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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
OCTOBER 27, 2018

Retired Brain Cells Are Trouble

Neptmoon Comes Into Focus

Particle Puzzle in Antarctica

Wiping Out Mosquitoes

TO TAME THE FLAMES

Analyzing wildfire behavior to save lives

Brazil Expedition Uncovers Thousands of Carats of Exquisite Natural Emeralds

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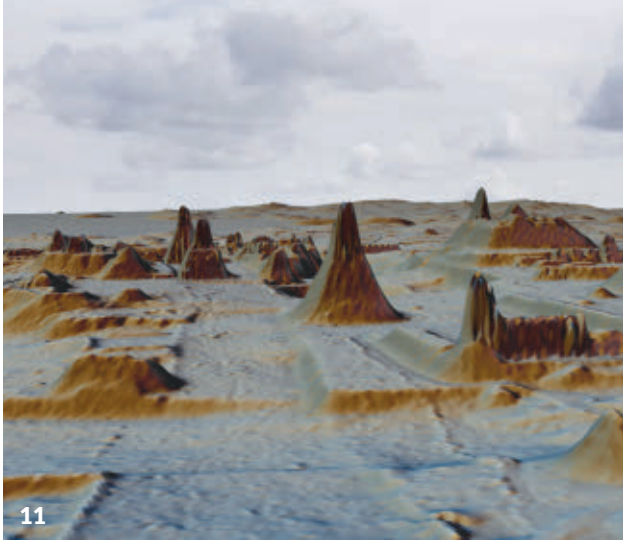
Features

News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Departments

COVER In Lake Elsinore, Calif., firefighters try to save homes from one of 2018's many wildfires. *Will Lester/Inland Valley Daily Bulletin/Getty Images*

FROM TOP: MATTHEW RAKOLA; L. ROCHA/© CALIFORNIA ACADEMY OF SCIENCES; F. ESTRADA-BELLI/PACUNAM

Waking up early to cover science's biggest honor

At 5:10 a.m. on October 1, news director Macon Morehouse walked into her kitchen, powered on her computer and hit "start" on the coffeemaker she had preloaded the night before. It was game day for the Nobel Prize in physiology or medicine, and she wanted to be ready when the announcement came from Stockholm, six time zones away.

It's a ritual we follow every year at *Science News*; reporters and editors rise before dawn to cover the Nobels, the biggest prizes in science. Now that we're all online it's a bit simpler — no need to get out of pajamas.

"Here we go!" digital director Kate Travis posted on Slack at 5:30 a.m. At 5:33 a.m., audience engagement editor Mike Denison had the news up on our Twitter account: James Allison of the University of Texas MD Anderson Cancer Center and Tasuku Honjo of Kyoto University in Japan had won for their work on checkpoint blockade cancer immunotherapy. Travis and associate digital editor Helen Thompson turned to mining the *Science News* digital archives for articles on the winners' work and to finding photos of Allison and Honjo.

Once molecular biology writer Tina Hesman Saey's initial news report was posted, she and biomedical writer Aimee Cunningham turned to reporting and writing a longer, more in-depth story. That included interviewing Norman Sharpless, director of the National Cancer Institute, for perspective on the winners' work.

That afternoon, the *Science News* staff turned to prepping for the next day's announcement on physics, with chemistry following on October 3 and economics on October 8. In each case, writers specializing in those fields took over the reporting duties. And as the stories went live, the *Science News for Students* team adapted them for readers ages 9 and up.

This year's awards (see Page 16) were notable for recognizing two women. Donna Strickland of the University of Waterloo in Canada became only the third woman to win the Nobel Prize in physics, for her work on laser physics. Frances Arnold of Caltech was the fifth women to earn the chemistry prize. She was honored for her method of creating customized enzymes, a technique that's been used to make new drugs and environmentally friendly biofuels.

"It's an adrenaline rush," Morehouse says of the annual ritual. "It's exciting to see who's going to win, and it was exciting to see the diversity this year." She says that directing the Nobel coverage provides a reminder of just how very long *Science News* has been covering these fields. "You can go back in our archives for decades and find stories about these key developments that end up resulting in a Nobel."

And though we typically don't cover awards, the Nobels are different. They offer an opportunity to look broadly at how individual discoveries seed the growth of new fields of science. This year's medicine award highlights the success of new forms of cancer immunotherapy. And the laser advances have led to remarkable new treatments for eye disorders.

So when you see those stories blip across your screen next year, think of our noble band of early risers. It's our pleasure. — *Nancy Shute, Editor in Chief*

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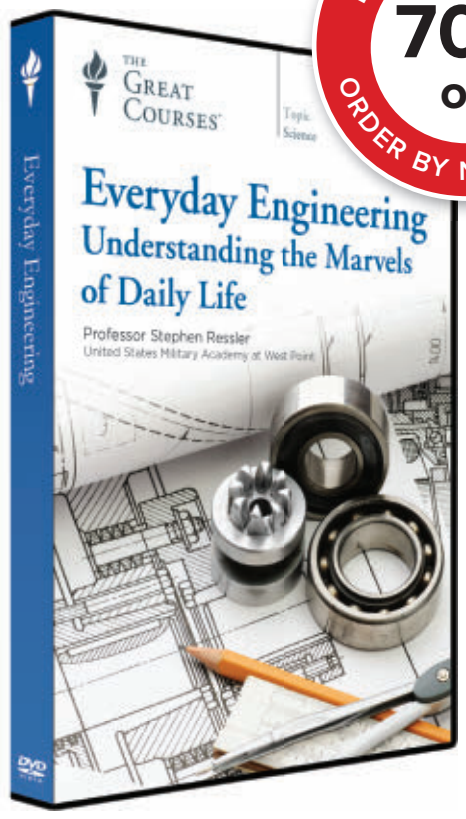

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Excerpt from the October 26, 1968 issue of *Science News*

50 YEARS AGO

Safety challenged

Americans consume 8,000 tons of artificial sweeteners every year ... confident that the chemical sweeteners are safe. Manufacturers insist that they are; the sugar industry ... insists they are not.... [B]oth camps swamped FDA with detailed evidence pro and con.

UPDATE: Let's not sugarcoat it: The debate isn't over. Fifty years ago, the Food and Drug Administration said there was no evidence of health hazards from cyclamates, one type of sweetener. Since then, various sweeteners have become ubiquitous in sodas, reduced-calorie yogurts and more. A 2014 study in mice and humans revealed that saccharin may alter the gut microbiome, mucking with the body's ability to use glucose (*SN: 10/18/14, p. 6*). Another study suggested that artificial sweeteners in diet sodas might encourage overeating by interfering with how the brain keeps tabs on calories (*SN: 7/14/12, p. 14*). These studies hint that artificial sweeteners may actually promote diabetes and obesity — the exact opposite of what's intended.

The musical mbira (left), inspired scientists to build a device from instrument parts (center) and scrap materials (right) that measures liquid density.

FOR DAILY USE

Thumb piano could root out bogus medicines

Identifying faulty drugs or diagnosing kidney problems could be as simple as playing an instrument and analyzing the sound.

An inexpensive, handheld tool inspired by an African instrument called an mbira, or thumb piano, can distinguish between liquids of different densities, researchers report in the September *ACS Omega*. The tool could help identify counterfeit and contaminated drugs, which make up an estimated 10.5 percent of all medications in low- and middle-income countries.

Bioengineer William Grover built his first mbira-inspired sensor with his 8-year-old son. "It probably took about 30 minutes," using scrap materials from around the house, says Grover, of the University of California, Riverside. The duo kept the instrument's wooden sounding board design, but swapped out the row of metal prongs that play different notes for a hollow, U-shaped metal tube, in which the liquid is placed.

Plucking the tube when it's filled with viscous liquids produces lower-frequency notes than when it's filled with thinner liquids, which produce higher pitches. A user can upload audio recordings from the sensor to a website that analyzes the sound frequencies to discern differences too subtle to hear. Comparing the frequency from a suspect liquid with that of a known sample can reveal whether the two have the same density, and thus the same ingredients.

William Grover and his 8-year-old son, Aiden, used an mbira-inspired sensor to test the contents of water at Whitewater River in Southern California.

Grover's team tested whether the device could differentiate between glycerol, a sweet syrup common in cough medicine, and a similar but poisonous syrup called diethylene glycol that has been mistaken by drug manufacturers for glycerol — with deadly consequences (*SN: 6/18/11, p. 22*). When the mbira sensor was filled with glycerol, it played notes about 10 hertz lower than when it was filled with diethylene glycol.

The device can also help determine the specific gravity of fluids — that is, their density compared with that of water. Field clinics could use the device, for example, to test the concentration of urine samples to look for signs of dehydration or kidney problems. Brewers could test the specific gravity of fermenting alcohol products to keep track of the declining sugar content and increasing alcohol content.

Already, south Indian villagers have begun using the sensor. UC Riverside researcher and study coauthor Vamsi Choday shared several in January with people in his grandparents' hometown of Valluru. Choday's mother, for instance, used one to measure the fat content of bison milk to help keep tabs on the animals' health. — *Maria Temming*

BOTH: W. GROVER/UC RIVERSIDE

INTRODUCING

Meet a Technicolor creature from down deep

While surveying a remote coral reef about 130 meters below the surface of the Atlantic Ocean last year, ichthyologists Luiz Rocha and Hudson Pinheiro noticed a flash of color within an otherwise drab rock crevice.

"It was like finding a bright emerald in a coal mine," Pinheiro recalls.

The fish, with a pink-and-yellow body and green fins, was so mesmerizing "it made us completely ignore a massive [shark] that was hovering over our heads," Rocha says.

Back in the lab, molecular biologist Claudia Rocha analyzed the highlighter-hued fish's DNA. Those results, combined with the observation of a few distinguishing characteristics — a longer spine here, an extra fin ray there — confirmed the fish as a new species, the California Academy of Sciences researchers report online September 25 in *Zookeys*. Due to its hypnotic beauty, they named the fish *Tosanoides aphrodite*, a nod to the ancient Greek goddess Aphrodite.

T. aphrodite belongs to the same fish group as similarly psychedelic Anthiadinae reef inhabitants. Although the fish is a resident of the Atlantic, its closest known relatives live in the Pacific, including a Hawaiian species named *T. obama* in 2016 after President Barack Obama.

Tosanoides aphrodite lives about 100 to 130 meters below the surface in a rocky Atlantic Ocean reef.

The new species turned up in a reef by St. Paul's Rocks, a series of mid-Atlantic islets about 1,000 kilometers east of Brazil. The area's isolation could help explain why so many of its species aren't found elsewhere. Still, deep reefs remain understudied habitats (*SN Online: 7/19/18*), and *T. aphrodite* or its relatives could be hiding out in other deep Atlantic reefs. — *Helen Thompson*

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RETHINK

Our search for E.T. hasn't covered much space

With no luck so far in our six-decade search for alien signals, you'd be forgiven for wondering, "Where is everyone?"

A new calculation shows that the volume of observable space combed for E.T. is equivalent to searching a large hot tub's worth of water for evidence of fish in Earth's oceans, Penn State astronomer Jason Wright and colleagues write in a paper posted online September 19 at arXiv.org. In a "hot tub's worth of water in the ocean, you wouldn't always expect a fish," Wright says.

Still, that's far more space searched than was calculated in 2010 for the 50th anniversary of the search for extraterrestrial intelligence, or SETI. In that work, SETI pioneer Jill Tarter and colleagues imagined a "cosmic haystack" of naturally occurring radio waves to sift through for the proverbial needle of an alien beacon (*SN Online: 5/29/12*). Tarter's haystack went beyond physical space to include factors such as a possible signal's duration and frequency, and the sensitivity of radio telescopes on Earth that would detect it. She concluded that searches had covered about a drinking glass's worth of seawater.

Wright and colleagues tweaked Tarter's haystack to consider factors like the bandwidth and periodicity of possible alien broadcasts, and also included more recent SETI searches in their calculation. — *Lisa Grossman*

SETI has covered the equivalent of **7,700 liters out of 1.335 billion trillion liters** of water in Earth's oceans.

Honeybees group in clusters, with individuals shifting to maintain the clump's stability.

MYSTERY SOLVED

How honeybee clumps withstand the wind

A stiff breeze is no match for a clump of honeybees, and scientists are beginning to understand why.

When scouting out a new home, honeybees tend to cluster together on tree branches or other surfaces, forming large, hanging clumps that help keep the insects safe from the elements. To keep the clump together, individual bees change their positions, fine-tuning the cluster's shape based on external forces, a new study suggests. Those shifts by individuals could help the group deal with disturbances such as wind shaking the branches.

Scientists at Harvard University built a movable platform with a caged queen in the center, around which honeybees clustered in a hanging bunch. When the researchers shook the platform back and forth, bees moved upward, flattening out the clump and lessening its swaying, the team reports online September 17 in *Nature Physics*.

The insects, the team hypothesized, might move based on strain — how much each bee is pulled apart from its neighbors as the cluster swings. So the researchers made a computer simulation of a cluster to determine how the bees decided where to move.

When the simulated bees were programmed to move to areas of higher strain, the simulation reproduced the observed flattening of the cluster. As a bee moves to a higher-strain region, the insect must bear more of the burden. So by taking one for the team, the bees ensure the clump stays intact. — *Emily Conover*

The malaria-carrying *Anopheles gambiae* mosquito may be in trouble if a new gene drive works as well in the real world as it did in the lab.

GENES & CELLS

Gene drive wipes out lab mosquitoes

Successful test raises hopes of eliminating a malaria carrier

BY TINA HESMAN SAEY

A new gene drive may push a species of malaria-carrying mosquito to extinction.

In a small-scale lab study, a gene drive, a genetic engineering tool, caused *Anopheles gambiae* mosquitoes to stop producing offspring in eight to 12 generations, researchers report September 24 in *Nature Biotechnology*. If the finding holds up in larger studies, the gene drive could be the first capable of wiping out a disease-carrying mosquito species.

"This is a great day," says evolutionary biologist James Bull of the University of Texas at Austin, who was not involved in the study. "Here we are with a technology that could radically change public health for the whole world."

Other gene drive studies have used computer simulations to predict how long it would take for the drives to spread through a population. This study marks the first time the approach has succeeded in actual mosquitoes.

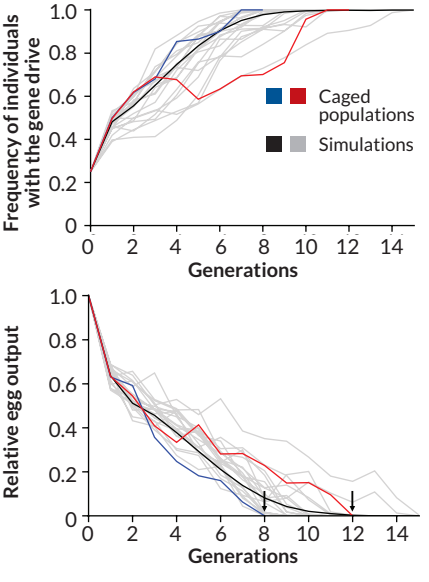
Gene drives use the molecular scissors known as CRISPR/Cas9 to copy and paste themselves into an organism's DNA at precise locations. Gene drives are designed to break the rules of inheritance, quickly spreading a genetic tweak to all offspring.

The new gene drive disrupts a mosquito gene called *doublesex*. Female mosquitoes that inherit two copies of the disrupted gene develop like males and are unable to bite or lay eggs. Males and females that inherit only one copy of the disrupted gene develop normally and are fertile.

In each of two cages, researchers mixed 300 female and 150 male normal *A. gambiae* mosquitoes with 150 males carrying the gene drive. Each generation, 96 to more than 99 percent of offspring inherited the gene drive. Normally, only 50 percent of offspring inherit a gene.

Within seven generations, all of the mosquitoes in one cage carried the gene drive. No eggs were produced in the next generation, and the population died out. In the other cage, the gene drive spread to all mosquitoes by the 11th generation and crashed the population in the 12th.

Path to extinction As more mosquitoes within two caged populations (red and blue) inherited a gene drive (top), the number of mosquitoes plummeted (bottom), producing no offspring after eight and 12 generations (arrows). Trends seen in the lab matched computer simulated predictions (gray and black).



Previous versions of gene drives have been passed to offspring at high rates (*SN: 12/12/15, p. 16*). But those experiments were plagued by mutations that destroy the cutting site for CRISPR/Cas9, making the mosquitoes that carry the mutation resistant to the drive.

A few mosquitoes in the new study also developed mutations, but "no resistance was observed," says study coauthor Andrea Crisanti, a medical geneticist at Imperial College London. There was no resistance because those mutations broke the *doublesex* gene, producing sterile females that couldn't pass the mutations on to the next generation.

All insects have some version of *doublesex*. "We believe that this gene may represent an Achilles heel for developing new pest-control measures," says Crisanti.

The tool raises the prospect of intentionally causing the extinction of a species. *A. gambiae* is the main mosquito that spreads malaria in Africa. Malaria kills more than 400,000 people each year worldwide, according to the World Health Organization.

"If you have a technology that could eradicate that [mosquito], it would be unethical not to use it," says Omar Akbari, a geneticist at the University of California, San Diego who was not involved in the work. But Akbari thinks it is unlikely that the gene drive would work as well in the wild as it did in the lab, because resistance is bound to pop up at some point.

No one knows the ecological consequences of removing mosquitoes, either, or if the gene drive could be passed to other species. What if a "James Bond–style villain" used a similar gene drive to attack honeybees or other beneficial insects, points out Philipp Messer, a population geneticist at Cornell University. "Humans will always come up with ways to abuse [technology], and in this case, it's just so easy. That's what worries me." ■

FROM TOP: JAMES D. GATHANY/CDC; K. KYROU *ET AL*/*NATURE BIOTECHNOLOGY* 2018

EARTH & ENVIRONMENT

1.5 vs. 2 degrees of global warming

Climate report shows benefits of lower temperature target

BY CAROLYN GRAMLING

Half a degree can make a world of difference. If Earth warms by just 1.5 degrees Celsius over preindustrial times by 2100, rather than 2 degrees, we would see fewer extremes of life-threatening heat, drought and precipitation, less sea level rise and fewer species lost.

Those findings are detailed in a report that the Intergovernmental Panel on Climate Change released October 8 following the IPCC's week-long meeting in Incheon, South Korea. "This will be one of the most important meetings in the IPCC's history," Hoesung Lee, a climate economist at Korea University in Seoul and current IPCC chair, said in his opening address October 1.

To compile the report, scientists sifted through more than 6,000 papers probing the impact of a global temperature hike of 1.5 degrees, says Natalie Mahowald, a climate scientist at Cornell University and one of the report's authors. But the heavy lift was worth it: The report's message is compelling and urgent, she says. "Such a small change in temperature will have big impacts on people."

In 2015, 195 nations signed the Paris Agreement to curb greenhouse gas emissions sufficiently to limit global warming to "well below" 2 degrees by 2100 (*SN: 1/9/16, p. 6*). Many scientists have warned that the target isn't stringent enough to prevent major environmental changes. And during the Paris talks, many nations called for a lower target of 1.5 degrees.

At the time, scientists knew relatively little about how to compare the risks of a 1.5-degree-warmer world with a 2-degree-warmer world, Lee noted in his October 1 address. As part of the decision to adopt the Paris Agreement, the nations invited the IPCC to assess those impacts.

As it turns out, the differences are stark. For instance, a half a degree less warming means about 0.1 meters less sea level rise on average by the next century, the report finds. As a result, at least 10 million fewer people would be exposed to such risks as flooding, infrastructure damage and saltwater intrusion into freshwater resources.

Somewhere between 1.5 and 2 degrees, ice sheets may become increasingly unstable, further increasing the potential for sea level rise. And in the 1.5-degree scenario, the Arctic Ocean is projected to be ice-free during the summer only once per century. An ice-free Arctic would happen once a decade in the 2-degree scenario.

For many plant and animal species, the lower temperature increase would mean less risk of habitat loss compared with 2 degrees of warming, (*SN: 6/9/18, p. 6*). Other risks to these species, including forest fires and the spread of invasive species, would also be lower.

Despite building a case for a lower temperature target, the trick will be how to get there. In 2017, the Paris climate accord faced a major setback when President Donald Trump announced that the United States, a major contributor of the greenhouse gases that drive warming, would pull out of the agreement. Achieving an even more stringent target seems particularly daunting.

The IPCC report examines various possible paths that limit the environmental impacts of warming. One variable considered is when emissions are projected to reach net zero, the point at which the amount of carbon released to the atmosphere is balanced by the amount removed. Another variable is how many more emissions will be allowed in the meantime.

Almost all of the projected pathways to 1.5 degrees have one thing in common, says Zeke Hausfather, a climate scientist with the London-based website Carbon Brief: They overshoot that temperature threshold around the year 2050. "They all exceed it — and then back down," he says.

To overshoot the mark by only a small amount, or not at all, requires reducing emissions by about 45 percent relative to 2010 levels by 2030 and reaching net zero by around 2050, the report notes. In comparison, to get to below 2 degrees, emissions must decline by about 20 percent by 2030 and reach net zero by about 2075.

Many species, including the pika, are already suffering habitat loss due to climate change. Limiting global warming to 1.5 degrees Celsius instead of 2 degrees could minimize the losses.

Barring such early, deep cuts, it will take "negative emissions" to bring the temperature back down after overshooting the mark. Negative emissions are a hoped-for reduction in emissions due to future technologies that can remove enough atmospheric carbon dioxide to reverse the greenhouse effect.

Those technologies, such as carbon capture and storage, are not yet commercially viable. And reversing the greenhouse effect is not so straightforward. "It's generally true that there's a linear relationship between warming and carbon dioxide in the atmosphere, as long as both are increasing," Hausfather says. "But once you start sucking carbon out of the atmosphere ... you need more negative emissions to reduce temperatures than positive emissions to increase them."

The challenges may seem insurmountable. Yet one of the report's key messages is that holding warming to 1.5 degrees "is not impossible," Mahowald says. Achieving the goal would require people to start cutting emissions right now and undergo behavioral changes, from diet to energy conservation.

But people would also face huge adjustments in a world that's 2 degrees warmer, or even higher, Mahowald says. "It still might be easier to reach 1.5 than to adapt to those higher temperatures." ■

MOOSE HENDERSON/ISTOCK.COM

ATOM & COSMOS

Odd signals may point to a new particle

Antarctic detector's data challenge physicists' standard model

BY EMILY CONOVER

Dangling from a balloon high above Antarctica, a particle detector has spotted something that standard physics is at a loss to explain.

Two unusual signals seen by the detector, known as the Antarctic Impulsive Transient Antenna, or ANITA, can't be attributed to any known particles, a team of physicists at Penn State reports online September 25 at arXiv.org. The result hints at the possibility of new particles beyond those cataloged in the standard model, the theory that describes the elementary particles that make up matter.

Like the house in the Pixar movie *Up*, ANITA floats on a helium balloon, at an altitude of 37 kilometers for about a month at a time. It searches for signals of high-energy particles from space, including lightweight, ghostly particles called neutrinos. Those neutrinos can interact within Antarctica's ice, producing radio waves that ANITA's antennas pick up.

The puzzling signals appear to be from extremely energetic neutrinos shooting skyward from within the Earth. A neutrino coming up from below isn't inherently surprising: Low-energy neutrinos interact with matter so weakly that they can zip through the planet. But high-energy neutrinos can't pass through as much material as lower-energy neutrinos can. So although high-energy neutrinos can skim the edges of Earth, they won't survive a pass straight through.

The steep angle of the particles' paths suggests that the neutrinos traveled through several thousands of kilometers of the Earth — too much for a high-energy neutrino to make it out the other side. That's according to computer simulations by the researchers, who are not members of the ANITA collaboration. ANITA researchers have been looking for a way to explain the signals with neutrinos, says Derek Fox, a coauthor of the new study. But according to the simulations, he says, "those attempts must fail."

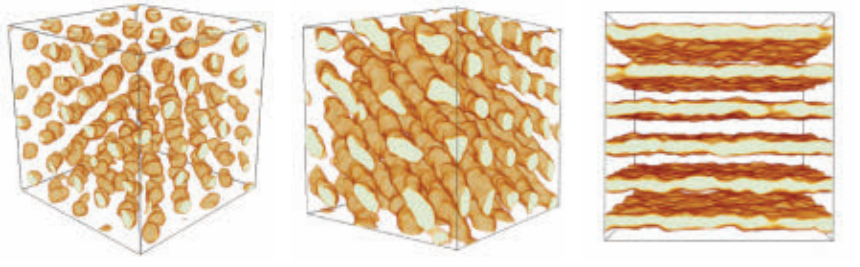
A high-energy particle could make such a long trek through the Earth only if it were even more reticent to interact with matter than neutrinos are. A hypothetical heavy particle called a stau, proposed in a theory called supersymmetry (*SN: 10/1/16, p. 12*), could fit the bill, Fox and colleagues say. After being created on the other side of the planet by a high-energy neutrino slamming into the Earth, a stau could make it through unscathed before decaying into lighter particles that would eventually

ATOM & COSMOS

Nuclear pasta is tougher than steel

Theoretical substance may be universe's strongest material

BY EMILY CONOVER



Al dente When atomic nuclei get squeezed together inside a neutron star, nuclear matter may form into shapes similar to gnocchi (left in these simulations), spaghetti (middle) and lasagna (right).

M.E. CAPLAN AND C.J. HOROWITZ/*REVIEWS OF MODERN PHYSICS* 2017

A dry strand of spaghetti snaps easily, but an exotic substance known as nuclear pasta is an entirely different story.

Predicted to exist in ultradense dead stars called neutron stars, nuclear pasta may be the universe's strongest material. Breaking the stuff requires 10 billion times the force needed to crack steel, according to simulations reported in the Sept. 28 *Physical Review Letters*.

"This is a crazy-big figure, but the material is also very, very dense, so that helps make it stronger," says physicist and study coauthor Charles Horowitz of Indiana University Bloomington.

Neutron stars form when a dying star explodes, leaving behind a neutron-rich remnant that is squished to extreme pressures by powerful gravitational forces, resulting in materials with bizarre properties (*SN: 12/23/17, p. 7*).

About a kilometer below the surface of a neutron star, atomic nuclei are squeezed together so close that they merge into clumps of nuclear matter, a dense mixture of neutrons and protons. These still theoretical clumps are thought to be shaped like blobs, tubes or sheets and are named after their culinary lookalikes, including gnocchi, spaghetti and lasagna. Even deeper in the neutron star, the nuclear matter fully takes over. The burnt-out star's entire core is nuclear matter, like one giant atomic nucleus.

Nuclear pasta is thought to be incredibly dense, about 100 trillion times the density of water. It's impossible to study such an extreme material in the lab, says physicist Constança Providência of the University of Coimbra in Portugal.

Instead, the team used computer simulations to stretch nuclear lasagna sheets. Immense pressures were required to deform the material, and the pressure required to snap the pasta was greater than for any other known material.

Earlier simulations had revealed that a neutron stars' outer crust was also vastly stronger than steel. "Now, what [the researchers] see is that the inner crust is even stronger," Providência says.

The results provide hope of finding real-world evidence of nuclear pasta.

result in the signals detected by ANITA.

But don't cancel your membership in the standard model fan club just yet. "It's still possible that there is a very mundane reason that we are seeing these events," says ANITA physicist Stephanie Wissel of Cal Poly in San Luis Obispo, Calif. Other spacefaring particles called cosmic rays, which rain down from above, produce similar signatures in ANITA. A basic misunderstanding of the physics behind cosmic rays' signatures could explain the observations, Wissel says.

Backing up their claim, Fox and colleagues also identify three events in another Antarctic neutrino detector, called IceCube, that they say have some similarly puzzling properties. But the leader of IceCube, physicist Francis Halzen of the University of Wisconsin–Madison, isn't convinced. "These events are of course worth paying attention to," he says, but he doesn't see any evidence that they require a new explanation. ■

Neutron stars tend to spin rapidly and, as a result, might emit ripples in spacetime called gravitational waves. The Advanced Laser Interferometer Gravitational-wave Observatory, or LIGO, can detect such waves. But the spacetime ripples will occur only if a neutron star's crust has "mountains," or mounds of dense material on the surface or within the crust.

"You need a big mountain," says physicist Edward Brown of Michigan State University in East Lansing. A stiffer, stronger crust would support larger mountains, which could produce more powerful gravitational waves. "Big" is relative: Due to neutron stars' intense gravity, the mountains would be centimeters tall. Scientists didn't know how big a mountain nuclear pasta could support.

"That's where these simulations come in," Brown says. The results suggest that nuclear pasta could support mountains tens of centimeters tall — big enough that LIGO could spot neutron stars' gravitational waves. If LIGO caught such signals, scientists could estimate the mountains' size and confirm that neutron stars have superstrong materials in their crusts. ■

GENES & CELLS

Gene editing speeds up domestication

CRISPR/Cas9 technique quickly tamed 'unruly' ground cherries

BY TINA HESMAN SAEY

Gene editing can speed up plant domestication, taming wild vines, bushes and grasses and turning them into new crops.

Editing two genes in ground cherries (*Physalis pruinosa*) produced plants that yielded more and bigger fruit, researchers report October 1 in *Nature Plants*. The edits mimic changes that occurred in tomato plants during domestication, bringing the tomato relative a step closer to becoming a major berry crop, says study coauthor Zachary Lippman, a plant biologist at Cold Spring Harbor Laboratory in New York.

Ground cherries and their close relatives Cape gooseberries (*Physalis peruviana L.*), or golden berries, are grown in many parts of the world, but have traits — such as dropping their fruit on the ground — that make them unattractive for large-scale agriculture.

"This is a really unruly plant with great potential," says Harry Klee, a plant geneticist at the University of Florida in Gainesville. The new work serves as a how-to manual for others interested in rapidly domesticating new crops, he says.

Lippman, plant biologist Joyce Van Eck of Cornell University and colleagues looked for genes in the ground cherry's genome that give domestic tomatoes some of their traits. Cutting a gene called *SELF-PRUNING 5G* with the gene editor CRISPR/Cas9 created a mutation that caused the plants to stop making shoots and leaves earlier than unaltered plants, leading to more flowers and fruit. These plants yielded 50 percent more fruit on each shoot than unaltered ground cherries. Snipping a second gene, *CLV1*, made the fruit grow 24 percent heavier.

Gene editing created ground cherries that were bigger (right) than unaltered fruit (left).

Z. LIPPMAN/COLD SPRING HARBOR LABORATORY

Breeders might make mutations in the same genes by irradiating seeds or treating them with chemicals, but weeding out unwanted mutations would take decades, Lippman says. Gene editing accelerated the process to just a couple of years. The berries aren't fully domesticated, but the researchers plan to make further modifications.

Other researchers are using CRISPR/Cas9 to replay domestication by altering tomatoes' wild ancestor, *Solanum pimpinellifolium*. A Chinese group cut four genes in ancestral tomato strains to create disease-resistant and salt-tolerant plants resembling domestic tomatoes, those researchers report October 1 in *Nature Biotechnology*.

Another domestication replay is also reported October 1 in *Nature Biotechnology*. By slicing six genes, an international research team created *S. pimpinellifolium* tomatoes that produce five times as much of the antioxidant chemical lycopene as commercial tomatoes.

Researchers might not be able to use the same tricks for plants without well-studied domestic relatives, says Martin Mascher, a computational geneticist at the Leibniz Institute for Plant Genetics and Crop Plant Research in Gatersleben, Germany. "CRISPR is a very precise tool, but it also requires precise knowledge."

Legal and financial difficulties may be bigger hurdles than technical ones, says François Belzile, a crop genomicist at Laval University in Quebec City. Academics and small companies may not have the money to license CRISPR/Cas9. And the European High Court ruled this year that gene-edited crops must be regulated as genetically modified crops. Only big companies may have the money to win regulatory approval, Belzile says. "If that's the case, then much of the promise of genome editing will be limited." ■

LIFE & EVOLUTION

Manta ray filters food in inspiring way

Marine animal's unique screening method avoids clogging

BY LAUREL HAMERS

Manta rays were built for speed — and to filter feed. The aerodynamic ocean dwellers efficiently separate plankton from seawater using a filtration system that resists clogs, researchers report September 26 in *Science Advances*.

Mantas pull plankton-laden seawater into their mouths, where cartilaginous fibers help them swallow the plankton but release the seawater. For some filter feeders, this process can be compared to straining a pot of pasta and letting the water run through, says Misty Paig-Tran, a marine biologist at California State University, Fullerton. But that analogy doesn't work for mantas. Some of the plankton they eat is small enough to slip through the gaps — more like grains of rice than chunky pasta. And mantas don't have sticky mucus to snag the small particles, as animals such as sponges do.

Paig-Tran and her colleagues took CT scans of several manta ray species, then 3-D–printed a replica of the filter found in the giant oceanic manta ray (*Manta birostris*). The team put the model in a tank filled with dye to track how water and planktonlike particles moved through the filter. Computer programs also helped calculate trajectories.

The manta ray's filter is made of a series of long, cartilaginous lobes arranged in parallel, with tiny gaps in between. Water entering the mouth flows between the lobes, forming vortices before eventually swooshing out to exit. Instead of getting sucked into these vortices, bits of plankton ricochet off the lobes back toward the manta's esophagus to be swallowed.

"What's unique about this particular mechanism is that the particles aren't captured by the filter" like they would be in a colander, says study coauthor James Strother, a theoretical biologist at Oregon State University in Corvallis.

The unusual filter in the mouth of the *Manta birostris* manta ray could inspire better designs for wastewater treatment.

"They're pushed away from the filter, so it remains clean."

That's an advantage for the mantas. "If there's no clogging, they don't have to shut their mouth and try to clean off all these little particles," Paig-Tran says. The animals can eat continuously.

"This system might conceivably enable larger animals to exist in areas with less food" because it's energy efficient, says evolutionary biophysicist Stuart Humphries of the University of Lincoln in England.

The manta ray's strategy could inform better designs at wastewater treatment plants. A manta-inspired filter might trap microscopic plastics before they escape into waterways and harm wildlife. ■

LIFE & EVOLUTION

DNA uncovers 3 big ivory cartels

Genetic detective work aims to curb elephant poaching

BY LAUREL HAMERS

Pairs of elephant tusks that are separated during smuggling are illuminating the tracks of wildlife crime.

Identifying matching elephant DNA in different shipments of tusks can help scientific sleuths connect the shipments to the same ivory-trafficking cartel. That technique has already revealed the presence of three major interconnected cartels in Africa, researchers report September 19 in *Science Advances*.

The method could give law enforcement officials ammunition to prosecute traffickers and others involved in killing protected wildlife, says Samuel Wasser, a conservation biologist at the University of Washington in Seattle.

Poachers kill as many as 40,000 elephants each year as part of an illicit ivory industry worth billions of dollars. Poachers sell to a pyramid of traffickers, who consolidate ivory from a tangled web of sources and smuggle shipments globally.

But when traffickers are nabbed, they're usually busted only for the ivory they're caught smuggling. Being able to tie them to other poaching and trafficking events could up the penalties the criminals face and help law enforcement bring down more people, Wasser says.

Previously, he and colleagues used DNA from elephant tusks and feces to link trafficked tusks to poaching hot spots (*SN: 7/25/15, p. 9*). His team noticed that tusks from the same animal often ended up in different shipments, linking those containers to the same people.

In the new study, Wasser's team sampled tusk DNA from 38 seizures of ivory and hunted for genetically identical tusks within that pool. Among 11 of the seizures, all made from December 2011 to May 2014, the team found a number of links — for example, two shipments containing genetically matched tusks that were seized from the same port within a short time of one another. Some shipments contained genetic matches to many others. Collectively, those connections indicate the presence of three big cartels in Africa, which sometimes work together, Wasser says.

Wasser's group collaborates with the U.S. Department of Homeland Security, which works with foreign governments to catch traffickers. Authorities are increasingly looking to prosecute these people for financial crimes and to seize assets. "The connection between multiple seizures gives us a lot more evidence to look at and data to mine," Homeland Security special agent John Brown said September 18 in a news conference. ■

STEVE KAJIURA

HUMANS & SOCIETY

Lasers shine new light on the Maya

Mapping reveals surprising complexity of ancient cities

BY BRUCE BOWER

A laser-shooting eye in the sky has revealed the previously unappreciated size and complexity of ancient Maya civilization, both before and during its presumed heyday, scientists say.

Maya people in what's now northern Guatemala built surprisingly extensive defensive structures and roads as part of political systems featuring interconnected cities, starting at least several hundred years before the rise of Classic Maya society, researchers report in the Sept. 28 *Science*. Classic Maya sites date to between around 250 and 900.

Aerial laser mapping of northern Guatemala in 2016 and map-guided ground surveys and excavations in 2017 compel a reevaluation of traditional assumptions about the ancient Maya, the team concludes. A long-standing idea that Classic Maya civilization, which covered parts of southern Mexico and much of Central America, once contained small city-states ruled by warring kings has drawn increasing skepticism over the last decade (*SN Online: 4/17/18*). Laser technology shot down that scenario by gazing through forests and vegetation at 10 Maya sites as well as in two areas with signs of Maya-era activity but no named sites. All of the examined areas date from a couple hundred years before the start of the Classic period to near its end.

"Every Maya city was bigger and more populated than we previously thought," says Francisco Estrada-Belli, an archaeologist at Tulane University in New Orleans. Estrada-Belli led the investigation along with archaeologists Marcello Canuto, also at Tulane, and Thomas Garrison of Ithaca College in New York.

A small plane carrying light detection and ranging equipment, or lidar, emitted laser pulses that gathered data on the ground's shape across 2,144 square kilometers of northern Guatemala. Based on the more than 60,000 lidar-identified structures, the researchers estimate that a minimum of 7 million to 11 million people inhabited northern Guatemala near the end of the Classic Maya period.

> "Every Maya city was bigger and more populated than we previously thought."
>
> **FRANCISCO ESTRADA-BELLI**

Lidar views of the ancient Maya's urban and rural infrastructure are particularly impressive, Estrada-Belli says. Water control was crucial. Much of the unsettled wetlands throughout northern Guatemala contain remnants of crisscrossing drainage channels that form grids within what must have once been agricultural fields. Some channels extend for a kilometer or more. Remains of stone terraces and low walls enclose many cultivation areas.

Drainage channels and terraces controlled water flow and eased soil erosion in heavily cultivated fields. "The ancient Maya were good stewards of their environment," Estrada-Belli says.

Evidence of carefully irrigated agricultural fields challenges a popular view that Classic-era centers relied on food from soil-damaging, slash-and-burn farming. That practice eventually contributed to the Maya civilization's downfall, some researchers have argued.

Although sustainable cultivation techniques appear to have been standard for the ancient Maya, farmland near the most populated Maya cities would not have provided enough food for local populations, the researchers say. Additional food was imported from distant sites belonging to common political networks, the team suspects.

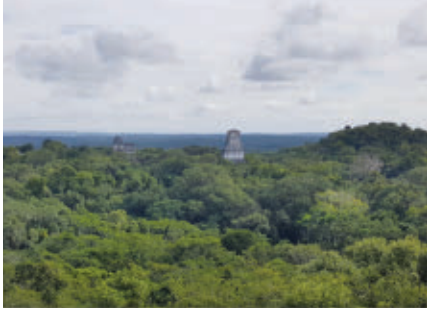
Laser maps show that Maya cities varied substantially in population density and typically included less crowded zones in between city centers and rural areas. Most sites had a surprising number of defensive structures, Estrada-Belli says. Strategically placed bridges, ditches, ramparts, stone walls and terraces suggest that military conflicts occurred frequently.

That didn't stop cities from maintaining long-distance contacts and forming networks of politically aligned sites. Raised roads, or causeways, connected the earliest Maya sites to nearby centers. These 10- to 20-meter-wide causeways run for as long as 22 kilometers. Later Maya cities primarily contain short causeways that served as entrances to public and ritual areas.

The study builds on previous, smaller-scale lidar studies in and around Caracol, a Classic Maya city in western Belize (*SN: 5/14/16, p. 22*). Archaeologists Arlen and Diane Chase of the University of Nevada, Las Vegas directed that research. "The new lidar data show that interconnected Maya cities go back to at least 300 B.C.," Arlen Chase says.

Further lidar-guided surveys and excavations are planned, Estrada-Belli says. Some newly identified causeways extend beyond the edges of lidar maps, a sign that Guatemala's forests hold further Maya revelations, he adds. ■

Dense forest surrounds the city center of Tikal, a Classic-era Maya site in Guatemala (left). Laser mapping of the same view (right) revealed structures and causeways hidden by the jungle.



BOTH: F. ESTRADA-BELLI/PACUNAM

BODY & BRAIN

Kids' screen time raises concerns

More than 2 hours a day linked to poorer thinking skills

BY LAURA SANDERS

Nearly two out of three U.S. kids spend over two hours a day looking at screens, a new analysis finds. And those children perform worse on memory, language and thinking tests than kids who spend less time in front of a device, the study of more than 4,500 8- to 11-year-olds shows.

Reported online September 26 in *Lancet Child & Adolescent Health*, the finding bolsters concerns that heavy use of smartphones, tablets or televisions can hurt growing minds. But because the study captures a single snapshot in time, it's not known whether too much screen time can actually harm brain development, experts caution.

Researchers used data from child and parent surveys on daily screen time, exercise and sleep, collected as part of a larger effort called the Adolescent Brain Cognitive Development Study. That bigger study also tested cognitive abilities. As a benchmark for the new study, the researchers used expert guidelines set in 2016 that recommend an hour of exercise a day, no more than two hours of recreational screen time and between nine and 11 hours of nighttime sleep.

Overall, the results are concerning, says study coauthor Jeremy Walsh, an exercise physiologist who at the time of the study was at the Children's Hospital of Eastern Ontario Research Institute in Ottawa. Only 5 percent of the children met all three guidelines on screen time, exercise and sleep, whereas 29 percent met none of the guidelines.

On average, children in the study spent 3.6 hours a day using screens for video games, videos and other fun. Children who spent less than two hours on screens scored, on average, about 4 percent higher on a battery of thinking-related tests than the kids who didn't meet any of the guidelines.

"Without consideration of what kids are actually doing with their screens, we're seeing that the two-hour mark actually seems to be a good recommendation for benefiting cognition," says Walsh, who is now at the University of British Columbia's Okanagan campus.

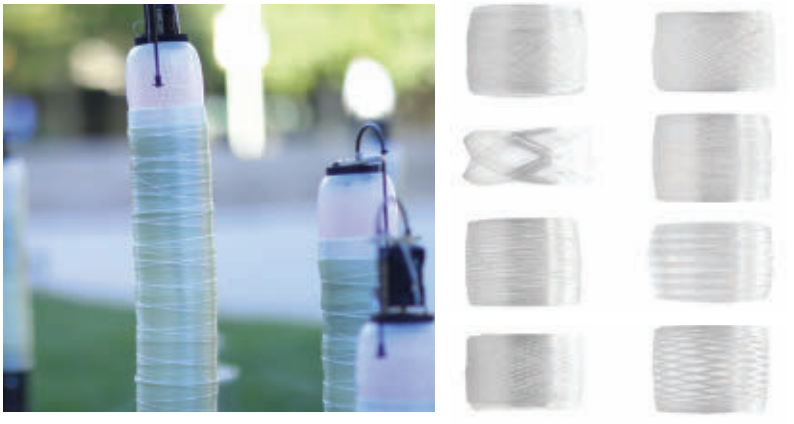
Kids who met the recommendations for both screen time and sleep tested better as well. When analyzed on their own, sleep and physical activity didn't seem to influence test results.

The study can't say whether screen time — or the resulting absence of another activity — lowered thinking skills. "You don't know which is the chicken and which is the egg," cautions pediatrician Michael Rich of Boston Children's Hospital. It could be that smarter kids are less likely to spend lots of time on screens, he says.

Looking for clear-cut blame is a bit of a "red herring," Rich says. Simple cause-and-effect relationships often don't exist in human behavior and development. Instead of blanket pronouncements, "we need to tailor what we learn from science to individual children," he says.

By looking at behaviors in combination, the results offer a comprehensive look at kids' health, one that's sorely needed, says kinesiologist Eduardo Esteban Bustamante of the University of Illinois at Chicago. "We don't know a lot yet about how these behaviors interact with one another to influence kids' cognitive development."

The Adolescent Brain Cognitive Development Study is slated to continue collecting data until 2028. "I'm really excited to see where this line of research goes," Bustamante says. ■



M. KAYSER *ET AL*/*SCIENCE ROBOTICS* 2018

MATH & TECHNOLOGY

Robots spin fiberglass structures

Much like a silkworm uses a single thread to swaddle itself in a cocoon, a new robot spins a single strand of material around its body to build custom-shaped fiberglass structures. The robots could someday create customized construction materials on-site and erect buildings and bridges in remote or dangerous locations, researchers report in the Sept. 26 *Science Robotics*.

Each bot (above left), slightly larger than a 1-liter bottle, is girded by a silicone balloon and topped with an arm that turns like a propeller. To build a piece of piping, the robot's arm winds resin-coated fiberglass thread around its puffed-up silicone belly. By spinning the thread in various patterns (right), the robot creates pipes of varying thickness. Ultraviolet light hardens the resin and glues the fiberglass strands together. When the robot completes a 9-centimeter-long segment, its belly deflates and the machine scoots up the tube where the arm resumes spinning fiberglass. By tilting in a new direction, the bot can control where the tube bends. — *Maria Temming*

LIFE & EVOLUTION

Giraffes inherit their spots from mom

Larger, more irregular patterns may boost a calf's odds of survival

BY JENNIFER LEMAN

The mottled patterns that adorn Africa's tallest creatures are passed down from their mothers, a new study suggests.

A giraffe calf inherits spots that are similar to those of its mother in terms of roundness and the smoothness of the spots' borders, researchers report October 2 in *PeerJ*. The size and shape of those splotches seem to affect a young giraffe's chances of surviving in the wild.

Giraffes — like tigers, zebras and jaguars — are covered in patterns that, among other things, may help signal to other animals that they're part of the same species. The markings can also act as camouflage, optically breaking up an animal's body to hide it from predators.

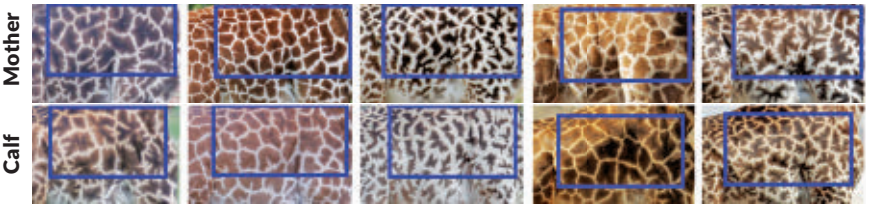
Enthusiasts "kept asking us, 'Why do giraffes have spots?' and 'Do calves inherit their spot patterns?' " says Derek Lee, a quantitative wildlife biologist at Penn State who is also a principal scientist at the Wild Nature Institute based in Concord, N.H. "We didn't have any answers, so we used our data to get them."

Scientists previously suggested that the patterns of animals' spots and stripes are conferred at random, or that they're influenced by environmental factors. Suspecting a hereditary link, Lee and colleagues photographed 31 mother-and-baby pairs of Masai giraffes (*Giraffa camelopardalis tippelskirchii*) in Tanzania from 2012 to 2016. Image analysis software helped the team compare the patterns within each pair according to 11 traits, including spot shape, size and color.

Two traits in particular, the roundness of the spots and the smoothness of their borders, were strikingly similar between mothers and their calves — a sign that the spot patterns are inherited. An examination of giraffe DNA is needed to confirm that conclusion, Lee says.

To see which aspects of spots might affect a youngster's ability to survive, the researchers widened their pool of subjects to 258 calves. The team sought to photograph each calf six times a year for the four years of the study. Each successful photo represented a "recapture" scenario. Statistical analyses estimated the likelihood of survival within the group. Calves with larger, irregularly shaped spots appeared to have the best chances of surviving the first few months of life.

"They're not suggesting that spots matter for survival, but that the differences in spots matter," says Hopi Hoekstra, an evolutionary biologist at Harvard University. "It's slightly subtle, but I think an important distinction." ■



Runs in the family Spots of a mother giraffe match those of her calf, as seen in these mother-calf pairs. Aspects of the spots related to shape and size appear to be inherited.

D. LEE *ET AL*/*PEERJ* 2018

BODY & BRAIN

Retired brain cells may cause trouble

In mice, killing senescent cells prevented memory loss

BY LAURA SANDERS

Brain cells past their prime may have a role in dementia. Culling these cells protected mice that were destined for brain decline.

Senescent cells, which accumulate with age, live in a state of suspended animation — they stop doing their jobs and stop dividing. Getting rid of these cells in the body extends mice's life spans and improves heart and kidney health, scientists have found (*SN: 3/5/16, p. 8*). A new study, published online September 19 in *Nature*, suggests that senescent cells also make mischief in the aging brain.

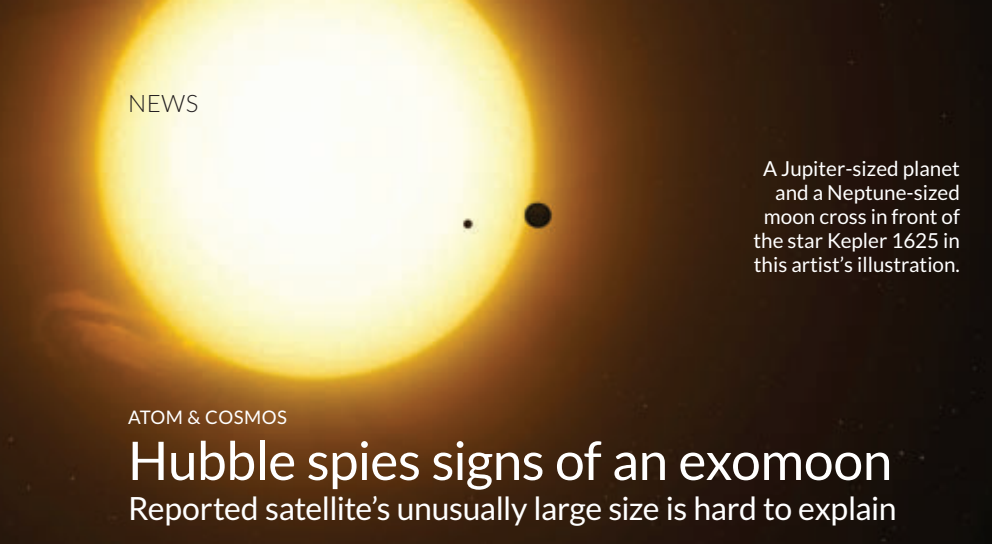
Molecular biologist Darren Baker of the Mayo Clinic in Rochester, Minn., and colleagues studied mice with mutations that led nerve cells in the brain to accumulate a toxic form of the protein tau. Damaging globs of tau called neurofibrillary tangles are a hallmark of Alzheimer's disease and other types of dementia.

In some mice, the team engineered a genetic trick — a sort of kill switch that destroys cells as soon as they become senescent. In mice with this switch, tau didn't accumulate as fast, and the mice did a better job recognizing new smells and objects than mice with more senescent brain cells. An anticancer drug called navitoclax that targets senescent cells also had protective effects in mutated mice's brains.

The senescent troublemakers were glial cells — support cells that help nerve cells do their jobs. The researchers suspect that nerve cells in trouble, such as those with toxic tau, prod glial cells to become senescent. Those senescent glial cells damage nerve cells by causing even more tau to accumulate. "It's a back-and-forth kind of system," Baker says.

Neuroscientist Mark Mattson of the National Institute on Aging in Baltimore says the study offers hints that senescent brain cells play a role in aging. But "there are a lot of open questions," such as what signals cause glial cells to become senescent and how the cells harm nerve cells.

Baker plans to study whether destroying senescent cells in animals that already have signs of disease can slow or reverse brain damage. ■



A Jupiter-sized planet and a Neptune-sized moon cross in front of the star Kepler 1625 in this artist's illustration.

ATOM & COSMOS

Hubble spies signs of an exomoon

Reported satellite's unusually large size is hard to explain

BY LISA GROSSMAN

The first suspected exomoon is coming into focus. Hubble Space Telescope data bolster the case for a Neptune-sized moon orbiting an exoplanet 8,000 light-years from Earth, astronomers report October 3 in *Science Advances*. If confirmed, the moon would challenge theories of how satellites are born.

David Kipping (*SN: 10/14/17, p. 22*) and Alex Teachey of Columbia University focused Hubble on Kepler 1625 for some 40 hours on October 28 and 29, 2017. The star was known to have a Jupiter-sized planet orbiting every 287 days, thanks to data from the Kepler space telescope, which detects dips in starlight that indicate a planet is transiting in front of a star.

Teachey and Kipping had seen signs in the Kepler data of a second dimming, either before or after the planet passed — what would be expected if an exomoon were orbiting the planet (*SN: 8/19/17, p. 15*). The pair named the possible moon Kepler 1625b i, or "Neptmoon." But more observations were needed to be sure it was really a moon, not another planet or activity on the star.

Hubble, whose sensitivity is 3.8 times Kepler's, saw a secondary dip in light after the planet crossed the star. The planet also started its 19-hour transit earlier than expected, suggesting that something was tugging gravitationally on the planet.

Both signals are consistent with the moon existing. Still, "we're not cracking open champagne bottles just yet," Teachey said October 1 at a news conference. The team wants to check with Hubble again, hopefully during the next transit in May 2019, he said. "Things look exciting, tantalizing, maybe compelling."

For now, astrophysicist René Heller of the Max Planck Institute for Solar System Research in Göttingen, Germany, says he remains skeptical. One reason for caution is the strangeness of the moon itself. In our solar system, moons form in one of three ways: by being knocked from a planet in an impact, by coalescing from gas and rock orbiting the planet or by being captured by the planet's gravity. It's unclear how these scenarios could create a moon as large as Kepler 1625b i.

"Kepler 1625b i, if real, would be about 10 times as massive as the mass of all moons and terrestrial planets in the solar system combined," Heller says. "This suggests that this moon would have formed in a completely different way than any moon in the solar system." ■

MATTER & ENERGY

Ultrafast laser sets pulses racing

Advance could aid astronomy, telecommunications and more

BY EMILY CONOVER

Blazingly fast lasers have just leveled up.

Ultrafast lasers emit short, rapid-fire bursts of light. Each pulse typically lasts tens of millionths of a billionth of a second. A new laser pulses 30 billion times a second — about 100 times as fast as most ultrafast lasers, researchers report in the Sept. 28 *Science*.

The speed boost comes thanks to a new technique for making ultrafast lasers. Typically, researchers use a technique called mode locking, in which light bounces back and forth in a mirrored cavity so that the light waves build on each other to create short flashes. The new method takes a more "brute force" approach, by carving up a continuous laser beam into individual pulses, says study coauthor David Carlson, a physicist at the National Institute of Standards and Technology in Boulder, Colo.

Ultrafast lasers can produce a frequency comb, light made up of discrete colors. Those evenly spaced hues look like the teeth of a comb when plotted. To make the new approach work, the scientists had to eliminate electronic jitter that would smear out the comb's sharp teeth.

These combs can be used as a kind of "ruler" for precisely measuring the frequency of light. Part of the 2005 Nobel Prize in physics was awarded to two researchers who developed the technique. Part of this year's Nobel Prize in physics was also awarded to ultrafast laser research, for a method to produce very intense, short laser pulses (see Page 16). But that technology was not used in this work.

The faster pulses achieved with the new technique result in a frequency comb with more widely spaced teeth. That property could be useful for calibrating telescope instruments called spectrographs, which slice up light from stars into various colors, aiding scientists in observations such as the hunt for planets beyond the solar system. Those spectrographs can't distinguish frequencies that are too close together, so the instruments require a wide comb.

Faster pulses could also speed up certain kinds of imaging of biological tissues. And the laser could be useful for telecommunications, says physicist and electrical engineer Andrew Weiner of Purdue University in West Lafayette, Ind., who called the work a "tour de force." Each color of light could carry its own stream of information in a fiber-optic cable. ■

DAN DURDA

BODY & BRAIN

Paralyzed man takes steps again

Spinal stimulator and rehab allow for some leg control

BY LAURA SANDERS

With the help of a spinal stimulator and intensive training, a formerly paralyzed man can command his legs to step. The feat, described September 24 in *Nature Medicine*, inches scientists closer to restoring movement to paraplegic people.

The therapy allows 29-year-old Jered Chinnock to control his leg movements with his thoughts. "This is highly significant," study coauthor Kendall Lee, a neurosurgeon at the Mayo Clinic in Rochester, Minn., said September 20 in a news conference.

A snowmobile wreck left Chinnock unable to move or feel sensations below the chest. Three years after the accident, he enrolled in a study designed to get him moving.

Surgeons implanted a stimulator that zaps nerve cells on the spinal cord below the site of the injury. With the stimulator on, therapists led Chinnock through exercises to reactivate muscles and nerves. Over two weeks of training, he could stand and, while lying on his side, make voluntary steplike movements.

Now, after 43 weeks of intensive rehabilitation, Chinnock has made even greater strides. He can step on a treadmill on his own and, with assistance and a walker, step across the floor. Over the course of one training session, he traveled 102 meters, about the length of a football field. Because Chinnock required assistance, researchers call his motion "independent stepping." Clinically speaking, walking is "a highly coordinated activity in terms of balance, strength and adaptation to the environment," says Lee's coauthor Kristin Zhao, also of the Mayo Clinic.

Chinnock's progress echoes results seen by others. Neuroscientist Susan Harkema of the University of Louisville in Kentucky and colleagues used spinal stimulation to help two of four paralyzed patients step across the ground with assistance. Those findings, reported in the Sept. 27 *New England Journal of Medicine*, plus the results in *Nature Medicine*, give heft to the approach. That replication is "really exciting," Harkema says.

With physical therapy and a spinal stimulator, Jered Chinnock regained the ability to step.

Lee's team suspects that Chinnock has some residual nerve cell fibers that span the damaged part of his spine. It's not clear whether a similar approach would work for paraplegic people with different sorts of spine damage. It's also unclear how physical training regimens should be designed, Zhao says. Chinnock attended 113 rehabilitation sessions conducted while he was lying down, sitting, standing and stepping with help from a trainer. Another unknown is whether Chinnock's improvements will persist. ■

BODY & BRAIN

New TB vaccine passes crucial test

People with a latent infection were protected from illness

BY AIMEE CUNNINGHAM

A new tuberculosis vaccine shows promise in preventing bacteria from causing the disease in people who are infected but not sick. If approved, the vaccine could help control the spread of a disease that caused 1.6 million deaths in 2017, according to the World Health Organization.

In a clinical trial funded by the pharmaceutical company GlaxoSmithKline, the vaccine halved the number of people who developed active TB from latent infections of *Mycobacterium tuberculosis*, compared with those who got a placebo. Of 1,623 participants treated with two doses of the vaccine and followed for just over two years, 10 developed TB. That's compared with 22 of 1,660 people who received two placebo shots, researchers report online September 25 in the *New England Journal of Medicine*.

"Extremely encouraging," says Richard Chaisson, director of the Johns Hopkins Center for Tuberculosis Research, who was not involved in the research. "This is the first study of new tuberculosis vaccines that has had such dramatic results."

The only available vaccine, bacille Calmette-Guérin, protects against TB in children but is not effective for adults.

In a latent infection, the immune system keeps the bacteria in check, preventing the development of symptoms and the spread of TB to others. About a quarter of the world's population is estimated to have a latent infection. But about 5 to 15 percent will develop TB, which causes a persistent, sometimes bloody cough, fever, chills and night sweats.

The new vaccine, M72/AS01$_E$, is made of two proteins from the bacteria that provoke an immune response, plus a substance that enhances that response. Nearly 3,300 African participants ages 18 to 50 were randomly assigned to get the vaccine or a placebo in a clinical trial designed to test the vaccine's efficacy. No serious safety issues emerged.

People with latent infections are more likely to get sick if they are also infected with HIV, have diabetes, smoke or are malnourished. TB is also more common in the first year of infection. Treating people at high risk with antibiotics is a viable strategy, but not feasible for all, says Chaisson. "A vaccine for the larger population could be an effective way to further reduce the incidence of the disease." ■

SCIENCE & SOCIETY

Meet 2018's Nobel Prize winners

Laureates worked on drugs, optical tweezers and more

This year's Nobel science prizes honor innovative ways of harnessing the power of nature — to fight cancer, design new proteins and create powerful lasers.

Stopping cancer by removing brakes on the immune system earned James Allison of the University of Texas MD Anderson Cancer Center in Houston and Tasuku Honjo of Kyoto University in Japan the physiology or medicine prize, announced October 1. Other cancer therapies target the tumors. But the laureates' strategy was to persuade the patient's immune system to go after the cancer (*SN: 7/11/15, p. 14*).

Allison discovered that CTLA-4, a protein on the surface of immune cells called T cells, holds T cells back from attacking tumors. His lab developed an antibody against CTLA-4 to release the brake and allow T cells to kill tumors. The therapy proved effective against melanoma (*SN: 9/25/10, p. 12*). In 2011, the U.S. Food and Drug Administration approved the resulting drug, ipilimumab.

Honjo uncovered another brake on T cells called PD-1. Antibodies to block PD-1 have had even more dramatic effects than CTLA-4 blockers, even helping people with cancer that has spread (*SN: 12/27/14, p. 8*). In 2014, the FDA approved the first "PD-1 blockade" antibodies. Now there are several antibodies against PD-1 and its partner on tumor cells, PD-L1, approved for several cancers.

"The seminal discoveries by the two laureates constitutes a paradigmatic shift and a landmark in the fight against cancer," Nobel committee member Klas Kärre said October 1 during a news conference.

The chemistry prize, announced October 3, went to scientists who put evolution on fast-forward to build new proteins. Frances Arnold of Caltech won for a method of creating customized enzymes for biofuels, eco-friendly detergents and other products. George Smith of the University of Missouri in Columbia and Gregory Winter of the University of Cambridge were recognized for developing and using phage display, which can make molecules for new drugs.

Arnold, the fifth woman to win a Nobel Prize in chemistry, developed an iterative process called directed evolution. A researcher begins with many copies of an enzyme, each with different genetic mutations. The genes for those enzymes are inserted into bacteria, which churn out each enzyme variant. The best-working enzyme is chosen for another round of mutation and selection. Over many rounds, scientists can fine-tune proteins the way nature does, but faster.

In a related line of work, Smith devised a method to put instructions for building proteins into viruses called bacteriophages, which then bore the proteins on their surface. That allows researchers to match a target molecule with the gene that carries the instructions for building that molecule. Combining phage display with directed evolution, Winter produced the antibody adalimumab, creating a drug that neutralizes a chemical that incites inflammation. The drug, known as Humira, was cleared to treat rheumatoid arthritis in 2002 and is now also used to treat psoriasis and inflammatory bowel disease (*SN: 8/1/09, p. 8*).

Fantastic feats of manipulating light won three scientists the physics prize, announced October 2. Arthur Ashkin of Bell Laboratories in Holmdel, N.J., created optical tweezers, a tool that can grab viruses and living cells with beams of light and move them around. Individual subatomic particles of light exert pressure. By focusing a laser beam just so, Ashkin realized small objects could be trapped and moved around by the forces of the light particles. Optical tweezers are used worldwide to investigate the inner lives of cells and DNA. And the technique led to a method to trap and cool individual atoms with lasers, which won the 1997 Nobel Prize in physics.

Gérard Mourou of École Polytechnique in Palaiseau, France, along with Donna Strickland of the University of Waterloo in Canada invented a way to amplify laser light into intense, short bursts using a method called chirped pulse amplification. Today, the method is used to create the world's most powerful laser pulses. Intense laser beams could be useful for accelerating particles (*SN: 9/29/18, p. 12*), achieving nuclear fusion or creating matter from light (*SN: 6/14/14, p. 14*). Laser pulses based on Strickland and Mourou's work are also used in more ordinary pursuits, such as laser eye surgery. The award marks only the third time a woman has been awarded the physics Nobel.

The Nobel Memorial Prize in Economic Sciences, announced October 8, honored two researchers for their efforts to untangle the economics of climate change and technological innovations.

William Nordhaus of Yale University developed computer simulations that weigh the costs and benefits of taking various steps to slow global warming. The U.S. Environmental Protection Agency and others have used his work to estimate climate change's economic impacts.

Paul Romer of New York University expanded economic theory by arguing that government policies, such as funding research and development, can stimulate technological advances. In his view, the presence or absence of such policies helps to explain national differences in wealth and economic growth. — *Bruce Bower, Emily Conover, Aimee Cunningham, Lisa Grossman, Laurel Hamers, Tina Hesman Saey and Maria Temming*

2018 Nobel Laureates

PHYSIOLOGY OR MEDICINE

James Allison
University of Texas MD Anderson Cancer Center

Tasuku Honjo
Kyoto University

CHEMISTRY

Frances Arnold
Caltech

George Smith
University of Missouri

Gregory Winter
University of Cambridge

PHYSICS

Arthur Ashkin
Bell Laboratories

Gérard Mourou
École Polytechnique

Donna Strickland
University of Waterloo

ECONOMIC SCIENCES

William Nordhaus
Yale University

Paul Romer
New York University

Read more in-depth coverage at bit.ly/SN_Nobels2018

An emergency liver transplant saved 53-year-old Trent Jackson, but he has struggled to keep his body from rejecting the donated organ.

MATTHEW RAKOLA

Transplant Tolerance

How to get replacement parts to be long-lasting

By Tina Hesman Saey

Trent Jackson's life changed abruptly in early 2015. The computer engineer thought he had the flu. His then-wife, Donna Sylvia, thought differently. His skin was turning a dark golden yellow, almost brown, "like he was getting some kind of weird tan," she says. On Wednesday, January 28, Sylvia and Jackson's brother Todd finally persuaded Jackson to see a doctor.

Sylvia's suspicions were confirmed: Jackson's liver had failed. His kidneys shut down, too. Doctors rushed him by air ambulance from Columbia, Md., to Johns Hopkins Hospital in Baltimore. There, he scored 39 on a 40-point scale that gauges how likely a person in liver failure is to die without a liver transplant in the next three months.

People in his condition are often considered too sick for surgery, Jackson says. But on February 15, he got a new liver. "I guess they decided that other than being mostly dead, I was pretty healthy."

Jackson, 53, got a second chance, but his ordeal hasn't ended. He takes three drugs every day to keep his immune system from attacking the donor organ. (Transplant recipients often take daunting drug regimens, but many are able to gradually reduce the amount of medication.) Over the long haul, the drugs leave people vulnerable to infections, kidney damage, cancer and type 2 diabetes. Jackson hasn't experienced the most dire side effects. But tacrolimus, an immunosuppressive drug, makes his hands shake, and a steroid he takes caused cataracts, for which he needed surgery last year.

Powerful as the drugs are, they are not a foolproof rejection remedy. In the three years since his transplant, Jackson has been hospitalized twice for acute rejection. With gallows humor, Jackson, now living in Carrsville, Va., jokes: "The good news is I have a great immune system. The bad news is it tries to kill me every day now."

Jackson isn't alone. In the first eight months of 2018, 24,214 people in the United States received a donated organ. In total, there are more than 354,000 people living in the United States with transplanted organs, most of whom are resigned to taking immunosuppressive drugs for the rest of their lives.

Before the drugs, people who got transplants often died within a year, says Andrew Cameron, a transplant surgeon at Johns Hopkins. After the introduction of the drug cyclosporine in 1983, about 80 to 85 percent of transplant recipients survived the first year. That number hasn't changed much in the last 40 years, Cameron says.

Long-term survival is the bigger challenge. Of 1,456 U.S. lung transplants in 2007, 1,045 had failed by 2017. On the plus side, about 55 percent of transplanted kidneys, 57 percent of livers and 60 percent of hearts survive a full decade.

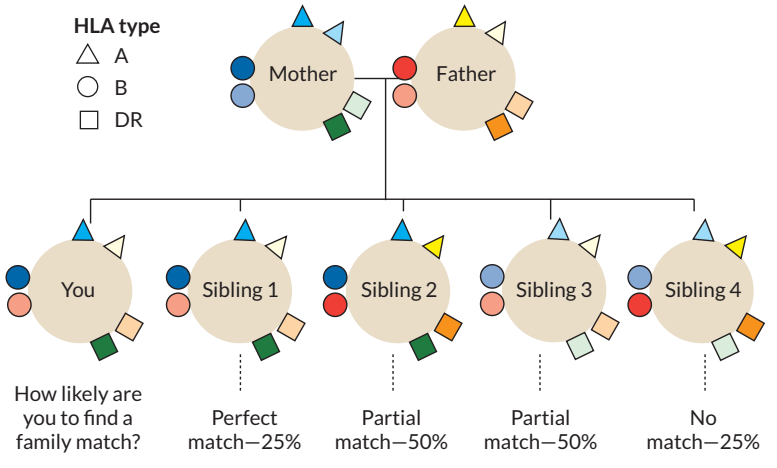
Cameron and other researchers are looking for ways to help more transplant patients live healthier and longer, without a lifetime of medications. For now, researchers are still experimenting to teach a patient's immune system to turn a blind eye to, or even welcome, the foreign organ. Scientists are marrying donors' and recipients' immune

354,078

Number of people in the United States with transplanted organs as of June 29, 2018

SOURCE: ORGAN PROCUREMENT AND TRANSPLANT NETWORK

Match points Cells are studded with HLAs, or human leukocyte antigens, which help the immune system decide which cells are part of the body. HLAs come in many varieties and are inherited as a set of one A, one B and one DR from each parent. People are most likely to find a perfect or partial match, with lower odds of rejection, among siblings.



E. OTWELL

Trent Jackson takes a host of drugs each day to prevent his body from rejecting his transplanted liver. Immune suppression leaves people vulnerable to infections, cancer and diabetes. Some drugs have additional side effects.

systems, revving up certain calming immune cells and even making the donor organ look a whole lot more like the patient.

The key to acceptance

This struggle to prevent rejection has been going on since doctors began transplanting internal organs in the 1950s, starting with kidneys. Today, transplants also include livers, hearts, lungs, intestines, pancreases and tissues such as skin, bones and tendons. In 2014, hands and faces became an option. Doctors recently transplanted a penis and scrotum for a U.S. veteran wounded in Afghanistan (*SN Online: 4/24/18*).

Because transplanted skin has a high likelihood of provoking an immune attack, researchers were skeptical that faces or extremities could be transplanted, Cameron says. But people who have gotten face and hand transplants have needed surprisingly few drugs to minimize rejection. A recipient gets a bit of a donor's immune system, in the form of blood-producing bone marrow stem cells within the donor's jaw, hand or arm bones.

Stem cells in the bone marrow give rise to immune system cells that patrol the body and decide what belongs and what doesn't. Having some of the donor's immune cells makes the recipient's body see the donor's tissue as part of itself (*SN Online: 3/7/12*). While bone marrow and organ transplant combos are uncommon and still experimental, doctors at Johns Hopkins thought bone marrow infusions after surgery would give the transplanted penis and scrotum the best chance to survive.

Three research groups have developed their own versions of this blended immune system tactic for kidney transplants, with some promising results. The blended immune systems are called "mixed chimeras" for the mythical fire-breathing hybrid with a lion's head, goat's body and snake's tail. Tests in small numbers of patients have been going on for more than a decade at Stanford University, Massachusetts General Hospital in Boston and in a joint venture of the University of Louisville in Kentucky and Northwestern University in Evanston, Ill.

"There have been varying degrees of success," says John Scandling, a transplant nephrologist at Stanford University Medical Center. "It's still very much a work in progress."

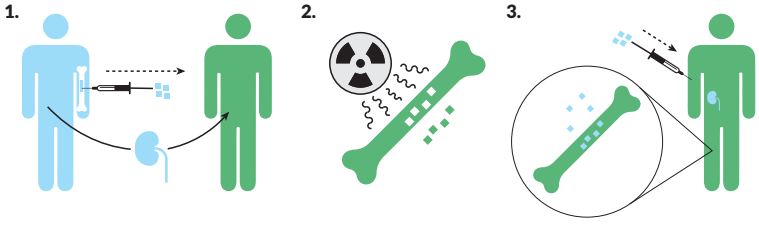
One problem is that the transplanted immune cells don't always last very long. In 2005, the Stanford group gave 29 patients bone marrow transplants along with kidneys from matched living donors. (Kidneys and livers from live donors last longer than those from deceased donors.) Matched donors and recipients have the same versions of proteins called human leukocyte antigens, or HLAs.

Those proteins help the immune system distinguish cells that belong to the body from invaders, such as viruses, bacteria and other people's cells. Rejection of a donor organ is more likely the more HLA mismatches a patient has with the donor.

Only nine of the bone marrow recipients still have part-donor immune systems. But even being a temporary chimera can help people hold on to donor organs. Of the 29 patients in the trial, 23 have been able to stop taking immune-suppressing drugs without rejecting the kidney for up to nine years so far, Scandling and colleagues reported in the May *Human Immunology*. That includes 14 who started with blended immune systems, but eventually lost the donor bone marrow cells.

People who are not well matched to their donors may have a different experience, however. Take Irene Bacani, an accountant in Livermore, Calif., who needed a kidney in late 2013. Her sister, Rezah Burgess, only a partial HLA match, agreed

How to tamp down rejection: Foster familiarity



Organ plus donor bone marrow stem cells The patient gets a donor kidney plus radiation (which kills some of the patient's bone marrow cells to make room for the donor's), followed by a bone marrow transplant. Those foreign cells become part of a patient's immune system, which is now less likely to see the organ as foreign.

FROM TOP: MATTHEW RAKOLA; C. CHANG

to donate one of hers. Scandling's team offered the sisters a chance to participate in a Stanford bone marrow stem cell study.

"My sister said right away, 'Let's do this,'" says Bacani, 53, who was less enthusiastic. Doctors told her she would need radiation to kill some of her bone marrow cells to make room for her sister's.

Bacani ultimately agreed because there was the tantalizing possibility that perhaps, one day, she wouldn't need to take immune-suppressing drugs to keep the gift her sister had given her. "I thought, if I don't try it, I'm always going to be thinking, 'what if?'" On November 30, 2015, Bacani got a kidney from her sister, followed by radiation therapy and then some of her sister's bone marrow.

Today, less than 2 percent of Bacani's blood cells come from her sister's bone marrow. That's enough to get her down to one daily dose of one drug, tacrolimus, but not enough to go drug free.

Bacani's story is typical of the mismatched donor-recipient pairs in the Stanford study. None of the HLA-mismatched participants have been able to stop drugs for more than several months before kidney rejection flares up.

A handful of patients in a small study of HLA mismatched kidney transplants at Mass General enjoyed years without immune-suppressing drugs thanks to a transplant of short-lived bone marrow, Hajime Sasaki and colleagues wrote in the May *Human Immunology*. Seven of 10 patients went off drugs. Three of the seven had to get back on drugs five to eight years after dropping them, either because the kidney disease returned or because of chronic rejection.

Making it stick

Mixed chimeras work best if the bone marrow stem cells can stick around.

Researchers led by transplant surgeons Suzanne Ildstad of the University of Louisville and Joseph Leventhal of Northwestern may have gotten a handle on that problem. Of 31 patients who got bone marrow and a kidney from a living donor, 23 have kept the donor immune system, and 22 of those have not needed immune-suppressing drugs for eight months to nearly seven years, the researchers reported in May in *Human Immunology*. Among seven patients who held on to the donor bone marrow for only a little while, five are down to a single low-dose medication, says Ildstad, who is also chief executive officer of the biotech company Regenerex.

Even if the patients can't completely stop the drugs, reducing the amount of medication is a win in her book.

> "I thought, if I don't try it, I'm always going to be thinking 'what if?'"
>
> IRENE BACANI

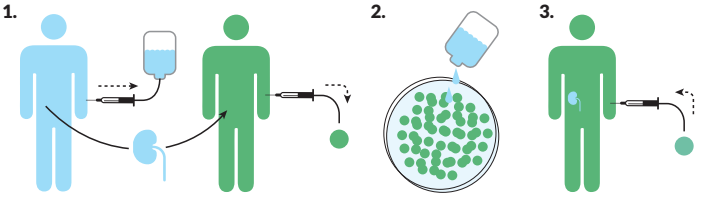
Ildstad and Leventhal's secret ingredient is a type of immune cell called a facilitator cell. Regenerex collects facilitator cells from the donor's blood (using a proprietary procedure) and transplants them with the bone marrow stem cells and the kidney. Those facilitator cells help the donor marrow settle in, so much so that more than 95 percent of the immune cells in the recipient's blood are made by the donor stem cells. The transplanted immune system ignores the donor kidney, because it looks like home.

But a donor-heavy immune system has its downside. In two of the 31 transplants, the donated immune system began attacking the recipient's body, a deadly condition known as graft-versus-host disease.

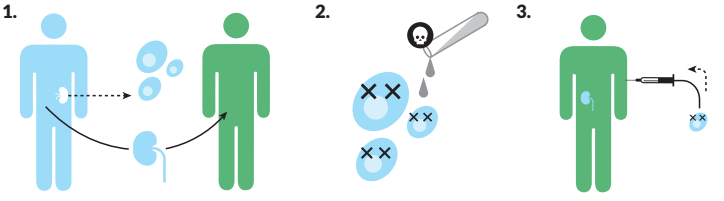
Soothing cells

While those groups are working out the kinks in bone marrow transplants, others are trying to hide the donated organ from immune attack. That's easier for some organs than others. The liver, in particular, is good at camouflage. When liver transplant patients choose to stop taking their drugs — against all recommendations — about 20 to 50 percent get away with it. (Kidney recipients rarely do, and that kind of freedom is unheard of for heart, lung and pancreas transplants.) Transplant surgeon Sandy Feng of the University of California,

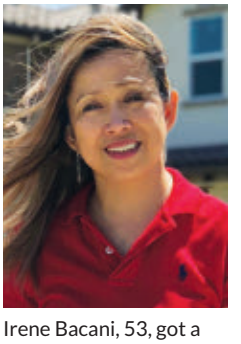
How to tamp down rejection: Two ways to calm the system



Organ plus B cells A donor gives a kidney plus some immune B cells. The patient's immune cells called T regs are removed and grown in the lab to expand their numbers. The donor B cells train the T regs, later injected into the patient, to quash attacks against the donor organ.



Organ plus dying cells A donor gives a kidney plus spleen cells. Those cells are chemically persuaded to commit suicide and are injected into the patient, tricking the immune system into treating the donor organ as normal, in part by stifling inflammation.



Irene Bacani, 53, got a kidney and bone marrow from her sister in 2015.

FROM TOP: C. CHANG; I. BACANI

Second chances
Replacements are getting more complex.

1954
In the first successful organ transplant, a living donor gave a kidney to his identical twin.

1960s
Successful liver, pancreas, heart and bone marrow transplants

1983
FDA approves cyclosporine to treat organ rejection.

1998
First successful hand transplant, in France

1998
Massachusetts General Hospital begins combining kidney and bone marrow transplants.

2005
First partial face transplant, in France

2010
First successful full face transplant is completed in Spain.

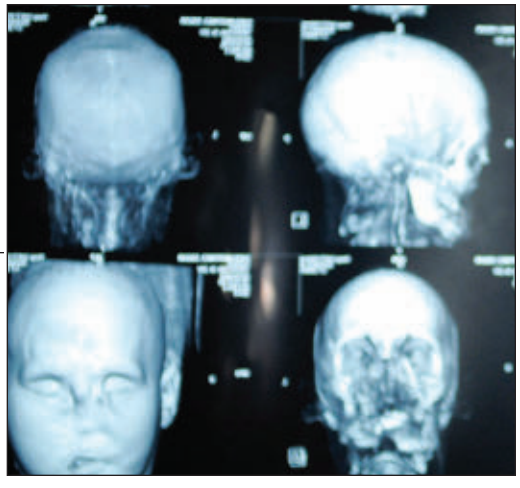
2018
Wounded U.S. veteran receives penis and scrotum transplant.

San Francisco wanted to know if kids with transplants could go off their meds. She took a look at children with a donated liver who are outwardly healthy but may not be tolerating the organ as well as their doctors think.

In those children, Feng and colleagues have seen what Feng calls "a smoldering rejection process." All of the 157 children enrolled in Feng's study had normal liver function according to blood tests. But biopsies revealed that about half of the kids had inflammation or fibrosis, a type of scarring that is a sign of tissue damage, Feng and colleagues report in a study to be published in *Gastroenterology*.

Feng hopes to smother that rejection with regulatory T cells, or T regs, immune cells that can calm the body's defenses. In ongoing studies, Feng and colleagues remove a patient's own T regs and grow them in the lab to expand their numbers. Immune cells called B cells are collected from the donor's blood or spleen and added to the dish to train the T regs to become familiar with the donor organ so they will quash immune attacks against the organ but not interfere with fighting off infections or cancer.

Richard Herrick (bottom, left) lived eight years after getting a kidney in 1954 from his identical twin, Ronald (right). Identical twins have the same HLA proteins. An accidental gun shot victim received the first full face transplant in Barcelona on March 20, 2010 (top, scans taken before surgery).



FROM TOP: DAVID RAMOS/ASSOCIATED PRESS; ASSOCIATED PRESS

Trained T regs and other regulatory cells may help donated organs get along with their hosts, but those calming cells are up against a mix of immune cells that want to annihilate the foreign organ. With so many enemies, friendly T regs can only do so much for a transplanted organ, says Xunrong Luo, a transplant immunologist at Duke University. "Just having a ton of good cells is not enough," she says. "You have to get rid of your bad cells."

Feng agrees. In patient studies, her group is trying to persuade the body to eliminate the cells that would attack an organ while boosting T regs. The aim is to achieve a balance both the host and the donor organ can live with.

Dead ringers

Luo and colleagues have a different just-ignore-me approach that may allow immune cells to see a donated organ but decide not to attack. The heroes in this technique are dead or dying cells that are perishing via a relatively gentle process called apoptosis, or cell suicide. In animal experiments, Luo's group takes cells from a donor's spleen and chemically persuades them to commit apoptosis, then injects the apoptotic cells into the transplant recipient. The apoptotic cells trick the immune system into treating the donor organ as a normal part of the body that it doesn't need to attack.

The researchers haven't worked out all the details of how the dying cells pull off the trick, but the team has recently discovered that cells responsible for clearing apoptotic cells from the body are involved in the process. Phagocytes grab and engulf apoptotic cells, then send a signal to decrease production of an inflammation-producing chemical called alpha-interferon, Luo and colleagues reported online August 22 in the *American Journal of Transplantation*. That stifling of the inflammation signal is important for the host to tolerate a transplant, the researchers found.

Apoptotic cells also marshal protective cells to transplanted organs and fend off attacks, Luo's team learned from heart transplants in mice. And in unpublished experiments, apoptotic cells have helped avert immune attacks in monkey-to-monkey pancreatic islet cell transplants, Luo says. (Those cells make insulin, a hormone that helps control blood sugar levels.) She is now

experimenting with pig-to-monkey transplants.

There is some hope the strategy could work for people, too. One small study showed that apoptotic cells could help patients with bone marrow transplants avoid graft-versus-host disease.

A more familiar organ

Instead of trying to avoid detection or make the recipient more like the donor, Cameron and colleagues are doing the opposite, incorporating a patient's stem cells into the donor organ. The idea was spawned by studies that showed some long-term liver transplant recipients had livers containing both donor and recipient cells. Stem cells from the recipient's bone marrow had migrated to the donor liver to repair damage. They became liver cells that grew as part of the foreign organ.

Stem cells are homebodies, rarely leaving the bone marrow for repair missions. But Cameron's group has used stem cell–mobilizing drugs as a sort of fire alarm that prompts the stem cells to evacuate their home and go in search of organs and tissues in distress. Once the cells find an ailing organ, they set up shop. The donor organ essentially becomes a scaffold that supports growth of a new organ made of a patient's cells.

The technique actually requires a little bit of rejection to draw the stem cells to the right place. But once the stem cells have integrated, the organ becomes the host's own as far as the immune system is concerned. Rats and miniature pigs have gotten kidney transplants plus stem cell–mobilizing drugs. Those animals lived with transplanted kidneys without any immune suppression, Cameron and colleagues reported in 2016 in the *American Journal of Transplantation*.

The pigs had both kidneys removed, then received one kidney from another pig. Pigs that got no immunosuppression or other treatment died within about 10 days, Cameron says.

With one stem cell–mobilizing drug, pigs lived a little longer, about 10 days to a month. Animals that got two stem cell–mobilizing drugs "lived three years and were going strong by the time we declared the experiment over," Cameron says. Those results suggest that a certain number of host stem cells need to integrate into the transplanted organ, but Cameron and colleagues don't yet know how many.

If such treatments were applied to people, Cameron says, "we would expect that you'd never reject that kidney just as you never reject your left hand, because it's 'self.'"

C. CHANG

How to tamp down rejection: Assimilation

Organ plus patient's own bone marrow A donor gives a kidney or other organ. The patient receives stem cell–mobilizing drugs that spur stem cells in the patient's bone marrow to go in search of organs in distress. Once the stem cells reach the transplanted organ, they set up shop and become part of the new organ. This process also has the potential to repair damaged organs so that no transplant is necessary.

He can even imagine a day when transplants aren't even necessary. People like Trent Jackson, with a failing liver, may be able to repair their own organs with the help of the stem cell–mobilizing drugs, Cameron's research suggests. He and colleagues dosed Yorkshire pigs with a liver toxin to cause acute liver failure. Untreated pigs died within 91 hours. With stem cell–mobilizing drugs, five of six poisoned pigs survived, the researchers reported in October in *Annals of Surgery*.

No one knows which, if any, of these approaches will free transplant recipients to live without fear of rejection. None of the techniques has been vetted enough yet, and none has worked for everyone, Luo points out. Each patient may need a different strategy or a combination of rejection-soothing therapies. Researchers need to push ahead on all fronts and not be afraid to explore other strategies, she says: At this stage of research, "we just cannot be ... fixated on one idea."

Jackson would be happy just to get his liver rejection and medication under control so he can get back to work. As a computer engineer, Jackson was proud of being the guy everyone could count on. His colleagues knew they could just pick up the phone and call him to fix their problems. "There's no way I'm that person now," he says.

Bouts of rejection give him yellowed eyes, night sweats, nausea and vomiting. Some days he can't get going until after noon. "I'm unreliable. I know that." His health has damaged his sense of self. "I was a go-to person. I was always there. Now I can't do it."

But he's feeling better and his liver is now working as it should. The new research may eventually help Jackson and others like him achieve lasting health. He'd like to be the go-to guy again. ■

Explore more

- Organ Procurement and Transplantation Network: https://optn.transplant.hrsa.gov

The Mendocino Complex Fire, the largest in California history, burned more than 1,800 square kilometers this year. As of October 4, more than 60 large wildfires were burning in the United States.

NOAH BERGER/AFP/GETTY IMAGES

Big Burn

New prediction tools zero in on how wildfires make weather

By Laurel Hamers

Wildfires are not known for their restraint. They'll jump rivers, spew whirling dervishes of flames and double in size overnight.

Take the Carr Fire, one of California's most destructive, sparked in mid-July when the rim of a flat tire met pavement. As the blaze grew, it jumped across the Sacramento River and ignited a flaming whirlwind that trapped and killed a firefighter near Redding. By the time it was fully contained on August 30, the fire had burned 930 square kilometers, destroyed more than 1,000 buildings and killed eight people.

"Once these fires are spreading fast enough and intensely enough, you can't stop them," says Ruddy Mell, a combustion engineer with the U.S. Forest Service based in Seattle.

Federal and state agencies that manage wildfires use mathematical equations — fire models — to predict how blazes will spread and help decide how to commit firefighting resources or whether an evacuation is needed. But the models can't always predict when a fire will suddenly veer in a new direction or grow exponentially.

Now, scientists are developing more nuanced fire models with increasingly detailed satellite data and better understanding of how fires can create their own weather and fan their own flames. These finer-scale models take hours or days to run on a computer, so they probably won't replace existing

quick-and-dirty field models for responding in the heat of the moment. But these new tools can help scientists figure out what drives wildfire behavior — and learn how to better protect communities when fires break out.

Record burns

Wildfires are on track this year to cause about as much damage in the United States as in 2017, when they burned a bigger area than in almost any year since consistent data collection began in 1983, according to the National Interagency Fire Center in Boise, Idaho. As of October 4, fires had torched an area larger than Massachusetts, more than 31,000 square kilometers nationwide. In the last few years, along with the immediate loss of lives and property, wildfires have cast an especially thick veil of particulate pollution over the western United States (*SN: 8/18/18, p. 9*).

While wildfires sparked naturally by lightning strikes are a healthy part of many ecosystems, humans have inadvertently made such fires worse. Years of forest management policies that suppress natural fires have made the ones that do bubble up even more ferocious, since there's so much fuel on the ground. Plus, people start 84 percent of all wildfires in the contiguous United States, accidentally or on purpose, researchers reported last year in the *Proceedings of the National Academy of Sciences*. Our influence has made fire season three times as long as it would be naturally, the study suggested.

Climate change will probably intensify the problem. Much of the western United States could see an increase in the area of land burned each wildfire season over the next 20 years. That's according to a 2017 study in *PLOS ONE* that analyzed temperature, snowpack (earlier snowmelt means a drier summer) and wildfire data. And in the future, cyclic climate fluctuations such as El Niño will exert a stronger influence on heat waves and wildfires, making such natural disasters more severe, researchers predicted in August in *Geophysical Research Letters*.

Wildfires are also influenced by another complex set of variables. What kind of plants cover the ground? Is the terrain flat or hilly? How fast is the wind blowing? What's the temperature?

Fire managers take these variables into account, but current prediction models are designed for emergency scenarios where a fast response is key. These rough equations don't capture the finer details — the way fires interact with the atmosphere, for instance, creating their own winds that can blow flames and spit embers in unexpected directions. Capturing fire behavior through mathematical equations, though, is almost as hard as stopping the burn.

Fire weather

Of course, gathering data about the way fires interact with the atmosphere poses logistical challenges. "It's pretty much impossible to set up instruments right next to a high-intensity wildfire," says meteorologist Warren Heilman of the U.S. Forest Service in Lansing, Mich. The heat would destroy the tools.

That's where a new prediction tool, developed by atmospheric scientist Janice Coen and colleagues, comes in. The way air moves when it's heated by a fire, and the way that air movement influences the fire's behavior, "boils down to complex math and fluid dynamics," says Coen, of the National Center for Atmospheric Research in Boulder, Colo. "If you get these things right, a lot of this horribly complex behavior unfolds." Equations involving atmospheric movement are already used in weather forecasting, but Coen's team is applying them to wildfires through a model dubbed Coupled Atmosphere-Wildland Fire Environment, or CAWFE.

Coen's team recently applied CAWFE retrospectively to the 2014 King Fire, which burned almost 400 square kilometers in California's Sierra Nevada. The fire had been traveling fairly slowly, but then raced 25 kilometers up a canyon in just 11 hours with puzzling ferocity. A nearby weather station was recording calm winds at the time. News reports blamed drought for leaving the landscape parched and easily combustible.

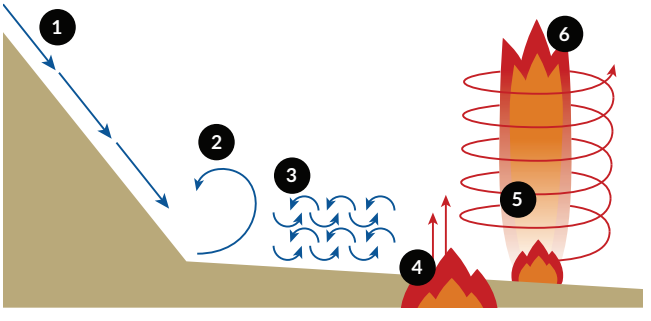
But Coen's analysis suggested that drought wasn't the key driver of the fire's sudden severity.

Instead, the King Fire's fast spread was fueled by atmospheric movement created by the fire itself, Coen's team reported in September in *Ecological Applications*. Differences in atmospheric pressure create wind, which is just air moving from higher-pressure areas to lower-pressure areas. When the fire warmed the air in the canyon, it lowered the air pressure and made the air expand and rise, creating winds far stronger than official measurements taken nearby, the model suggests.

Models like Coen's can re-create other surprising fire events, such as the "firenado" that the Carr wildfire whipped up on July 26. That vortex generated winds exceeding 200 kilometers per hour and temperatures of up to 1500° Celsius, per estimates from the California Department of Forestry and Fire Protection. Such flaming whirlwinds form when rising air heated by a wildfire collides with turbulent ambient air.

Such detailed fire models offer clues on how to manage future fires: In analyzing the King Fire, for example, Coen's

Fire it up The Carr Fire created a fire tornado, or firenado, on July 26. An analysis suggests that the phenomenon started when fast winds swept down the slope of nearby mountains (1), bottomed out and broke like a wave (2). The action created turbulent, swirling air at the base of the hills (3). Meanwhile, air warmed by the fire became less dense and rose (4). As the flames met with turbulent air (5), the fire and hot air swirled and rose together in a whirling column of flames (6).
SOURCE: CAL FIRE



E. OTWELL

team found that the amount of brush (and its level of dryness) influenced the fire's spread rate only on sloped ground. That suggests that, given limited resources, officials should focus brush-clearing efforts on hilly terrain rather than on flat land when trying to slow a fire's spread.

Remember the embers

While Coen's model looks at internal wildfire weather, other models in development capture what happens when wildfires butt up against urban areas and threaten buildings.

How fires behave at this wildland-urban interface is poorly understood compared with fires within buildings or on open land, says Mell, the Forest Service combustion scientist. Wildland-urban interface fires are more complicated to study, too, with a greater variety of fuels available compared with wildfires in a remote forest. Plus, fires that strike communities usually ignite multiple buildings, creating a domino effect that isn't an issue in, say, a standard house fire.

After the Tubbs Fire hit California's wine country hard in October 2017, Mell visited a charred neighborhood in northwest Santa Rosa. The suburb hadn't been identified as a high fire risk, and indeed, the main fire never reached the community. The destruction came entirely from firebrands — chunks of burning vegetation or debris — that swept in on strong winds. Firebrands can pile up and ignite buildings, which can then generate their own firebrands. At that point, "it's very difficult to stop," Mell says.

The arrangement of buildings, the materials they're made of and the surrounding vegetation all affect a community's vulnerability to wildfire, but exactly how is still unclear. To tease out these interactions, Mell, like Coen, incorporates the physics of fire. But the focus is at finer resolution — on how fires burn on the scale of meters, rather than the way they influence air movement over kilometers.

The "dragon," designed by researchers at the National Institute of Standards and Technology, shoots showers of embers to help scientists study fires in the laboratory. A time-lapse photo (bottom) shows the paths of embers moving through the air.

Mell is designing sets of equations to estimate how a firebrand will transfer heat to a surface or how fuels break down at different temperatures.

The larger goal with such models: A more rigorous evaluation of ember hazards so that fire-prone communities can be designed and managed as safely as possible.

These wildland-urban interface models depend on data from lab experiments that test how embers fly and burn. Firebrands are unique from other projectiles because they're burning up as they go, says Samuel Manzello, an engineer at the National Institute of Standards and Technology in Gaithersburg, Md. Their density is constantly changing, which affects how they move through the air. Firebrands from torched vegetation behave differently than those from burning buildings.

Some of Manzello's work involves collecting embers after a fire and studying their properties — how big they are, what they're made of and how much they weigh. His team has also built several "dragons" — contraptions that feed on wood chips and then spit showers of embers. Scientists can control the size of the wood chips ignited in the dragon's belly, as well as the speed at which they fly out of its mouth, to pinpoint vulnerabilities in the designs or materials of construction plans.

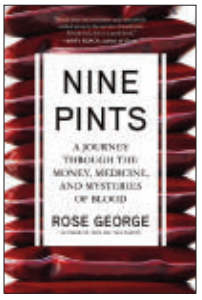
The tile roofs popular in California, for example, seem fireproof because the ceramic doesn't burn. But "we've found out that, when we expose tile roofs to firebrand showers, [firebrands] penetrate under the tiles and light under the roof," Manzello says. Embers land on the roofs and burn until small enough to fit through cracks between the tiles. Now, he says, wildland-urban interface safety standards have been updated: Tile roofs should have combustion-proof materials underneath or materials that plug the gaps. ■

In 2017, flying embers from the Tubbs Fire in California destroyed an entire neighborhood, even though the wildfire didn't touch the community.

Explore more

■ National Interagency Fire Center: www.nifc.gov

TOP: ANNE BELDEN/ISTOCK.COM; OTHERS: S. MANZELLO/NIST



Nine Pints
Rose George
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BOOKSHELF

The history of blood is an engrossing tale

The title of journalist Rose George's new book, *Nine Pints*, quantifies how much blood George has flowing through her body. Her supply takes a temporary dip in the book's opening chapter, when she donates about a pint (a story that continues on to recap the amazing accomplishment that is blood banking). This act of generosity is an appropriate kickoff to the bounty of knowledge and insight that George shares about blood as she mines its cultural and scientific history.

Blood, George notes, is revered, feared and mysterious — the stuff of legend. Chief among the legends are vampires, which, naturally, make an appearance in the book. But in George's hands, ancient tales of purported blood sucking lead readers to modern-day experiments examining whether blood can truly bring youth and health when transferred to the old or sick (*SN: 12/27/14, p. 21*). George's bright writing and companionable tone, along with a healthy dose of skepticism, make her a welcome guide to the past and the future of this giver and taker of life.

Like blood circulating through the body, the book winds its way around the world, exploring myths, facts and scientific discoveries about blood. The cast of characters includes Welsh leech handlers; HIV patients and clinic staff in South Africa; the British physiologist Janet Vaughan, who was instrumental in establishing blood transfusion stations during World War II; and Arunachalam Muruganantham, the "Menstrual Man" who devised a low-cost method to produce sanitary pads in India in the 2000s.

Some of the chapters will make your blood boil. One recounts the corporate and government malfeasance in the 1980s that led to tainted plasma (the liquid component of blood) continuing to be used after officials knew the supplies could transmit hepatitis and HIV, and the patients who died as a result. Another chapter describes the shame and shoddy science that still surrounds menstruation, from girls in Nepal who are forbidden to have contact with their families when they are bleeding to the ridiculous origin of the claim that menstruating women should not go camping in bear country.

George says early on in *Nine Pints* that she is comforted to know that her blood is "moving around my body at any time at two to three miles per hour, taking oxygen to my organs and tissues, removing carbon dioxide, keeping my heart going, keeping me going." Blood is unassuming, doing its duty without much fanfare. But reading George's dramatic tales and learning about the awe-inspiring nature of this essential substance, readers will likely be left amazed as well as comforted. — *Aimee Cunningham*

BOOKSHELF

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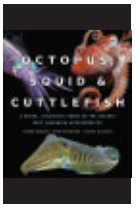
In this enthusiastic look at botanical reproduction and evolution, a geneticist uses tomatoes, bananas and more to enlighten readers about the fascinating sex lives of the plants we eat. *Univ. of Chicago, $20*

Timefulness
Marcia Bjornerud
By better understanding geologic time and Earth's evolution, a geologist argues, people will develop a better sense of their place in the world and treat each other and the planet with more respect. *Princeton Univ., $24.95*

Moon: Art, Science, Culture
Robert Massey and Alexandra Loske
An astronomer and an art historian explore our scientific and cultural fascination with the moon. More than 180 images take readers through a captivating history of our closest cosmic neighbor. *Ilex Press, $24.99*



Octopus, Squid and Cuttlefish
Roger Hanlon, Mike Vecchione and Louise Allcock
Cephalopods are often misunderstood creatures. Three biologists set the record straight on the behaviors and evolution of these invertebrates of the sea. *Univ. of Chicago, $40*

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SEPTEMBER 15, 2018

SOCIAL MEDIA

Rocking New Horizons

A glow at the solar system's edge, reported in "Spacecraft sees hints of hydrogen wall" (*SN: 9/15/18, p. 10*), inspired Reddit user **PM_ME_UR_CHILDHOOD** to parody Oasis' hit 1995 song "Wonderwall."

Today was gonna be the day
that we reach the wall and drive thru/
By now we should've somehow
realized Fermi's paradox
might be true/
I can't believe that New Horizons
will continue to look for the wall
about twice each year...

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Wonderwall

An ultraviolet glow spotted by NASA's New Horizons spacecraft may signal a hydrogen wall that separates the solar system from the rest of the Milky Way galaxy, ***Lisa Grossman*** *reported in "Spacecraft sees hints of hydrogen wall"* (SN: 9/15/18, p. 10). Online reader **RayRay** wondered if researchers could see similar walls at the edges of other solar systems.

Probably, but it's difficult, **Grossman** says. "The wall would show up as an ultraviolet glow around the star, similar to what New Horizons may be seeing. But the star has to be moving the right way with respect to Earth for the wall to be visible," she says. "Researchers are currently using the Hubble Space Telescope to look for walls around four sunlike stars, and they made their first observations this summer. I'm hoping to write about it if they see anything!"

Porcine potential

Pigs implanted with lab-grown lungs showed no signs of rejection, ***Maria Temming*** *reported in "Lab-made lungs implanted in pigs"* (SN: 9/15/18, p. 8). The lungs were made by stripping donor pig lungs of their cells and then seeding those scaffolds with cells from the porcine patients. Online reader **Fishingrod49** asked if pig scaffolds could be used to grow human lungs.

That's certainly possible, says **Laura Niklason**, a biomedical engineer at Yale University. But researchers could have more control over the size of lab-grown lungs if they made scaffolds from scratch, rather than harvesting lungs from pigs. Using 3-D scans of a patient's chest cavity, researchers hope to someday make 3-D–printed scaffolds from human proteins that would grow lungs tailored to the patient.

Other researchers want to make whole organs from pigs transplantable into people. For instance, biologist **Luhan Yang** of eGenesis, a biotech start-up in Cambridge, Mass., has used the molecular scissors CRISPR/Cas9 to rid pig organs of harmful retroviruses. **Yang** hopes to incorporate additional genetic tweaks to get around immune rejection (*SN: 10/14/17, p. 26*).

Words worth

There's little consensus in science over the use of the word "promiscuous" to describe animals' mating behaviors, ***Betsy Mason*** *reported in "In the animal kingdom, what is promiscuous?"* (SN: 9/15/18, p. 4). *Some researchers suggest dropping the term altogether.*

"This is a welcome (if overdue) realization on the part of researchers!" wrote online reader **Maia**. "Language matters, especially when it comes to words with negative connotations in human social contexts, such as 'promiscuous,' 'cheating,' 'divorce' and the like. It's obvious these (and similar) words do NOT apply to animal mating relations, and should be dropped!"

The case of the missing DNA

DNA analysis of a bone fragment that belonged to a girl who died 50,000 years ago indicates that she was a Neandertal-Denisovan hybrid, ***Tina Hesman Saey*** *reported in "Child had Neandertal mom, Denisovan dad"* (SN: 9/15/18, p. 9). "The parental genetic contributions shown add up to 80.9 percent of the child's genes," reader **Tim Cliffe** wrote. He wondered what happened to the other 19.1 percent.

The child's DNA is extremely old, and some bits of her genetic instruction manual probably aren't represented because those parts have worn away or researchers couldn't decipher them. "What's important is to focus on the big picture," **Saey** says. "This girl got roughly equal amounts of DNA from a Neandertal mother and a Denisovan father, representing the first direct evidence of a hybrid individual from these two extinct human relatives."

Correction

In "Plant partners" (*SN: 9/15/18, p. 20*), microbes called methylotrophs were incorrectly described as consumers of methane gas. Methylotrophs eat methanol.

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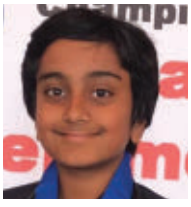

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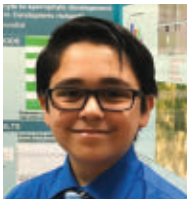

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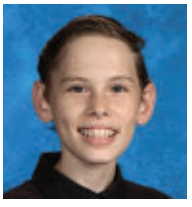

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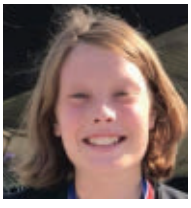

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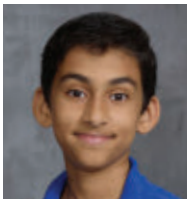

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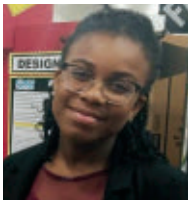

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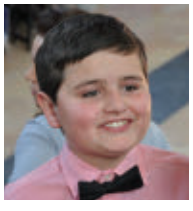

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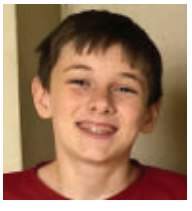

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Math explains dragonflies' intricate wing designs

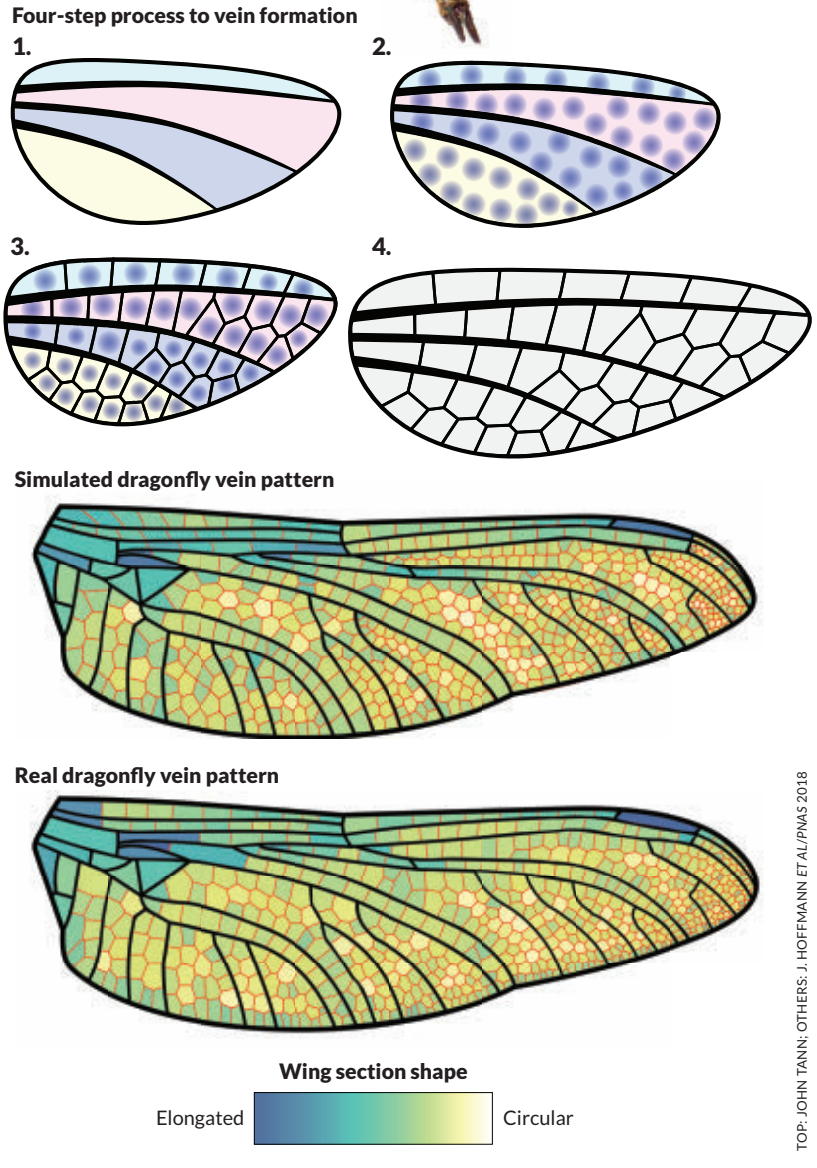
Dainty veins gracing the wings of dragonflies and other insects are like fingerprints: Each wing has a distinct pattern. But scientists don't know how those patterns come to be. Now, by characterizing the patterns of 468 wings from 232 species of dragonflies and damselflies, a study finds that math can explain how the veins form the complex designs.

Veins provide structural support to wings. Long, relatively straight primary veins are found in the same locations on the wings of each member of a species. But smaller secondary veins appear in slightly different places on every wing, sectioning off the appendage into a multitude of tiny pieces.

A four-step simulation re-created vein patterns, researchers report in the Oct. 2 *Proceedings of the National Academy of Sciences*. The team began with a scaled-down dragonfly wing to mimic what happens during development. First, the placement of primary veins divided the wing into regions (No. 1 in top illustration, regions indicated by colors). Then, the team randomly selected evenly spaced locations, termed "inhibitory centers" (2, centers marked with dots). In a real insect, these centers might correspond to places where a chemical cue prevents vein formation.

Researchers then selected locations for secondary veins via a mathematical mechanism called a Voronoi tessellation. It sections off a region around each center such that every spot inside a section is closer to its inhibitory center than to any other (3). Finally, the wing grows and stretches the sections, elongating some of them (4).

Simulated dragonfly wings had sections that largely matched those of real wings in shape and size (example at right; primary veins are in black, secondary veins in red). — *Emily Conover*



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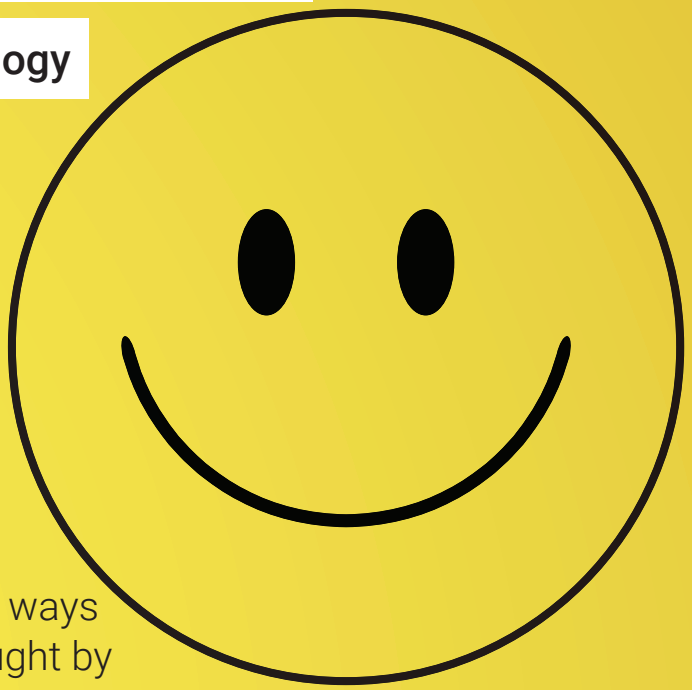
Catherine Sanderson
Ph.D., Princeton University
Professor, Amherst College



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* This offer is valid in the United States (and Puerto Rico) except in TX, FL, CO, OK, RI, NH, WV, OR, SC, VA, CA and ID. These state residents will be charged one cent ($.01) + shipping & processing for the item. Void where prohibited or restricted by law. Offer subject to state and local regulations. Not valid with any other offers and only while supplies last. This offer is limited to one item per shipping address.

† *Free is only for customers using the offer code versus the price on Stauer.com without your offer code.*