103 regions of the genome where tame foxes tend to have a different pattern of genetic variants compared with aggressive foxes.

Many of the genes in the 103 regions relate to the brain. The team found that versions of a gene called *SorCS1*, which encodes a protein involved in transmitting chemical information between brain cells, determined whether foxes wanted to interact with humans, says Kukekova. One version of *SorCS1* was in 61 percent of tame foxes but none of the aggressive foxes. In people, some versions of the gene are associated with autism or schizophrenia.

Other genes that differed between tame and aggressive foxes included ones involved in brain-cell signaling with the chemical messenger glutamate. Changes in these genes are associated with domestication in dogs, cats and rabbits.

Finding the same tweaked genes in studies of many different domesticated animals gives researchers confidence that they are closing in on the genes of domestication, says evolutionary geneticist Krishna Veeramah of Stony Brook University in New York. But because of its long history and wealth of data, the fox study is the true test, he says. Having the same genes pop up in silver foxes "is incredibly encouraging that they are the real ones involved in domestication." ■

MATH & TECHNOLOGY

Algorithm makes fake videos lifelike

Tool tweaks a person's head tilt, facial expressions and more

BY MARIA TEMMING

"The camera never lies" is a thing of the past. A new computer program can manipulate a video so that the person on-screen mirrors the movements and expressions of someone in a different video. Unlike other film-fudging software, the algorithm, presented August 16 at the SIGGRAPH 2018 meeting in Vancouver, also tweaks head and torso poses, eye movements and background details to create more lifelike fakes.

These video forgeries are "astonishingly realistic," says computer scientist Adam Finkelstein of Princeton University. This system could help produce dubbed films where the actors' lip movements match the voice-over, or movies that star dead actors reanimated through old footage, he says. But giving internet users the power to create ultra-realistic phony videos could also take fake news to the next level (*SN: 8/4/18, p. 22*).

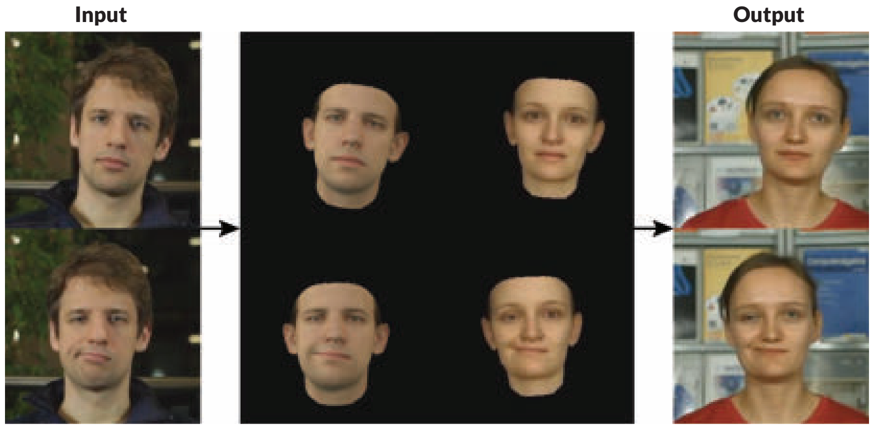
The algorithm starts by scanning two videos frame by frame, tracking 66 facial "landmarks," including points along the eyes, nose and mouth. The program can then distort one person's image to adopt another's head pose, facial expression and line of sight in each frame. The algorithm can also tweak shadows, change hair or adjust the height of the shoulders to match the new head pose. Using the program, researchers made a video of Russian President Vladimir Putin doing an eerily on-point imitation of former U.S. President Barack Obama's exact motions and expressions.

Christian Theobalt, a computer scientist at the Max Planck Institute for Informatics in Saarbrücken, Germany, and colleagues tested their program on 135 volunteers, who watched five-second clips of real and forged videos and reported whether they thought each clip was authentic. Dummy videos

DARYA SHEPELEVA

fooled, on average, 50 percent of viewers. But people may have been more critical of doctored footage during the study than they would be normally because they were primed to anticipate fakes. Even when participants were watching genuine clips, 20 percent, on average, still believed the clips were not real.

The software has some limits: It can fiddle only with videos shot by a stationary camera, framed to show someone's head and shoulders in front of a static background. And the algorithm can't shift a person's pose too much. That is, a clip of Putin speaking into the camera couldn't be edited to make him turn around, because the software wouldn't know what the back of Putin's head looks like.



A new algorithm analyzes the appearance of someone in one video ("input") and transfers that person's facial expression, head pose and line of sight onto a person in another video ("output"). That can generate footage of the second person doing and saying things she never actually did.

H. KIM ET AL/ACM TRANSACTIONS ON GRAPHICS 2018

Still, it's easy to imagine how this kind of digital puppetry could be used to spread misinformation. "Learning how to do these types of manipulations is [also] a step towards understanding how to detect them," says computer scientist Kyle Olszewski of the University of Southern California in Los Angeles. A future computer program could study both true and fake videos to learn how to spot the difference. ■

EARTH & ENVIRONMENT

Sick sea algae may help clouds grow

Virus-infected phytoplankton rapidly shed their tiny shells

BY CAROLYN GRAMLING

When microscopic sea algae get sick, they may sneeze the seeds of clouds.

Emiliania huxleyi phytoplankton infected with a virus shed the small calcium carbonate plates that make up their shells much more quickly than do healthy phytoplankton. Kicked up by thrashing waves into sea spray, those calcium bits may become part of the complex dance of cloud formation, researchers report online August 15 in *iScience*. This is the first study to suggest the role that viruses may play.

The finding adds to a growing body of work showing that cloud formation is regulated not just by physical processes, such as evaporation, but also by biological processes, says marine biologist Roberto Danovaro of the Università Politecnica Delle Marche in Ancona, Italy.

Phytoplankton contribute gases and particles that can become "seeds" around which water vapor in the air can condense to form clouds. Studies in the Southern Ocean have shown that phytoplankton blooms increase the number of cloud-forming droplets in the atmosphere over the ocean by about 60 percent each year.

In the lab, atmospheric chemist Miri Trainic of the Weizmann Institute of Science in Rehovot, Israel, and colleagues watched how the progression of a phytoplankton viral infection altered the shedding of calcium carbonate plates as well as the composition of sea spray.

The team filled a 10-liter container with several liters of seawater and added a population of *E. huxleyi*. Then the team added a phytoplankton virus.

Even healthy *E. huxleyi* shed some of the tiny plates that make up their shells, called coccoliths. But when infected by the virus, the phytoplankton tend to burst and rapidly drop their coccoliths. Within three days, seawater surrounding infected phytoplankton had three times as many plates as did water around the microbes' healthy counterparts. To simulate sea spray, the researchers pumped air through the tank and measured the particles released by breaking waves and bursting air bubbles.

Spray above virally infected populations had about two particles per cubic centimeter of air — about an order of magnitude more particles than in the spray above uninfected phytoplankton.

Once in the atmosphere, the flat, aerodynamic plates tend to linger, increasing their opportunities to affect cloud formation in various ways. One cloud-boosting role the plates may play is through chemical reactions in the atmosphere, forming calcium nitrate particles that can become giant cloud condensation nuclei.

But the particles may also hinder cloud formation, the study's researchers say, by removing other potential cloud seeds from the air. Phytoplankton-emitted dimethylsulfide gas, which transforms into sulfuric acid in the atmosphere, has also been hypothesized to help seed clouds. But in the presence of particles with relatively large surface areas, such as the coccoliths, the acid may condense onto these particles instead.

There are still many unknowns when it comes to how large of a role coccoliths actually play in cloud formation and whether they may do more to help or hinder cloud seeding, says atmospheric chemist Patricia Quinn of the National Oceanic and Atmospheric Administration's Pacific Marine Environmental Laboratory in Seattle. She notes that, for example, no one has yet measured the actual number of coccolith particles in the atmosphere over the ocean. ■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FEATURE

SOLAR SWEEP

NASA's Parker Solar Probe (illustrated) will swoop closer to the sun than any spacecraft has before.

NASA'S GODDARD SPACE FLIGHT CENTER

The Parker Solar Probe was built to survive close encounters with the sun

By Lisa Grossman

NASA has a mantra for preparing spacecraft to launch: "Test as you fly." The idea is to test the entire spacecraft, fully assembled, in the same environment and configuration that it will see in orbit. But the Parker Solar Probe, which launched August 12, is no ordinary spacecraft (*SN: 7/21/18, p. 12*). And it's headed to no ordinary environment. In November, Parker will make the first of 24 sweeps through the sun's scorching atmosphere for humankind's closest encounter with the star at the center of the solar system.

"Solar Probe is a little bit special," says space plasma physicist Stuart Bale of the University of California, Berkeley. Getting the whole thing into a setting that simulated the sun's energetic particles, intense light and searing heat "was deemed impossible," he says. Scientists had to get creative to test the technology that will skim the sun, using everything from huge mirrors to dust tunnels to reams of paper.

Taking the heat

The first order of business was to find materials that can stand the heat. The sun's outer atmosphere, or corona, sizzles at millions of degrees Celsius (*SN Online: 8/20/17*) — but it is so diffuse that it doesn't pose much threat to the spacecraft. Direct sunlight, however, can heat exposed components to about 1370° Celsius. Two of the spacecraft's experiments, plus parts of its solar panels and its revolutionary heat shield, will be exposed to that searing sunlight during its repeated close-ups.

"Normal things ... would melt," says Kelly Korreck, a solar physicist at the Smithsonian Astrophysical Observatory in Cambridge, Mass.

Korreck works on the Solar Wind Electrons Alphas and Protons instruments, known by the acronym SWEAP, which will catch the charged particles of the solar wind with a sensor called a Faraday cup (*SN Online: 8/18/17*). The cup sticks out from the heat shield "and will be able to touch the sun," Korreck says. "That cup is special."

To build the cup and other parts that will see the sun directly, engineers settled on three main materials — a niobium alloy called C103 that is used in rocket engines; an alloy of titanium, zirconium and molybdenum called TZM; and tungsten. Some cables carrying power to the SWEAP cup are also lined with sapphire, a good insulator at high temperatures. And the probe's heat shield is made of two kinds of carbon-based materials.

Figuring out how each of these materials would behave in space was tricky. Engineers couldn't just use an oven to test the components. Because heat can react with oxygen to rust or corrode metals and carbon can react with oxygen to combust, the heat tests had to happen in an airless vacuum chamber.

"Getting things hot on Earth is easier than you would think," says Elizabeth Congdon of the Johns Hopkins University Applied Physics Laboratory in Laurel, Md., and the heat shield's lead engineer.

"Getting things hot on Earth in vacuum is difficult."

One way the Parker team mimicked the sun's heat was by using actual sunlight. Engineers took material samples to the world's largest solar furnace, the PROMES facility in Odeillo, France. A series of 63 mirrors built on a hillside redirects sunlight onto an enormous concave mirror on the side of an eight-story building. That mirror then focuses the sunlight into a beam no more than 80 centimeters wide that heats materials to 3000° C inside a small vacuum chamber in a laboratory that's on stilts to reach the height of the beam.

The beam is so hot, "you can take a two-by-four and swing it through the beam, and [the wood] burns right off," Bale says. "Just a flash of smoke." Bale leads another of the probe's experiments, called FIELDS, that also needed heat testing. FIELDS is comprised of five long antennas, four of which will be exposed to the sun, that will measure electric and magnetic fields in the corona.

The SWEAP team needed a simulator that would also deliver intense sunlight at the same angles that Parker will experience. The engineers found an unlikely solution in IMAX film projectors, which emit light in a similar range of wavelengths to the sun.

"It took a completely custom test facility," says Anthony Case, an astrophysicist at the Smithsonian Astrophysical Observatory who works on the SWEAP instrument. He, Korreck and colleagues turned four IMAX projectors around so the lamps focused light into a small vacuum chamber, rather than spreading it across a huge screen. That setup gave the SWEAP team the right light intensity and angles to test the particle-catching cup.

This building-sized curved mirror focuses sunlight into a tight beam and sends it into a vacuum chamber, where the Parker probe's parts were tested for heat tolerance.

FROM LEFT: SLOOT/ISTOCKPHOTO; E. OTWELL

Biting the dust

Solar heat isn't the only threat to the Parker Solar Probe. The region around the sun that the spacecraft will explore is expected to be full of dust. Scientists don't know exactly how much dust to expect, but it's likely to be moving almost as fast as the spacecraft, about 170 kilometers per second.

That dust is a big worry for Parker's main telescopes, together called the Wide-field Imager for Solar Probe, or WISPR. One of the telescopes will be facing the direction that Parker is traveling, so the telescope will be heading directly into the dust storm. "It can't be protected," says astrophysicist Russell Howard of the U.S. Naval Research Laboratory in Washington, D.C., and WISPR team leader.

Dust particles hitting the telescope's lens will leave it pocked with little craters. Only 0.6 percent of the lens should be pitted by the end of Parker's seven-year mission, according to computer simulations of dust in the inner solar system. But even a few pits can obscure the real observations, so the WISPR team wanted to minimize the damage by choosing the right type of glass.

Howard and colleagues tested three possible materials for the lens in a dust acceleration tunnel at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. The tunnel accelerated charged iron particles, ranging from half a micrometer to 3 micrometers wide, to speeds from half a kilometer per second to 8 km/s — fast enough for the scientists to extrapolate up to the dust speeds Parker might experience.

Sapphire withstood the barrage best, but it was unclear how it would behave as a lens. The team also rejected diamond-coated BK7 glass, commonly used for space telescopes, after the coating separated from the glass and left an extra ring around the impact spot. Regular, uncoated BK7 was the best option.

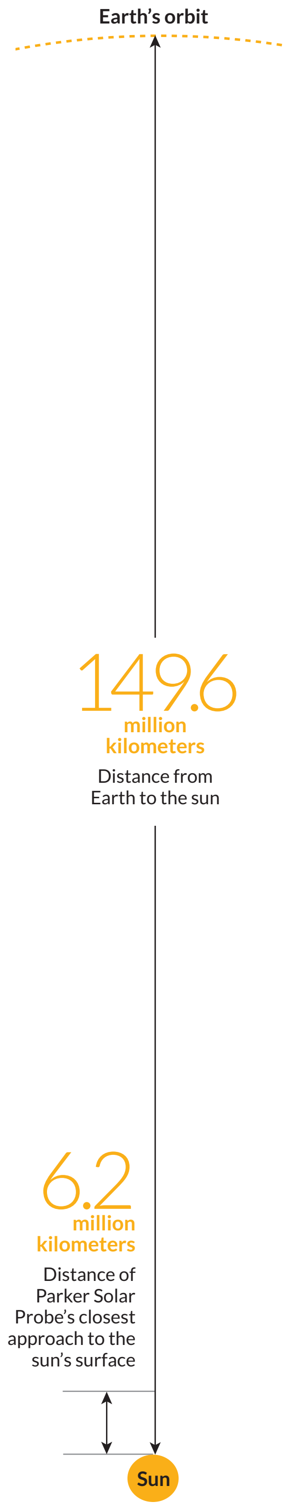
Running hot and cold

Aside from SWEAP and FIELDS, most of the spacecraft will be tucked behind the all-important heat shield and thus protected from the dust and the sun's extreme heat.

That 2.5-meter-wide heat shield is made of carbon foam sandwiched between two carbon sheets. The whole thing is just 11.5 centimeters thick and coated on the sun-facing side with white ceramic paint to reflect as much sunlight as possible. Even

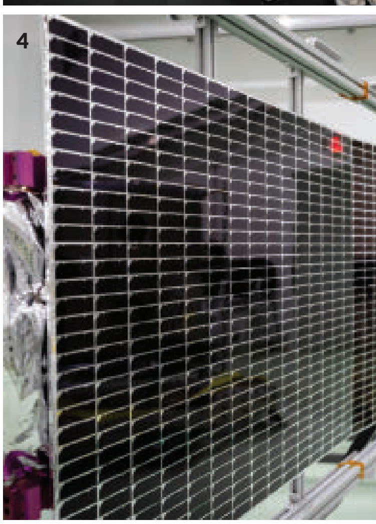
A trip fit for Icarus

Each of the Parker Solar Probe's 24 orbits will bring it closer to the sun. The last three orbits will take the probe within 6.2 million kilometers of the solar surface.



In the hot zone

The Parker Solar Probe will use four sets of scientific instruments plus innovative self-protective measures to explore the environment near the sun. Take a tour of the spacecraft's tech.



1. Taking the heat
A custom-built heat shield (shown at left during testing in a vacuum chamber) will guard most of the spacecraft from the worst of the sun's heat. Withstanding temperatures up to 1370° Celsius, the shield will keep everything behind it at an average of 30° C.

2. Hunting for particles
The Integrated Science Investigation of the Sun experiment will detect solar particles across a wide range of energies to decipher how the sun accelerates the solar wind. One detector will search for low-energy particles; another one will search for high-energy particles. Small telescopes help show where the particles come from.

3. Taking sun selfies
The Wide-field Imager for Solar Probe, or WISPR, telescopes will take images of the solar corona, solar wind, shocks and flares. These images will help scientists interpret data from the other instruments. One telescope will look ahead of the spacecraft, the other to the side.

4. Powering up
Two solar panels (one shown at lower left) are mounted on a movable joint to control how much sunlight the panels absorb. Close to the sun, the panels will fold behind the heat shield, leaving only the last row of solar cells exposed to take in energy.

5. Keeping cool
Parker will let off heat through a set of radiators (black material shown at left during testing) worn like a collar between the heat shield and the bulk of the spacecraft. Tubes of water carry heat from the solar panels to the radiators, where the heat can escape into space.

6. Fielding signals
Five antennas make up the FIELDS experiment, which will measure electric and magnetic fields in the sun's neighborhood, helping scientists figure out what makes the sun's corona so hot. Four of the antennas are made of a special material because they will be exposed to direct sunlight.

7. Catching wind
At the back of the probe (not visible in the illustration above) is a cup that is part of the Solar Wind Electrons Alphas and Protons, or SWEAP, experiment. It will catch charged particles in the solar wind and determine their temperature, density and speed. The cup will be exposed to sunlight 475 times as intense as is felt on Earth.

ILLUSTRATION: JHU-APL, NASA; CUP: ANDREW WANG; OTHER PHOTOS: ED WHITMAN/JHU-APL, NASA then, that side could get as hot as 1370° C. But behind it, the bulk of the spacecraft will chill at just 30° C on average (about 85° Fahrenheit).

"We hide in the shadows," says solar physicist Eric Christian of NASA's Goddard Space Flight Center in Greenbelt, Md. He's the deputy principal investigator of the Integrated Science Investigation of the Sun experiment, which will measure solar particles across a wide range of energies. His team was able to use ordinary materials and skip the rigorous heat testing. "We're the lucky ones."

But Parker won't always be near the sun. The spacecraft's 24 orbits will bring it as far from the sun as Venus, where temperatures are a frigid –270° C. At that distance, the spacecraft needs onboard heaters to keep it at 20° C. So Parker needed to be tested for cold and extreme temperature changes, too.

"We're not just worried about hot cycles," Congdon says. "We're worried about hot then cold then hot then cold."

In January, the entire spacecraft was lowered into a thermal vacuum chamber at NASA Goddard for two months of testing. The chamber, a cylinder standing 12 meters tall and 8 meters wide, was cooled to –190° C. A radiator glowing at about 315° C represented the heat from the side of the heat shield not facing the sun — but most of that heat never reached the scientific instruments because a titanium truss holds the heat shield at a safe distance from the spacecraft's main body. The team cycled through hot and cold several times to simulate what Parker will experience.

At all temperatures, the probe's solar panels need to stay cool. "You think, obviously, you're going to the sun, solar power makes the most sense," Congdon says. "But solar panels don't like to get hot." So the panels are threaded with veins that carry water to cool them off. The water absorbs heat from the panels and carries it to radiators that release the heat into space.

The solar panels are also on a shoulder joint, so they can tuck behind the heat shield at Parker's closest approaches to the sun. Only the last row of cells will see the sun then. "That single row of cells can produce the same amount of power as the full wing can when we're by the Earth," says solar physicist Nicola Fox of the Johns Hopkins University Applied Physics Laboratory, the probe's project scientist.

Up and away

Making sure Parker would survive the launch into space (it did) took more preparation.

The Parker Solar Probe, shown here on July 16, is mounted atop the final rocket stage that launched the spacecraft toward the sun on August 12.

ED WHITMAN/JHU-APL, NASA

With its violent shaking, a spacecraft launch is a tense time for scientists, even if they've tested all of the parts in an acoustic vibration chamber. Watching SWEAP's vibration test "made me swear," Korreck says. "It's very scary to watch this thing you've spent 10 years on flop around as it keeps shaking more and more."

Her team faced an unusual challenge in making Parker ready to rattle. The team could not use glue to prevent the screws from shaking loose, because epoxies would melt in sunlight. So the researchers twisted thin niobium wire by hand to tie hundreds of screws together in such a way that, if one comes loose, the others hold it in.

Launch can be a high-pressure time for the spacecraft, too — literally. Engineers initially thought Parker's launch aboard a powerful Delta IV Heavy rocket would subject the heat shield to a force 20 times that of Earth's gravity. Later, however, the engineers realized the launch force wouldn't be so severe. Still, to make sure the 72.5-kilogram shield wouldn't bend or break, the team stacked 1,360 kilograms, or 150 reams, of paper on top of it.

Parker's first scientific data should start trickling back to Earth in December. These missives will let scientists take a big step toward unlocking the secrets of the sun's superheated atmosphere and its energetic winds.

"It's like being a proud parent. I worry that something could happen, but I don't worry that we didn't prepare or test her well," Fox says of the probe. "I just hope she writes home every day with beautiful data." ■

Explore more

- NASA's Parker Solar Probe: bit.ly/NASAparker
- Nicola J. Fox *et al.* "The Solar Probe Plus Mission: Humanity's first visit to our star." *Space Science Reviews.* December 2016.

PLANT PARTNERS

Scientists are tinkering with plant microbiomes to feed the world and save endangered species

By Amber Dance

One fine Hawaiian day in 2015, Geoff Zahn and Anthony Amend set off on an eight-hour hike. They climbed a jungle mountain on the island of Oahu, swatting mosquitoes and skirting wallows of wild pigs. The two headed to the site where a patch of critically endangered *Phyllostegia kaalaensis* had been planted a few months earlier. What they found was dispiriting.

"All the plants were gone," recalls Zahn, then a postdoctoral fellow at the University of Hawaii at Manoa. The two ecologists found only the red flags placed at the site of each planting, plus a few dead stalks. "It was just like a graveyard," Zahn says.

The plants, members of the mint family but without the menthol aroma, had most likely died of powdery mildew caused by *Neoerysiphe galeopsidis*. Today the white-flowered plants, native to Oahu, survive only in two government-managed greenhouses on the island. Why *P. kaalaensis* is nearly extinct is unclear, though both habitat loss and powdery mildew are potential explanations. The fuzzy fungal disease attacks the plants in greenhouses, and the researchers presume it has killed all the plants they've attempted to reintroduce to the wild.

Phyllostegia kaalaensis grew on Oahu's Koolau Range (above) until about 1970. Researchers are looking to microbes to help the mint plant.

Zahn had never encountered extinction (or near to it) so directly before. He returned home overwhelmed and determined to help the little mint.

Just like humans and other animals, plants have their own microbiomes, the bacteria, fungi and other microorganisms living on and in the plants. Some, like the mildew, attack; others are beneficial. A single leaf hosts millions of microbes, sometimes hundreds of different types. The ones living within the plant's tissues are called endophytes. Plants acquire many of these microbes from the soil and air; some are passed from generation to generation through seeds.

The friendly microbes assist with growth and photosynthesis or help plants survive in the face of drought and other stressors. Some protect plants from disease or from plant-munching animals. Scientists like Zahn are investigating how these supportive communities might help endangered plants

DAVID L. MOORE-HI/ALAMY

in the wild, like the mint on the mountain, or improve output of crops ranging from breadbasket wheat to tropical cacao.

Beyond the garden store

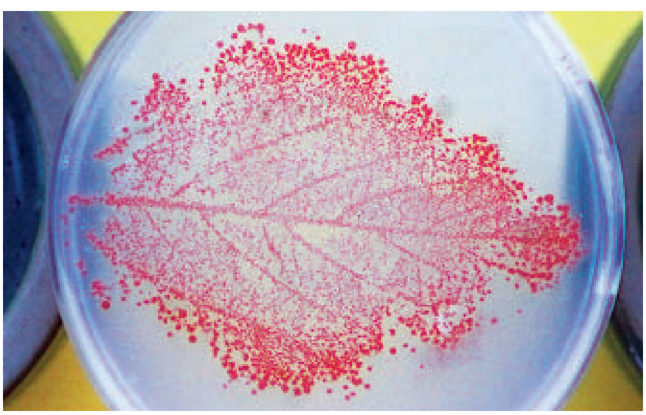
Certain microbial plant partners are well-known, and there are scores of microbial products already on the market. Gardeners, for instance, can spike their watering pails with microbes to encourage flowering and boost plant immunity. But "we know very little about how the products out there actually do work," says Jeff Dangl, a geneticist at the University of North Carolina at Chapel Hill. "None of those garden supply store products have proven useful at large scale."

Big farms can use microbial treatments. The main one applied broadly in large-scale agriculture helps roots collect nitrogen, Dangl says, which plants use to produce chlorophyll for photosynthesis.

Farmers may soon have many more microbial helpers to choose from. Scientists studying plant microbiomes have described numerous unfamiliar plant partners in recent decades. Those researchers say they've only scratched the surface of possibilities. Many start-up companies are researching and releasing novel microbial treatments. "The last five years have seen an explosion in this," says Dangl, who cofounded AgBiome, which soon plans to market a bacterial treatment that combats fungal diseases. Agricultural giants like Bayer AG, which recently bought Monsanto, are also investing hundreds of millions of dollars in potential microbial treatments for plants.

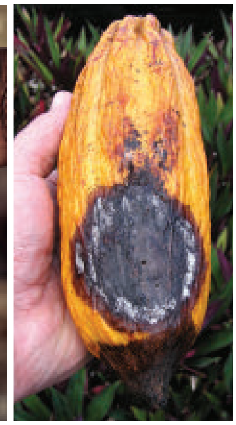
The hope is that microbes can provide the next great revolution in agriculture — a revolution that's sorely needed. With the human population predicted to skyrocket from today's 7.6 billion to nearly 10 billion by 2050, our need for plant-based food, fibers and animal feed is expected to double.

"We're going to need to increase yield," says Posy Busby, an ecologist at Oregon State University in Corvallis. "If we can manage and manipulate microbiomes ... this could potentially represent an untapped area for increasing plant yield in agricultural settings." Meanwhile, scientists like Zahn are eyeing the microbiome to save endangered plants.



When pressed against a plate of nutrients that support methane-eating microbes, a soybean leaf leaves behind spots of growing bacteria. Those bacteria may help grow more robust plants.

CLOCKWISE FROM TOP LEFT: CHANG/ISTOCKPHOTO; SCOT NELSON/FLICKR; NEWLEAF SYMBIOTICS



Healthy cacao pods (left) contain cacao beans encased in white flesh. The fungus that causes black pod rot (right) is a constant threat to plantations globally.

But before microbiome-based farming and conservation can truly take off, many questions need answers. Several revolve around the complex interactions between plants, their diverse microbial denizens and the environments they live in. One concern is that the microbes that help some plants might, under certain conditions, harm others elsewhere, warns microbiologist Luis Mejía of the Institute of Scientific Research and High Technology Services in Panama City.

Save the chocolate

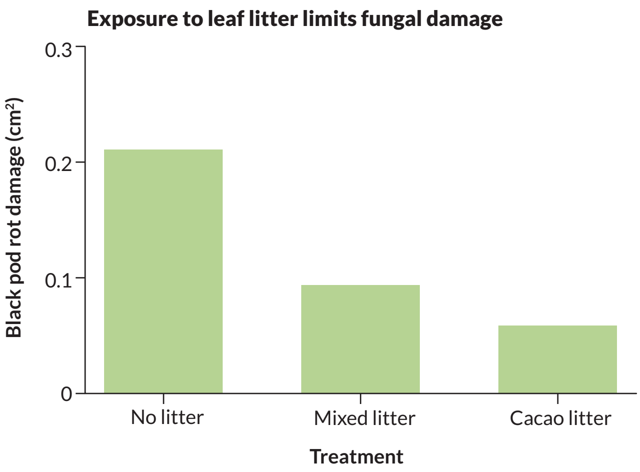
Cacao crops — and thus humankind's precious M&M's supply — are under constant threat from undesirable fungi, such as *Phytophthora palmivora*, which causes black pod rot. But there are good guys in cacao's microbiome too, particularly the fungus *Colletotrichum tropicale*, which seems to protect the trees.

Natalie Christian, as a graduate student at Indiana University Bloomington, traveled to the Smithsonian Tropical Research Institute on Panama's Barro Colorado Island in 2014 to study how entire communities of microbes colonize and influence cacao plants (*Theobroma cacao*). Christian suspected that the prime source of a young cacao tree's microbiome would be the dead and decaying leaves on the rainforest or orchard floor.

To test this hunch and see what kind of protection microbes picked up from leaf litter might offer, Christian raised fungus-free cacao seedlings in a lab incubator. When the plants reached about half a meter tall, she placed them in pots outside, surrounding some with leaf litter from a healthy cacao tree, some with litter from other kinds of trees and some with no litter at all.

After two weeks, she brought the plants back into the greenhouse to analyze their microbiomes. She found nearly 300 kinds of endophytes, which she, Mejía and colleagues reported last year in *Proceedings of the Royal Society B*.

The microbiome membership differed between the litter treatments. Plants in pots with either kind of leaf litter possessed less diverse microbiomes than those without litter, probably because the microbes in the litter quickly took over



Defenses up After cacao plants were grown with or without leaf litter around their roots, scientists exposed the plants to black pod fungus and measured rot damage. Microbes from cacao-based litter were most beneficial to the plants, but even mixed litter offered protection against the fungus. SOURCE: N. CHRISTIAN *ET AL/PROCEEDINGS OF THE ROYAL SOCIETY B* 2017

before stray microbes from elsewhere could settle in. These results suggest that a seedling in the shadow of more mature trees will probably accumulate the same microbiome as its towering neighbors.

To see if some of those transferred microbes protect the cacao from disease-causing organisms, Christian rubbed a bit of black pod rot on the leaves of plants in each group. Three weeks later, she measured the size of the rotted spots.

Plants surrounded by cacao litter had the smallest lesions. Those with litter from other trees had slightly more damage, and plants with no litter had about double the damage of the mixed litter plants.

"Getting exposed to the litter of their mother or their own kind had a very strong beneficial effect on the resistance of these young plants," says plant biologist Keith Clay of Tulane University in New Orleans, a coauthor of the study.

Scientists aren't sure how the good fungi protect the plants against the rot. It may be that the beneficial fungi simply take up space in or on the leaves, leaving no room for the undesirables, Christian says. Or a protective microbe like *C. tropicale* might attack a pathogen via some kind of chemical warfare. In the case of cacao, she thinks the most likely explanation is that the good guys act as a sort of vaccine, priming the plant's immune system to fight off the rot. In support of this idea, Mejía reported in 2014 in *Frontiers in Microbiology* that *C. tropicale* causes cacao to turn on defensive genes.

Cacao farmers may need to rethink their practices. The farmers normally clear leaf litter out of orchards to avoid transmitting disease-causing microbes from decaying leaves to living trees, says Christian, now a postdoc at the University of Illinois at Urbana-Champaign. But her work suggests that farmers might do well to at least hold on to litter from healthy trees.

Crop questions

Litter is a low-tech way to spread entire communities of microbes — good and bad. But agricultural companies want to grab only the good microbes and apply them to crops. The hunt for the good guys starts with a stroll through a crop field, says Barry Goldman, vice president and head of discovery at Indigo Ag in Boston. Chances are, you'll find bigger and hardier plants among the crowd. Within those top performers, Indigo has found endophytes that improve plant vigor and size, and others that protect against drought.

The company, working with cotton, corn, rice, soybeans and wheat, coats seeds with these microbes. Once the seeds germinate, the microbes cover the newborn leaves and can get inside via cuts in the roots or through stomata, tiny breathing holes in the leaves. The process is akin to what happens when a baby travels through the birth canal, picking up beneficial microbial partners from mom along the way.

For example, the first-generation Indigo Wheat, released in 2016, starts from seeds treated with a beneficial microbe. In Kansas test fields, the treatment raised yields by 8 to 19 percent. Farmers are also reporting improved drought tolerance.

FROM TOP: C. CHANG; RUSLANDASHINSKY/ISTOCKPHOTO

The fungus in the fescue

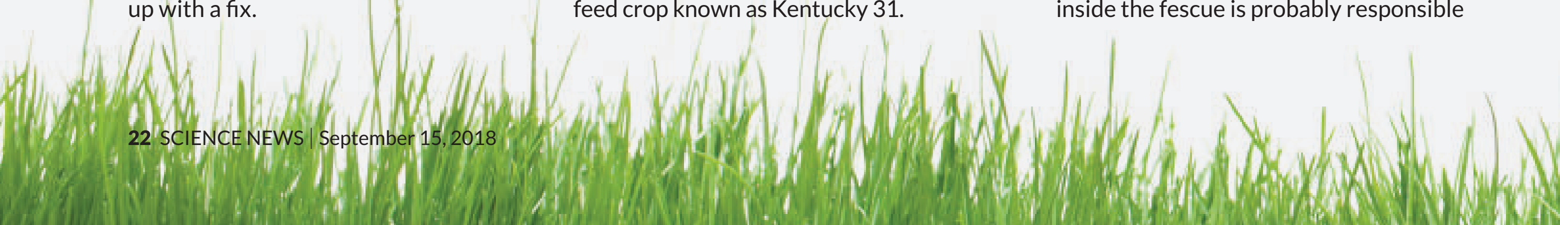
Plant microbes can be good, bad or a bit of both. Take the fungus living in tall fescue (*Lolium arundinaceum*), a grass that sways across 35 million acres of lawns and pastures in the eastern United States and beyond. The fescue is wildly successful because of the fungus. But the same fungus also makes the grass a toxic meal for livestock. It took scientists decades to figure out why and come up with a fix.

1800s Tall fescue finds its way to the United States from Europe. The grass may have come along with a shipment of meadow fescue seed or, as one legend has it, as packing material for bone china.

1931 E.N. Fergus, an agronomist at the University of Kentucky in Lexington, collects a type of tall fescue from the local farm of William Suiter. The grass grows well under drought conditions and in poor soils. It would become a popular ground cover and feed crop known as Kentucky 31.

1940s Soon after the official release of Kentucky 31, farmers report that animals grazing on tall fescue exhibit bizarre symptoms: They don't gain weight as they should. Their feet turn lame, swollen and even gangrenous. Cows give less milk and horses suffer miscarriages. The syndrome is eventually called fescue toxicosis.

1977 Charles Bacon of the U.S. Department of Agriculture in Athens, Ga., and colleagues report that a fungus living inside the fescue is probably responsible



During the first six months of 2018 with only two rains, the participating Kansas farmers had given up on and plowed over fields with struggling regular wheat, but not those growing Indigo Wheat, Goldman says.

In St. Louis, NewLeaf Symbiotics is interested in bacteria of the genus *Methylobacterium*. These microbes, found in all plants, are known as methylotrophs because they eat methane gas, which plants release as their cells grow. In return for methane, M-trophs, as NewLeaf calls them, offer plants diverse benefits. Some deliver molecules that encourage plants to grow; others make seeds germinate earlier and more consistently, or protect against problem fungi.

NewLeaf released its first products this year, including Terrasym 401, a seed treatment for soybeans. Across four years of field trials, Terrasym 401 raised yields by more than two bushels per acre, says NewLeaf cofounder and CEO Tom Laurita. One bushel is worth about $9. On farms with thousands of acres, that adds up.

Farmers are pleased, but NewLeaf's and Indigo's work is hardly done. Plant microbiome companies all face similar challenges. One is the diverse environments where crops are grown. Just because Indigo Wheat thrives in Kansas doesn't mean it will outgrow standard varieties in, say, North Dakota. "The big ask for the next-gen ag biotech companies like AgBiome or Indigo ... is whether the products will deliver as advertised over a range of field conditions," Dangl says.

Another issue is that crop fields and plants already have microbiomes. "We're asking a lot of a microbe, or a mix of microbes, to invade an already-existing ecosystem and persist there and do their job," Dangl says. Companies will need to make sure their preferred microbes take hold.

And while scientists are well aware that diverse microbial communities cooperate to affect plant health, most companies are working with one kind of microbe at a time. Indigo isn't yet sure how to approach entire microbiomes, Goldman says, but "we certainly are thinking hard about it."

Researchers are beginning to address these questions by studying microbes in communities — such as Christian's leaf-litter microbiomes — instead of as individuals. In the lab, Dangl developed a synthetic community of 188 root microbes. He can apply them to plants under stress from drought or heat, then watch how the communities respond and affect the plants.

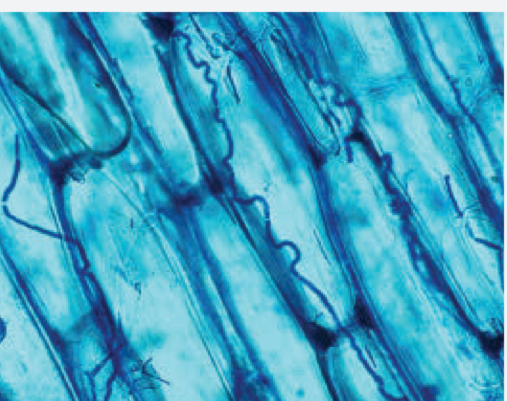
Indigo Ag's microbial treatment for cotton seeds results in bigger, bushier plants under low-water conditions compared with untreated plants.

A major aim is to identify the factors that determine microbiome membership. What decides who gets a spot on a given plant? How does the plant species and its local environment affect the microbiome? How do plants welcome friendlies and eject hostiles? "This is a huge area of importance," Dangl says.

There's some risk in adding microbes to crops while these questions are still unanswered, Mejía cautions. Microbes that are beneficial in one situation could be harmful in other plants or different environments. It's not a far-fetched scenario: There's a fungal endophyte of a South American palm tree that staves off beetle infestations when the trees are in the shade. Under the sun, however, the fungus turns nasty, spewing hydrogen peroxide that kills plant tissues.

And although *C. tropicale* benefits cacao, the genus has a dark side: Many species of *Colletotrichum* can cause leaf lesions

FROM TOP: INDIGO AG; NICK HILL/USDA



for toxicosis. The fungus, *Epichloë coenophiala*, produces toxins called ergot alkaloids. Yet *E. coenophiala* (at left, blue squiggles inside fescue cells) is also the reason tall fescue grows so well: The fungus helps the plant resist stressors such as drought and flooding.

2000 Pennington Seed, Inc. releases a tall fescue variety called Jesup MaxQ, which contains a different fungus that provides the stress resistance without the toxic alkaloids.

Today While several low-alkaloid versions of tall fescue seed are available, farmers have not yet gone to the effort to replace all their pastures, and it's not clear the new versions work well in all environments. Scientists at the University of Kentucky, led by Christopher Schardl, continue to tinker with the fungus and its genes in the hopes of eliminating alkaloid production and making grasses that thrive in environments where the current options don't.

and rotted fruit or flower spots in a variety of plants ranging from avocados to zinnias.

Microbes for conservation

Back in Hawaii, after that disheartening hike to the *P. kaalaensis* graveyard, Zahn pondered how to protect native plants in wild environments such as Oahu's mountains.

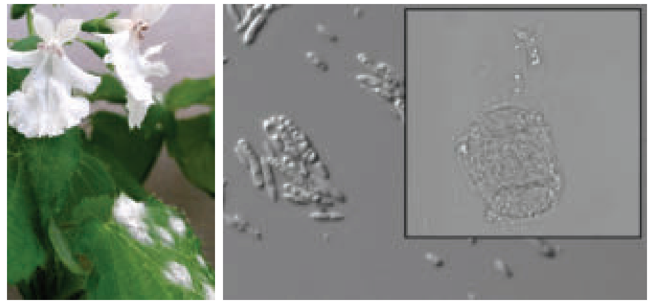
In people, Zahn considered, antibiotics can damage normal gut microbe populations, leaving a person vulnerable to infection by harmful microbes. *P. kaalaensis* got similar treatment in the greenhouse, where it received regular dosing of fungicide. In retrospect, Zahn realized, that treatment probably left the plants bereft of their natural microbiome and weakened their immune systems, leaving them vulnerable to mildew infection once dropped into the jungle.

For people on antibiotics, probiotics — beneficial bacteria — can help restore balance. Zahn thought a similar strategy, a sort of plant probiotic, could help protect *P. kaalaensis* in future attempts at moving it outside.

For a probiotic, Zahn looked to a *P. kaalaensis* cousin, *Phyllostegia hirsuta*, which can survive in the wild. He put *P. hirsuta* leaves in a blender and sprayed the slurry over *P. kaalaensis* growing in an incubator.

Then, Zahn placed a leaf infected with powdery mildew into the incubator's air intake. The mint plants treated with the *P. hirsuta* slurry experienced delayed, less severe infections compared with untreated plants, Zahn and Amend, also at the University of Hawaii at Manoa, reported last year in *PeerJ*. The probiotic had worked.

Zahn used DNA sequencing to identify the microbes in the slurry. Many of the microbiome members probably benefit *P. kaalaensis*, but he thinks he's found a major protector: a yeast called *Pseudozyma aphidis* that lives on leaves. "This yeast normally just passively absorbs nutrients from the environment," Zahn says. "But given the right victim, it will turn into a vicious spaghetti monster." When mildew spores land nearby, the yeast grows tentacle-like filaments that appear to envelop and feed on the mildew.



Powdery mildew attacks *Phyllostegia kaalaensis* (left), preventing the plant from taking hold in the wild. But a beneficial yeast (rods, right) found on the leaf of another species of *Phyllostegia* sends out filaments that attack the mildew (blob in inset) and protect the plants.

Emboldened by his results, Zahn trekked back to the jungle and planted six slurry-treated plants in April 2016. They survived for about two years, but by May 2018, they were all dead.

"It was still a huge win," says Nicole Hynson, a community ecologist also at Manoa. After all, *P. kaalaensis* without probiotics last only months. And the probiotics approach might apply beyond one little Hawaiian mint, Hynson adds: "We're really at the beginning of thinking how we might use the microbiome to address plant restoration."

Zahn has since moved to Utah Valley University in Orem, where he's hoping to help endangered cacti with microbes. Meanwhile, he's left the *Phyllostegia* project in the hands of Jerry Koko, a graduate student in Hynson's lab. Koko is studying how the yeast and some root-based fungi protect the plant.

Hynson says their goal is to build "a superplant." With probiotics on both roots and shoots, an enhanced *P. kaalaensis* should be well-equipped to grow strong and resist mildew. In greenhouse experiments so far, Koko says, the plants with both types of beneficial fungi seem to sport fewer, smaller powdery mildew patches than plants that received no probiotic treatment.

While the restoration of a little flowering plant, or a few more bushels of soybeans, may seem like small victories, they could herald big things for plant microbiomes in conservation as well as agriculture. The farmers and conservationists of the future may find themselves seeding and tending not just plants, but their microscopic helpers, too. ■

Botanical beneficiaries Bacteria and fungi that live in and on plants can help their hosts in several ways. Here's a sampling.

Plant	Microbe	Effects
Legumes and other plants	Rhizobia	Provide the plant with extra nitrogen, which boosts photosynthesis and helps the plant produce bitter, nitrogen-containing alkaloids that defend against plant-eating animals
Maize (*Zea mays*)	*Glomus mosseae*	Increase the plant's root length and water uptake
Dang shen (*Codonopsis pilosula*), a medicinal herb also known as poor man's ginseng	Some strains of *Bacillus subtilis*	Improve plant size, chlorophyll content and photosynthesis
Black cottonwood (*Populus trichocarpa*)	*Stachybotrys*	Reduce the severity of leaf rust caused by the fungus *Melampsora*
Alfalfa (*Medicago sativa*)	*Sinorhizobium meliloti*	Help the plant withstand freezing

Explore more

- Natalie Christian *et al.* "Exposure to the leaf litter microbiome of healthy adults protects seedlings from pathogen damage." *Proceedings of the Royal Society B*. July 12, 2017.
- Geoffrey Zahn and Anthony S. Amend. "Foliar microbiome transplants confer disease resistance in a critically-endangered plant." *PeerJ*. November 10, 2017.

Amber Dance is a freelance writer based in Los Angeles.

BOTH: G. ZAHN AND A. AMEND/*PEERJ* 2017

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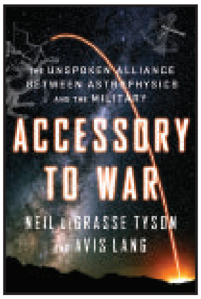

Accessory to War
Neil deGrasse Tyson and Avis Lang
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BOOKSHELF

How space science aids and abets warfare

Late-night comedians skewered Vice President Mike Pence in August when he announced preliminary plans for a new branch of the U.S. military dubbed the "Space Force." Jimmy Kimmel likened the idea to a Michael Bay action movie, while Jimmy Fallon quipped that the Space Force's chain of command would go "E.T., Yoda, then Groot."

But, as a new book by astrophysicist Neil deGrasse Tyson and researcher-writer Avis Lang demonstrates, the militarization of space is no joke.

In *Accessory to War,* Tyson and Lang chronicle how warmakers have long wielded knowledge of outer space as a weapon. This bloody history features Christopher Columbus exploiting his awareness of an upcoming lunar eclipse to threaten natives on the island of Hispaniola with divine retribution, as well as the United States using satellite intelligence to fight the Gulf War.

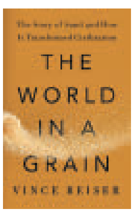
"As for America's forthcoming wars," Tyson and Lang predict, "they will be waged with even more formidable space assets."

But just as militaries have long used space science and space-based technology to their advantage, astronomers and astrophysicists have reaped the rewards of military investment. James Cook, a captain in the British Navy, for example, established an observatory in Tahiti. Observations of Venus passing across the face of the sun in 1769 from that observatory helped astronomers pin down the distance between Earth and the sun. During the Cold War, U.S. military satellites designed to watch for nuclear detonations discovered gamma-ray bursts, some of the most spectacular explosions in the universe (*SN: 1/10/15, p. 15*).

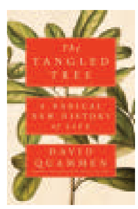
Tyson and Lang's millennia-long world history is sprawling. The book is exhaustively researched, almost to the point of information overload. It's easy to get bogged down in parenthetical asides about minor characters or paragraph-long lists. The book is the antithesis of Tyson's starry-eyed, bite-sized *Astrophysics for People in a Hurry* and may end up on the shelves of more history buffs than astro nerds.

Still, *Accessory to War* lives up to much of the promise of a Neil deGrasse Tyson read: Written from Tyson's perspective, the narration is rich with wry humor and vivid descriptions of cosmic goings-on. For anyone who is, like Tyson, "smitten by the cosmos," the book is a stark reminder that astrophysics has been both a benefactor and beneficiary of human conflict — and that the final frontier will likely be the battleground of many future skirmishes. *— Maria Temming*

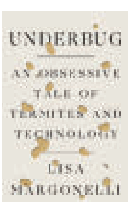
BOOKSHELF



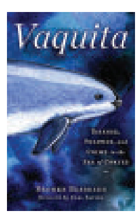
The World in a Grain
Vince Beiser
Why is sand, found in everything from buildings to the Hubble Space Telescope, so vital to society? This book dives into that question and what our dependence on sand means for the health of the planet. *Riverhead Books, $28*



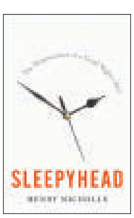
The Tangled Tree
David Quammen
A science journalist argues that the tree of life is more tangled than we thought, as recent molecular biology discoveries have shifted our understanding of evolution. *Simon & Schuster, $30*



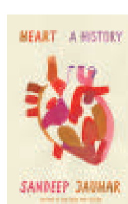
Underbug
Lisa Margonelli
A journalist travels the world learning about termites' impact on ecosystems and societies, and how the insects' biology offers inspiration for human technologies. *Scientific American/Farrar, Straus and Giroux, $27*



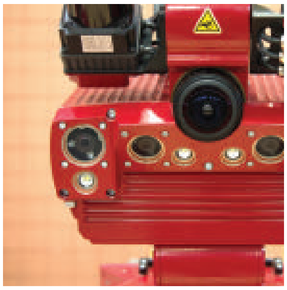
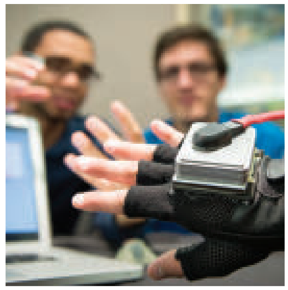
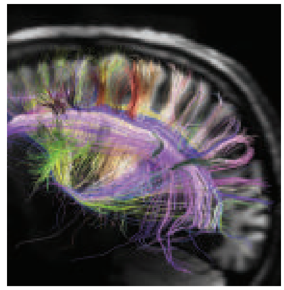
Vaquita
Brooke Bessesen
Journey to Mexico's Upper Gulf of California and learn about the vaquita, one of the world's most endangered marine animals, and how scientists and local residents are trying to save this porpoise species. *Island Press, $30*

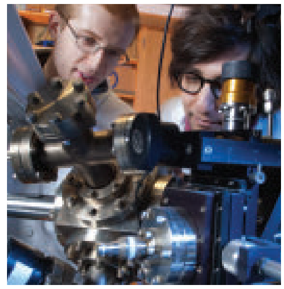


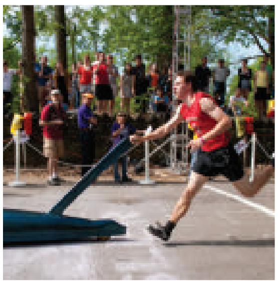
Sleepyhead
Henry Nicholls
This book introduces readers to the science behind sleep disorders and why people with narcolepsy, insomnia and sleep apnea can't seem to get a good night's rest. *Basic Books, $30*

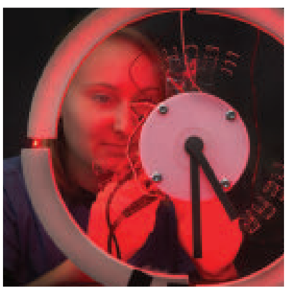


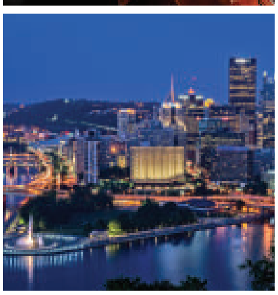
Heart: A History
Sandeep Jauhar
To recount the scientific history of the heart, a cardiologist tells the stories of the doctors who learned how to heal the body's most vital organ with the help of their brave patients. *Farrar, Straus and Giroux, $27*

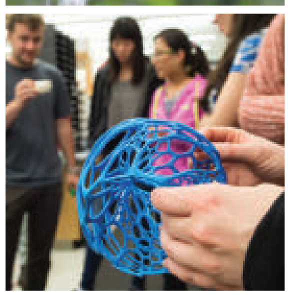





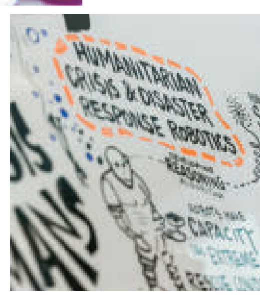




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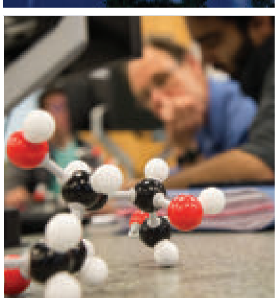
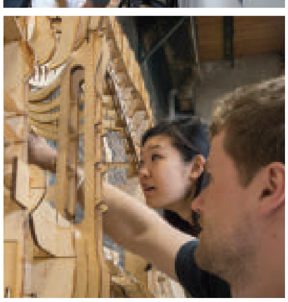
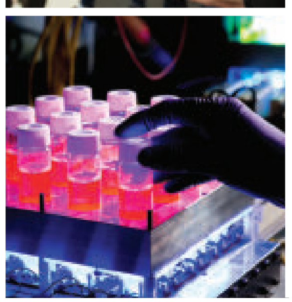
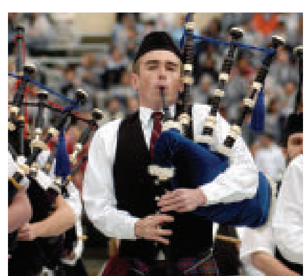

CONVERSATIONS WITH MAYA

DIVYA NAG
HEALTH SPECIAL PROJECTS
APPLE

COURTESY OF D. NAG

Maya Ajmera, President & CEO of Society for Science & the Public and Publisher of *Science News*, sat down to chat with Divya Nag, who works for Apple in the Health Special Projects section. Nag is also a member of the Society's National Leadership Council. We are thrilled to share an edited summary of the conversation.

You competed in the Intel International Science and Engineering Fair (ISEF) in 2007 and 2009. How did these competitions impact your life, and are there any particular moments that still stand out for you?

I could gush about ISEF for hours on end. It was during ISEF that I realized I loved science. One moment that is etched in my memory is walking on the floor for the first time and seeing hundreds of rows of booths with absolutely brilliant high school students and these larger-than-life poster boards. I call it my Disneyland — my happiest place on Earth.

Until that experience, I never thought it was possible for high school students to do such cutting-edge work. Seeing this incredible work opened my eyes to opportunities that I should be fighting for. In 2007, I didn't place, but when 2009 came around, it was a very different experience for me. I came in with a completely new level of confidence and a higher level of science.

What was different? What did you do to open more doors?

I petitioned University of California, Davis, which was the university closest to my high school, to let me conduct research during the school year. I sent hundreds of e-mails to professors there to see if anyone would let a high school student work in their lab. Then, I spent all my time at the lab after school. In those two years, I published my first peer-reviewed paper. By the time I got to ISEF in 2009, I had already won because I had shown myself what was possible.

What was your project about?

My project focused on preventing forest fires, specifically trying to understand if we could chemically change the composition of soil to stop forest fires from happening. I was excited and passionate about the earth sciences. 2009 was a time when Sacramento, which is where I went to high school, had a number of forest fires.

You transitioned from earth science to studying health care at Stanford University. How did you make that pivot? What led you to start your companies, Stem Cell Theranostics and StartX Med?

When I came to Stanford, I thought I would major in earth sciences. But after doing some research into the opportunities that were available at the time, I felt like I had already explored the earth science research topics available to me.

Additionally, at that time, there was an air of mystique and untapped potential, and even danger, around stem cell use. Embryonic stem cell use had been banned and that piqued my interest. It seemed like a very high risk, very high reward area to research.

It was a huge mental shift for me to think about entering biology, but I'm driven by the type of impact you can make. Stem cell use to potentially treat very serious conditions was extremely exciting, and so during the start of my freshman year, I joined Stanford's Institute for Stem Cell Biology and Regenerative Medicine. That lab work led to the creation of Stem Cell Theranostics, a company that today provides drug companies with a method to more accurately predict cardiotoxicity and cardiovascular drug efficacy.

Tell me about StartX Med. What does the company do and when did you launch?

StartX Med is an interesting story. When Andrew Lee, another student, and I started Stem Cell Theranostics with our professors, we dropped out of Stanford to work full time. But we realized that we knew nothing about running a company. All we had was science and passion and that's not nearly enough to make a company successful.

That led us to join Stanford's accelerator program, Stanford

Divya Nag (second from right) sits in the audience for the Intel International Science and Engineering Fair 2009 Grand Awards Ceremony, where she won a Second Place Award in Earth and Planetary Sciences.

COURTESY OF D. NAG

Student Enterprises (SSE) Labs. Because of its name, we mistakenly thought the program provided lab space, which we were in desperate need for. Unfortunately, the name was a misnomer, and the program only offered a laptop and desk. Although it was predominantly a consumer IT accelerator program, after a few sessions, it became clear that there are some universal truths when starting a company: the importance of picking a right co-founder, raising money, establishing a team culture and hiring your first non-cofounding employee.

There were a lot of differences too, and so in 2012 — while I was still running Stem Cell Theranostics — I started StartX Med, the medical arm of SSE Labs. StartX Med sought to create specialized resources for medical entrepreneurs, like help with U.S. Food and Drug Administration approvals.

You left Stanford during your sophomore year to build your company. What was going through your mind when you made such a critical decision? Did you get any pushback?

My parents still ask me if I plan to finish my degree. In many ways, it was the hardest decision I've ever had to make, but also, the easiest because the promise of the work that we developed was all-consuming.

In 2014, at just 23 years old, you joined the Apple Special Projects Group. What is your current role and what has it been like for you having this type of position at such a young age?

I never thought I'd end up at a place like Apple. My job description is essentially to push boundaries and dream of what the future of health care looks like and what role Apple can play. Apple's cultural DNA is fueled by making products that consumers love, and I think that focus when applied to industries like health care, which haven't traditionally put consumers at the center, has been incredible.

You serve as a role model for women who'd like to enter male-dominated fields like science, engineering and technology. What advice do you have for young women like yourself?

I want to live in a world where science, engineering and technology have the best and brightest minds working on some of these challenging problems and that cannot happen if half of the mindshare isn't even at the table. I would like to tell women not to give up. Don't be disheartened by being the only woman in a classroom or in a boardroom. Own it. Love it. Be curious. Tackle problems that are super, super hard. Fail at things, but spectacularly, and don't be afraid of that, and you'll undoubtedly find not only value in all those experiences, but grow and learn as a person.

What books inspired you when you were young?

I think that reading fiction not only builds empathy, but exposes readers to a different way of life. You can imagine flying cars and life in space. When I was younger, all the books that I remember most fondly, like *Brave New World*, were where you empathize and live in imaginary worlds.

You once told *Fortune*, "I want to put people in charge of their health. It's not about living with a specific disease or condition. It's about living, full stop." This is a powerful statement. Can you tell me more about what you meant?

I view health as a fundamental human right, and I'm obsessed with empowering consumers to have a voice in their own health care. It's crazy to me that other people dictate what we can and can't know about our health. In our system, people are not thought of as people — they are thought of as their condition. It's all about treating diabetes or cancer, and as a result, medical products and innovation in this space involve horrible user experiences. These products are being designed for conditions, not individuals. I want to change that by putting people back at the center.

There are so many challenges in the world today. What keeps you up at night?

I'm concerned about the growing inequalities in the world, whether that's the education gap, the income gap, incarceration inequity or the health gap where the sick get sicker. So I spend my nights thinking about how technology can help close that opportunity gap and bring us closer to an even playing field. ◆

JULY 21, 2018

Summertime favorites

Stories about a roughly Delaware-sized Antarctic iceberg and a cache of liquid water on Mars fascinated online readers this summer. Tantalizing biology and medical tales also made for good reads. These were the five most-read *Science News* stories published online in July:

1. "The clean cycle" by Laura Beil (*SN: 7/21/18, p. 22*)
2. "Lake of liquid water detected on Mars" by Lisa Grossman (*SN: 8/18/18 & 9/1/18, p. 6*)
3. "Massive iceberg gets stuck in Antarctica" by Leah Rosenbaum (*SN: 8/18/18 & 9/1/18, p. 7*)
4. "Edited cancer cells combat cancer" by Laurel Hamers (*SN: 8/4/18, p. 13*)
5. "The curious case of the pregnant male shark" by Yao-Hua Law (*SN: 8/4/18, p. 4*)

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Sunny-side up

NASA's Parker Solar Probe is on its way to "touch" the sun. ***Maria Temming*** *reported on the mission before the August 12 launch in "NASA spacecraft is aiming for the sun"* (SN: 7/21/18, p. 12).

Astronomy writer **Lisa Grossman**, who wrote a follow-up story (see Page 16), answered readers' questions about the probe on Reddit.

Reddit user **Gildolen** wondered how the probe could touch the sun, if the star doesn't have a solid surface.

Gildolen is correct that the sun doesn't really have a surface, **Grossman** says. "It's all gas and plasma in different densities and configurations." The spacecraft will fly through the solar corona, the wispy atmosphere that can be seen during a total solar eclipse. The corona is "definitely connected to and influenced by the sun, but it's not the part we normally think of as the sun's 'surface,'" she says. "There are named regions — the photosphere is the part we can see, the chromosphere is just above that, the corona is farther out still — but the boundaries between them aren't well defined."

Reddit user **iklassic** asked why the probe wouldn't burn up in the corona.

The corona won't burn the probe because the corona is so diffuse, **Grossman** says. "It's like how you can put your hand in the oven for a short time and be fine, but if you touched a stove at the same temperature, it would burn you. The same idea applies to the spacecraft," she says.

"What sort of recording (video, audio, photographs) will the probe be doing?" asked Reddit user **MikeCanter**.

"The probe will mostly be recording things like how many charged particles of a particular type pass by the detectors in a given amount of time — not very pretty," **Grossman** says. "The scientists will be able to translate some of the data into audio, and it may sound like a hiss." Scientists will be able to compare the things that Parker sees close to the sun with images from telescopes that take pictures of the sun while orbiting Earth, she says.

Tinkering with general relativity

Einstein's general theory of relativity passed yet another test, this time over a distance of about 6,500 light-years, ***Emily Conover*** *reported in "Einstein's general relativity reigns supreme, even on a galactic scale"* (SN: 7/21/18, p. 15)*. The result challenges certain proposed tweaks to the theory.*

Reader **John Jaros** wanted to know more about what it means to "tweak" general relativity.

There are various reasons why scientists think general relativity is not the final theory of gravity. For one, general relativity is incompatible with quantum mechanics, **Conover** says. "It's clear how gravity works between two planets or two tennis balls, but go very small and it doesn't work. Physicists don't know how to calculate the gravitational interaction between two quantum particles," she says. That's because, according to quantum mechanics, particles can be in two places at one time. "So scientists are trying to 'quantize' gravity, which means, essentially, to make it behave in a quantum way. String theory, in which each particle is represented by a vibrating string, is one attempt at a theory of quantum gravity," **Conover** says.

Down to the wires

Seafloor cables that ferry internet traffic across oceans could be used to detect earthquakes, ***Maria Temming*** *reported in "Fiber-optic cables can detect quakes"* (SN: 7/21/18, p. 8)*. The cables can also pick up underwater sounds from other sources.*

Online reader **mmcln** wondered if researchers could now detect signals that the cables may have intercepted long ago, such as ones from Malaysian Airlines Flight 370, which disappeared over the Andaman Sea in 2014.

Detecting past signals is not possible, **Temming** says. "You have to intentionally send laser light into the cable, and look at it when it comes out the other side," she says. "People weren't using this technique when the Malaysian plane went down, so no one would have 'heard' anything through the cables."


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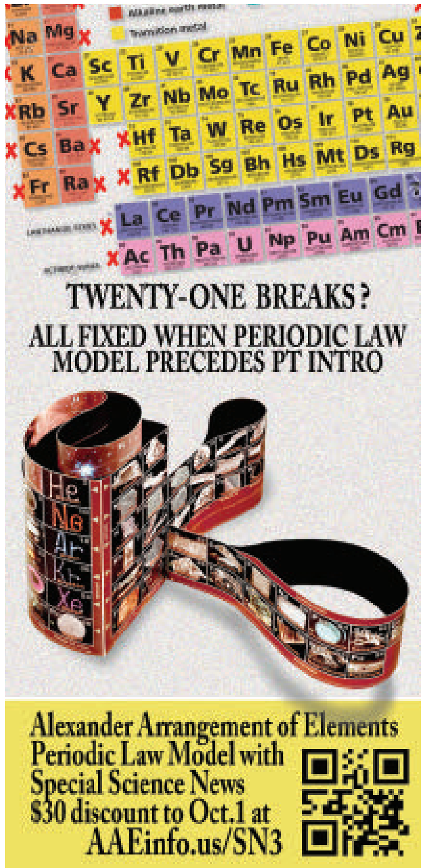
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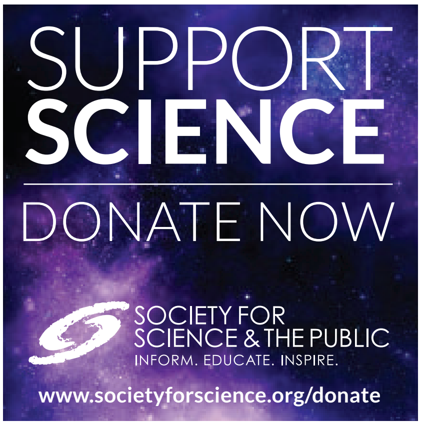
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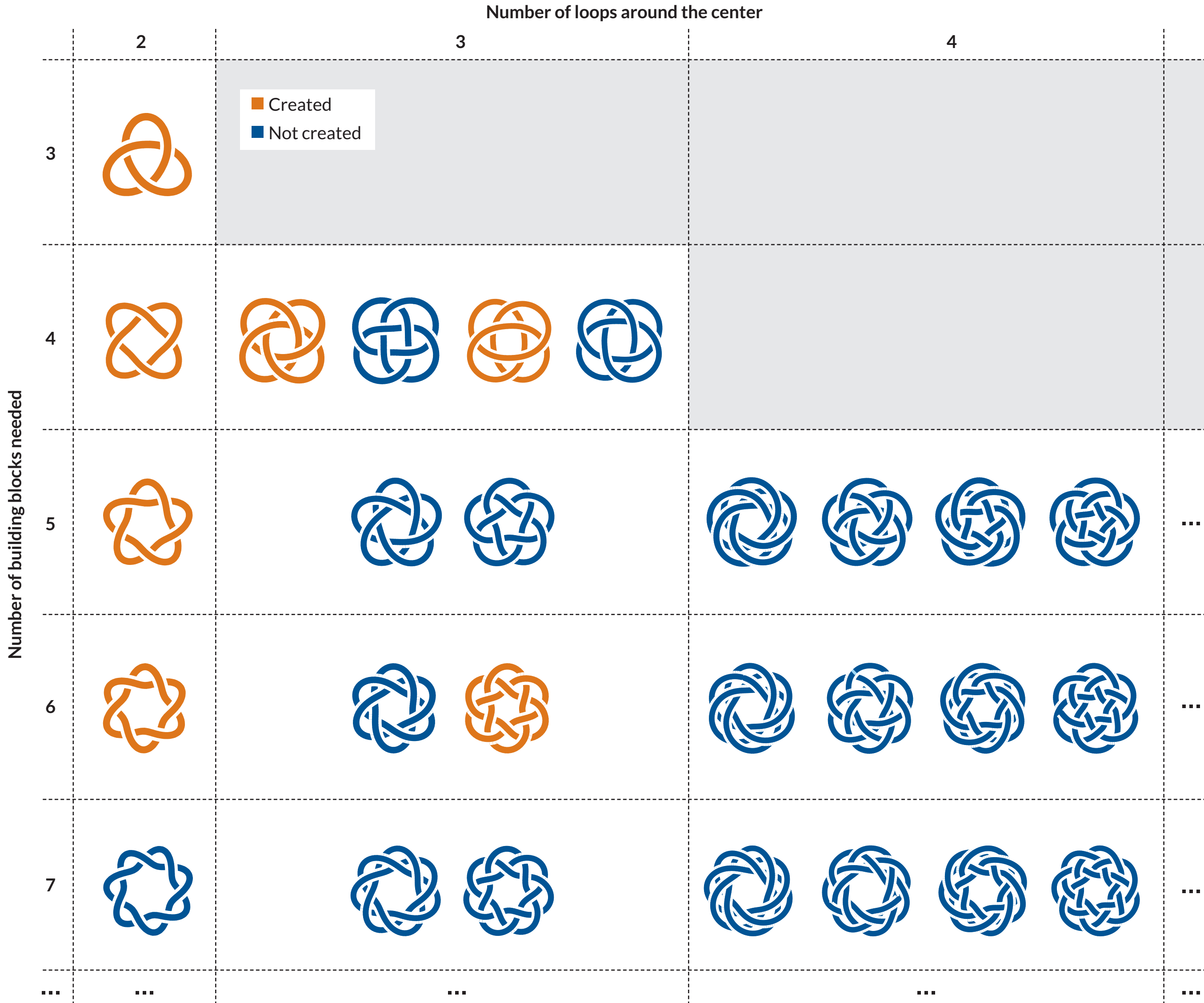

A 'periodic table' of molecular knots

Like a scouting handbook for the molecular realm, a new chart reveals how to tie molecules in knots of increasing complexity.

Mathematicians have cataloged billions of distinct knot types, but researchers have been able to make only a few molecular versions. Scientists craft the minuscule knots using a solution filled with building blocks of curved strings of atoms, which glom onto one another.

Now, using computer simulations, physicist Cristian Micheletti of the International School for Advanced Studies in Trieste, Italy, and colleagues have created a "periodic table" of the molecular pretzels. The table reveals which molecular knots are able to be created and arranges them in order of increasing complexity, the researchers report August 3 in *Nature Communications*. Knots that scientists have already synthesized (orange) are included as are knots yet to be made (blue). Ellipses indicate that the table continues.

The team organized the table based on the realization that two characteristics predict how difficult it is to create a molecular knot: the number of molecular building blocks needed to construct each pretzel shape and the number of times each knot's strands loop around the knot's center.

The chart offers a road map to help chemists figure out which molecular knots to make next. Such knots could one day lead to useful new materials, including nanocages that could store chemicals such as drugs for release when needed. *— Emily Conover*

CHART: C. CHANG; SOURCE: M. MARENDA, E. ORLANDINI AND C. MICHELETTI/*NATURE COMMUNICATIONS* 2018

Find an interactive version of this chart at **bit.ly/SN_Knots**


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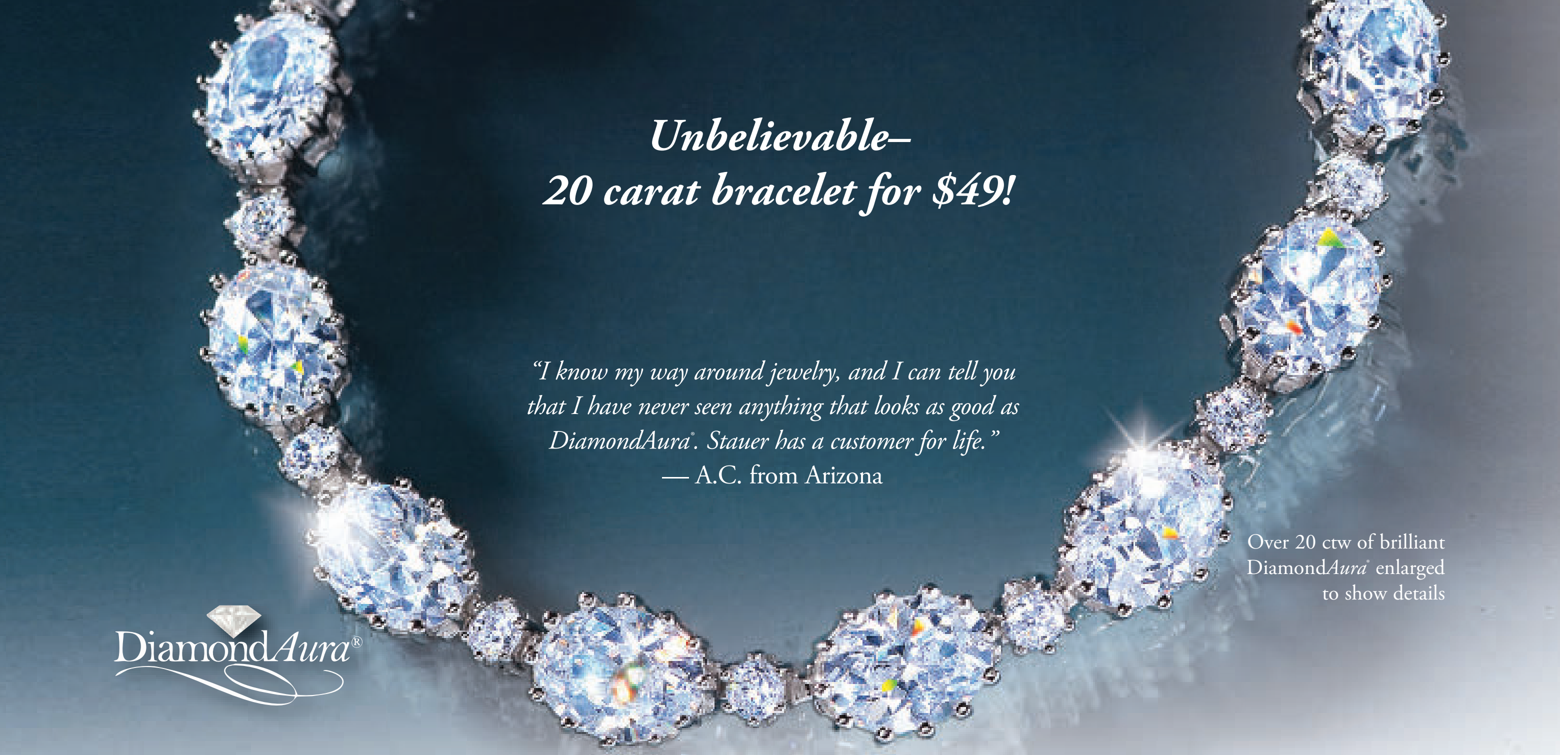

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Albert said the bracelet once belonged to the Countess Rivieré, a regular in his Paris jewelry shop. "She wore diamonds like no woman I've ever seen," he said. "Every one of these stones sparkles less in her absence." We never met her, but we still fell in love with her bracelet. And so will you. Once you snap this band of brilliant white fire around her wrist, it will look (and feel) like she just inherited a fortune. But the only fortunes involved are the one you saved and our good fortune finding a designer talented enough to transform a $49,000 heirloom into the spectacular 20 total carat Diamond*Aura*® ***Rivieré Bracelet*** for **only $49**.

An elegant present with a mysterious past. Of course, Albert didn't recall what Madame Riviere was the Countess of, or what happened to her after she stopped visiting his tiny shop on the Rue Saint-Honoré. But he still misses her terribly. And his story almost compelled me to buy the bracelet. Almost.

I say almost because vintage white diamonds don't come cheap. The original was a gorgeous piece with the kind of flash that surely sparked whispers and stares back in her day. But I knew we could use science to create a bolder, more beautiful version for much less.

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