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MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ NOVEMBER 23, 2019

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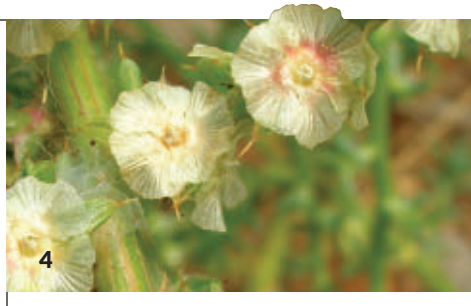
Features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News


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Departments

COVER The slogan U=U means a brighter future for people with HIV who take their medications. *Matthew Rakola*

FROM TOP: THE BALBUSSO TWINS; FOREST AND KIM STARR/STARR ENVIRONMENTAL, BUGWOOD.ORG (CC BY 3.0 US); PERSON HUANG

Problem solving and the power of humankind

In 1983, AIDS was a death sentence. The HIV virus had just been identified as the cause of a terrifying disease that was killing young, previously healthy people. Even though scientists had determined that the disease could not be spread by casual contact, people with HIV were shunned. In 1985, 13-year-old Ryan White was barred from his Indiana middle school because he had contracted the virus through a blood transfusion to treat hemophilia. Researchers around the world raced to come up with a way to stop the virus, but the death toll kept rising.

Slowly, the global effort to combat the virus started to pay off. Today, more than a million people in the United States are living with HIV, and most of them can look forward to long, productive lives if they get treatment. That amazing turnaround is due to the invention of antiretroviral drugs that can suppress the virus in a person's body to the point that the virus is undetectable. People with undetectable HIV won't get sicker as long as they take medication, and can't transmit HIV sexually. People who are at risk of infection can take medications that largely block transmission. HIV is now preventable.

To those of us who lived through the first horrible decades of the HIV epidemic and saw friends die, the fact that people can live a normal life with HIV is astonishing. But this triumphant tale of science is awaiting its final chapter.

As *Science News* biomedical writer Aimee Cunningham explains in this issue, many people don't have access to these lifesaving drugs, despite public health efforts to provide them (Page 16). She examines efforts under way in Washington, D.C., to reach the 22 percent of residents infected with HIV who aren't getting treatment. The final battle against HIV will be fought not by virologists and biochemists, but by community organizers and public health nurses.

From a vast battle against a global scourge, this issue's second feature turns to a far quieter challenge — the story of a woman who helped define the limits of mathematical understanding in the 20th century.

Freelance writer Evelyn Lamb profiles Julia Robinson, an American mathematician who devoted much of her life to solving Hilbert's 10th problem (Page 22). Robinson was honored as the first woman to be elected to the mathematics section of the National Academy of Sciences, the first female president of the American Mathematical Society and as a MacArthur awardee — even though she was denied a faculty position for decades. I would struggle to describe Robinson's work, but Lamb easily overcomes that challenge. I hope you'll be as delighted as I was by this exploration of the life of a singular thinker. — *Nancy Shute, Editor in Chief*

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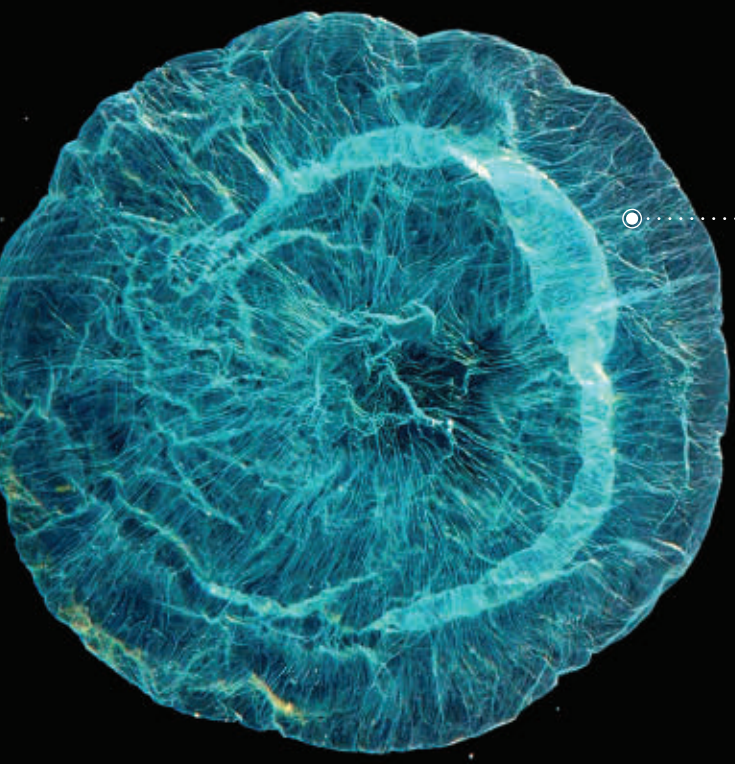

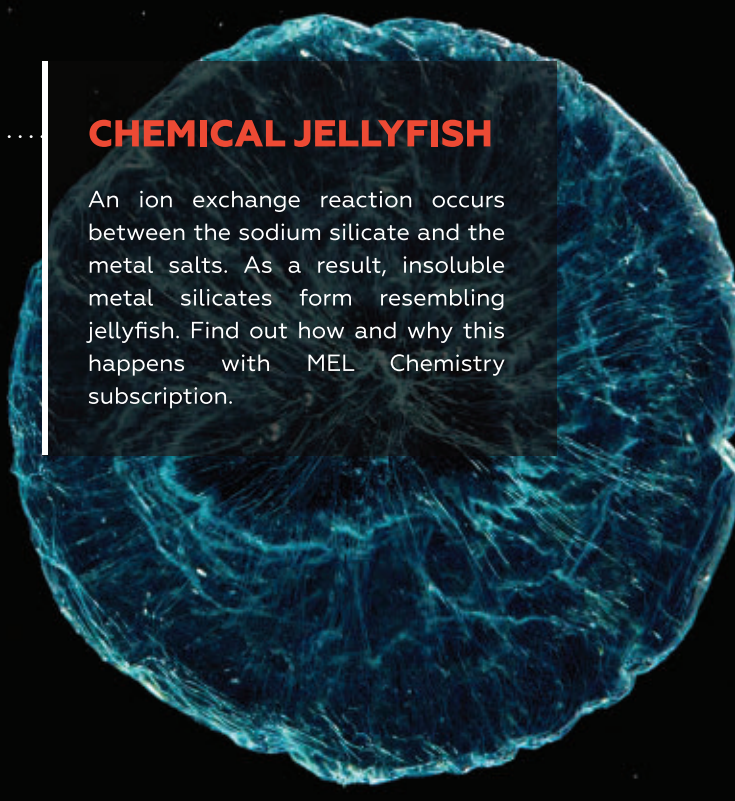

CHEMICAL JELLYFISH

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Excerpt from the November 15, 1969 issue of *Science News*

50 YEARS AGO

Earth's cooling climate

The average temperature for the entire Earth rose gradually from the 1880s until the early 1940s. At that time, a cooling trend suddenly set in which is continuing today.... The amount of dust and other particulate matter in the atmosphere has increased dramatically in recent decades, a change that could counteract the thermal effect of carbon dioxide buildup.

UPDATE: From 1940 to about 1975, the average global surface temperature decreased by about 0.1 degrees Celsius, interrupting a decades-long warming trend even as carbon emissions continued to rise. Many scientists thought the cooling trend was possibly caused by sulfate particles from the burning of fossil fuels that can scatter sunlight and reduce atmospheric warming (*SN: 11/21/09, p. 5*). That hunch proved correct: When the United States and other countries began to lower sulfur emissions in the 1970s to reduce acid rain and respiratory illnesses, the cooling ended abruptly. Since 1975, the average global temperature has risen by about 0.6 degrees C.

When mature and dry, *Salsola* plants separate from their roots and roll around to spread their seeds, forming tumbleweeds.

IT'S ALIVE

Tumbleweeds: Old West versus science fiction

Spotting a tumbleweed doesn't necessarily mean you're anywhere near the O.K. Corral.

Those dried-up, gray and brown tangles of *Salsola* plants have blown through many a Western movie, but they actually aren't all that Western. You can find *S. tragus* in at least 45 U.S. states, including Louisiana, Maine and Hawaii. And that tumbleweed species isn't even native to North America, says evolutionary ecologist Shana Welles of Chapman University in Orange, Calif.

When the plant arrived on the continent over a century ago, it was not welcome. An 1895 agricultural bulletin blames the arrival on "impure" flaxseed brought from Russia to South Dakota during the 1870s. From there, the adaptable *S. tragus* rode the rails, surviving a range of climates and thriving in places like California's Central Valley. "I definitely have stood next to ones that were taller than me," says Welles, who is 5 feet, 8 inches tall.

These rosettes on a tumbleweed branch are immature fruits, forming from the plant's flowers.

The plants are more famous dead than alive. "The flowers look like almost nothing," says Welles, who did her Ph.D. on tumbleweeds. The lentil-sized fruits do have a certain botany-geek charm, though. Each one grows papery, sometimes pinkish flares of tissue called fruit wings.

In its one year of life, a single *S. tragus* plant can create more than 100,000 of those fruits, which are crucial to understanding the big hairball-like tangles. When fruits and seeds form, the plant grows a "break here" tissue layer that weakens the main stem at the base. Wind then snaps off the whole branching architecture to blow where it will. "There is no living tissue from the mother plant when it's tumbling," Welles says. A tumbleweed is just a maternal corpse giving her living seeds a chance at a good life somewhere new.

In North America, *S. tragus* has had improbable offspring. Never mind that the other parent of some of those progeny is *S. australis*, a different species with only half as many chromosomes. (It invaded, perhaps from Australia or South Africa.) Mismatching chromosome numbers can be a deal breaker for animals looking to mate, but plants have their ways. When *tragus* met *australis* sometime in the last century, the latter just added an extra copy of its DNA, and the numbers worked out. The species *S. ryanii* was born.

Welles wondered if the newbie plant was a super-tumbler. Biologists have predicted that such hybrids should grow with extra vigor. Perhaps. In one of two years of experiments, the cross-species tumbleweeds outgrew their parent species, Welles and geneticist Norman Ellstrand of the University of California, Riverside reported July 13 in *AoB Plants*. Tumbleweeds and their genetics may be less at home in tales of the gunslinger West than in a sci-fi opera of romance at first contact. — *Susan Milius*

FROM TOP: LUTSENKOLARISSA/SHUTTERSTOCK; FOREST AND KIM STARR/STARR ENVIRONMENTAL. BUGWOOD.ORG (CC BY 3.0 US)

HOW BIZARRE

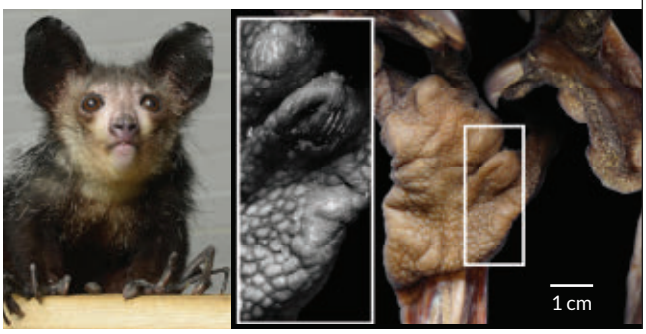
Aye-aye hands have six digits

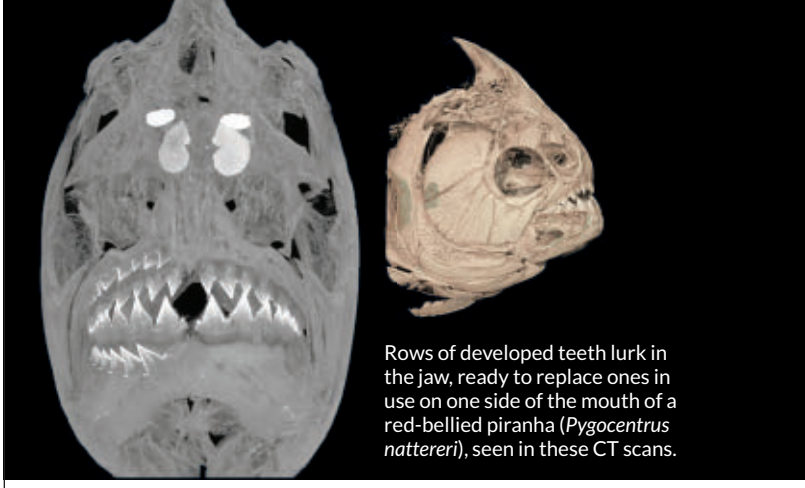
Already considered unusual for their large cartoonish ears and continuously growing incisor teeth, aye-ayes just got weirder, with the discovery of a sixth "finger" on each hand.

The nubby little "pseudothumb," made of bone and cartilage, carries its own distinctive fingerprint. And the digit, manipulated by three muscles, can move in three directions. That may help aye-ayes (*Daubentonia madagascariensis*) grip objects or branches, researchers report online October 21 in the *American Journal of Physical Anthropology*.

It's the first time a pseudothumb has been found on any primate. The researchers speculate that the sixth digit may compensate for the Madagascar lemurs' other fingers, which are thin and highly specialized, including an especially long, skinny finger that has a ball-and-socket joint. The lemurs hunt by tapping that finger on dead and rotting wood before using echolocation to find bugs hiding inside. Aye-ayes then bite a hole in the wood and use the finger to fish out bugs and grubs from within. — *Sofie Bates*

Aye-ayes have a sixth digit, a pseudothumb of bone and cartilage (shown in the white box at right and enlarged in the inset at center). The digit has a distinctive fingerprint and three muscles that move it.





Rows of developed teeth lurk in the jaw, ready to replace ones in use on one side of the mouth of a red-bellied piranha (*Pygocentrus nattereri*), seen in these CT scans.

RETHINK

Piranha teeth aren't all that unique

When it comes to scary teeth, piranhas' are among the most fearsome. The razor-sharp chompers strip prey's flesh with the ease of a butcher's knife.

In a process that may avoid dulling, the fish lose all teeth on one side of the mouth at once, with a fresh set growing in five days later. The same then happens on the other side of the jaw months later. Scientists thought that trait was unique to piranhas, and evolved as the fish adapted to a diet of scales, fins and flesh.

But it turns out the carnivorous fish share this trait with their plant-eating cousin, the pacu, suggesting that this tooth-replacement strategy evolved in the herbivorous ancestors of piranhas and pacus, scientists report in the September *Evolution & Development*.

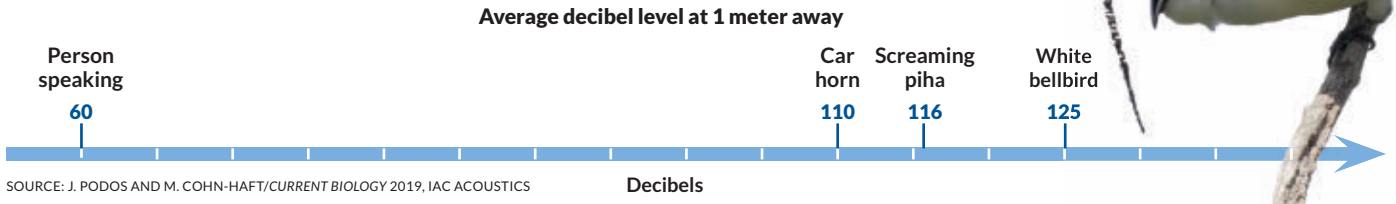
Micro CT scans of 93 piranha and pacu museum specimens revealed developed teeth embedded in the jaw beneath teeth that had already emerged on one side of the mouth. Mature teeth in both fish form sawlike blades that lock together as a unit. A microscopic look at jaw tissue showed tiny tooth buds developing along the opposite jaw at the same time.

Cycling through sets of teeth, instead of replacing them one at a time, may help the fish distribute the wear and tear from chewing. — *Priyanka Runwal*

THE -EST

Make some noise! White bellbirds do

The white bellbirds of the Amazon are now the bird species with the loudest known mating call. A male reaches an average 125 decibels at the loudest point in one of his songs (chart below), blasted in the face of a nearby female. These bellbirds (*Procnias albus*) beat the 116 decibel average max of the previous record-holder — the screaming piha (*Lipaugus vociferans*) of the Amazon, scientists report in the Oct. 21 *Current Biology*. White bellbirds, weighing about 250 grams, appear to be built for making a riot, with thick abdominal muscles and beaks that open extra wide. But the birds can't hold a note for long. Their loudest call sounds like two staccato beats of an air horn. Screaming piha songs build gradually. — *Sofie Bates*



SOURCE: J. PODOS AND M. COHN-HAFT/*CURRENT BIOLOGY* 2019, IAC ACOUSTICS

CLOCKWISE FROM TOP: MATTHEW KOLMANN/GWU; ANSELMO D'AFFONSECA; DAVID HARING/DUKE LEMUR CENTER; ADAM HARTSTONE-ROSE

HUMANS & SOCIETY

Health care algorithm is racially biased

Simple tweaks could eliminate disparities in access to care

BY SUJATA GUPTA

A widely used algorithm that helps hospitals identify patients who could benefit most from access to special health care programs is racially biased, a study finds.

Eliminating bias in that algorithm could more than double the percentage of black patients automatically eligible for specialized programs aimed at reducing complications from chronic health problems, such as diabetes, anemia and high blood pressure, researchers report in the Oct. 25 *Science*.

This work "shows how once you crack open the algorithm and understand the sources of bias and the mechanisms through which it's working, you can correct for it," says Stanford University bioethicist David Magnus, who wasn't involved in the study.

To identify patients who should receive extra care, health care systems in the last decade have come to rely on machine-learning algorithms, which study past examples and identify patterns to learn how to complete a task.

The top 10 health care algorithms on the market — including Impact Pro, the one analyzed in the study — use patients' past medical costs to predict future costs. Predicted costs are used as a proxy for health care needs, but spending may not be the most accurate metric. Even when black patients are as sick as or sicker than white patients, research shows, black patients spend less on health care, including doctor visits and prescription drugs. That disparity exists for many reasons, including unequal access to medical services and a historical distrust of health care providers. That distrust stems in part from events such as the Tuskegee experiment, in which hundreds of black men with syphilis were denied treatment.

As a result of this faulty metric, "the wrong people are being prioritized for these [health care] programs," says study coauthor Ziad Obermeyer, a machine-learning and health policy expert at the University of California, Berkeley.

Concerns about bias in machine-learning algorithms — which help diagnose diseases and predict criminal activity, among other tasks — are not new (*SN: 9/16/17, p. 26*). But isolating sources of bias has been challenging, as researchers asking these questions seldom have access to data used to train algorithms.

However, Obermeyer and colleagues were already working on another project with an academic hospital (which they decline to name) that used Impact Pro and realized that the data used to get that algorithm up and running were available on the hospital's servers.

So the team analyzed data on patients with primary care doctors at that hospital from 2013 to 2015 and zoomed in on 43,539 patients who self-identified as white and 6,079 who identified as black. The algorithm had given all patients, who were insured through private insurance or Medicare, a risk score based on past health care costs.

Patients with the same risk scores should, in theory, be equally sick. But the researchers found that black patients with the same scores as white patients had more chronic diseases on average. For risk scores that surpassed the 97th percentile, for example, the point at which patients would be automatically identified for enrollment into specialized programs, black patients had 26.3 percent more chronic illnesses than white patients — or an average of 4.8 chronic illnesses compared with white patients' 3.8. Less than a fifth of patients above the 97th percentile were black.

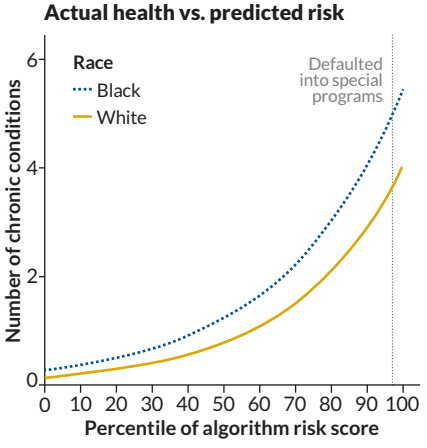
Obermeyer likens the biased assessment to patients waiting in line to get care. Everyone lines up according to risk score. But "because of the bias," he says, "healthier white patients get to cut in line ahead of black patients, even though those black patients go on to be sicker."

When the team ranked patients by number of chronic illnesses instead of past health care spending, black patients went from 17.7 percent of patients above the 97th percentile to 46.5 percent.

Obermeyer's team is partnering with Optum, the maker of Impact Pro, to improve the algorithm. The company replicated the new analysis and compared chronic health problems among black and white patients in a national dataset of almost 3.7 million insured people. At all risk scores, black patients had more chronic conditions than white patients, a combined excess of almost 50,000 conditions — evidence of the racial bias. Retraining the algorithm to rely on past health care costs and other metrics, including preexisting conditions, reduced the disparity in chronic health conditions between black and white patients at each risk score by 84 percent.

Because the infrastructure for specialized programs is in place, this study shows that fixing algorithms could quickly connect the neediest patients to programs, says Suchi Saria, a machine-learning and health care researcher at Johns Hopkins University. "In a short span of time, you can eliminate this disparity." ■

Unequal treatment To identify patients most in need of special health programs, a popular algorithm uses past medical costs to generate risk scores. But at the same level of predicted risk, black patients have more chronic illnesses on average than white patients.



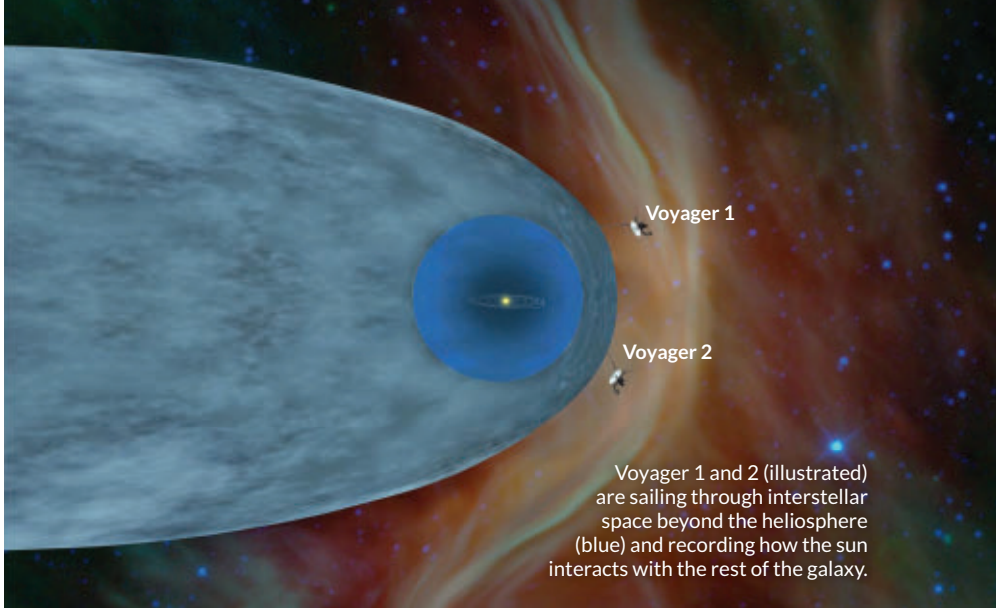
Z. OBERMEYER *ET AL/SCIENCE* 2019

ATOM & COSMOS

Voyager 2 inspects interstellar space

Spacecraft reveals dynamic nature of solar system's edge

BY CHRISTOPHER CROCKETT



Voyager 1 and 2 (illustrated) are sailing through interstellar space beyond the heliosphere (blue) and recording how the sun interacts with the rest of the galaxy.

JPL-CALTECH/NASA

Humankind's second ambassador to interstellar space has reported back from the frontiers of the solar system — with the message that the border of the sun's territory is a complex and ever-changing place.

Late last year, NASA's Voyager 2 spacecraft broke through the heliopause, the boundary where the solar wind gives way to the plasma that permeates the galaxy. Six years earlier, its sister probe, Voyager 1, made its own heliopause crossing (*SN: 12/28/13, p. 27*). Now, the combined results of these two journeys, published November 4 in several papers in *Nature Astronomy*, offer the most detailed look yet at this largely unexplored region of space.

These two robotic explorers "are taking humankind to astonishing new places that 60 years ago we never imagined" going, says Gary Zank, a space physicist at the University of Alabama in Huntsville who was not involved with this research.

The view from Voyager 2 changed on November 5, 2018, when the craft was about 17.8 billion kilometers from the sun — 119 times farther away than Earth is — and the density of the surrounding plasma jumped by about a factor of 20. The steady stream of low-energy atomic particles from the sun dropped away, replaced by a barrage of far more energetic particles known as cosmic rays. These changes told researchers that Voyager 2 had left the sun's protective magnetic bubble, 41 years after beginning its sight-seeing expedition across the solar system.

"It's been a wonderful journey," mission lead Edward Stone, a planetary scientist at Caltech, said October 31 in a news conference about the findings.

Voyager 1 — which launched in 1977, the same year as Voyager 2 — had gotten there first, but Voyager 2 had an advantage: a working sensor that measured the speed, temperature and density of the surrounding plasma. "That makes a huge difference in providing us with a significantly greater level of understanding" of how the solar plasma intermingles with the interstellar medium, Zank says. Voyager 1's sensor had shut down long before the craft reached the heliopause, so researchers had to infer many plasma properties from other measurements, which might not have been as accurate as a direct measurement.

Despite encountering the heliopause at different times and locations — the two spacecraft are farther from each other than each is from the sun — some things looked similar. The magnetic field looked pretty much the same on the inside and the outside of the boundary: Somehow, contrary to expectations, the sun's magnetic field lines up nearly perfectly with the local galactic field. "We could dismiss that as coincidence in one case, but we can't do that twice," study coauthor Leonard Burlaga of NASA's Goddard Space Flight Center in Greenbelt, Md., said in the news conference.

There were notable differences in the two crossings as well. Voyager 1 sailed through a largely stagnant solar wind for two years before reaching the heliopause, whereas the stream of solar particles alongside Voyager 2 was quick and steady right up to the boundary. Voyager 1 encountered galactic material intruding into the solar bubble, while Voyager 2 instead witnessed solar particles leaking far out into interstellar space. "We're seeing the same beast, but it's behaviorally quite different," Zank says.

Figuring out what many of these results mean will be challenging. The probes interrogated two boundary spots separated by nearly 24 billion kilometers. But this boundary is always changing. It breathes in and out in sync with the sun's 11-year activity cycle, and eruptions on the sun's surface make their way out to the heliopause and stir things up. "That complicates all these stories," Stone said.

New data will have to wait. So far, four spacecraft have made it this far into space — but the Voyagers are the only ones sending back reports. Pioneer 10 and 11, launched in 1972 and 1973, stopped working years ago. New Horizons, which paparazzied Pluto in 2015 (*SN: 12/26/15, p. 26*), recently detected a possible glow of hydrogen gas at the solar system's edge (*SN: 9/15/18, p. 10*). But that craft may run out of power before it reaches the heliopause. In the meantime, NASA is looking into launching a dedicated interstellar probe as early as the 2030s.

For now, the Voyagers are humankind's eyes and ears in interstellar space, and the mission team estimates that both spacecraft have about five years of service left. Electrical power comes from heat generated by a nugget of plutonium in each, and as the probes cool, they lose the ability to keep their instruments running. When asked if he expected the Voyagers to last this long, Stone replied: "We're certainly surprised." ■

ATOM & COSMOS

Strontium found in neutron star crash

Discovery bolsters idea that the collisions make heavy elements

BY MARIA TEMMING

For the first time, astronomers have definitively ID'd a specific heavy element forged by a neutron star merger.

Evidence for strontium appeared in the wavelengths of light, or spectra, of the afterglow from the first observed neutron star smashup (*SN: 11/11/17, p. 6*). The strontium discovery, reported in the Oct. 24 *Nature*, offers the most direct evidence yet that these collisions trigger a chain of reactions, called the r-process, thought to have created many of the elements in the universe heavier than iron.

Theories have long predicted that about half of the universe's heavy elements, such as silver and gold, were formed by the r-process, in which atomic nuclei snatch neutrons from their surroundings and radioactively decay to become heavier elements. No one had directly seen the r-process happening in a specific celestial object or event until 2017, when astronomers saw the merger of two neutron stars, the superdense remnants of exploded stars. Spectral analyses indicated that the collision had created a hodgepodge of heavy elements characteristic of the r-process.

But those investigations didn't pinpoint specific elements. That's because researchers were examining relatively heavy r-process elements, whose complex atomic structures can generate millions of spectral features that haven't all been identified yet, says astrophysicist Darach Watson of the University of Copenhagen.

Relatively light strontium, however, has a simple atomic structure that generates a few strong spectral marks that have been measured in the lab. By expanding the analysis to consider this and other r-process elements, Watson and colleagues identified strontium's fingerprint in spectra collected with the Very Large Telescope in Chile in the first several days after the merger.

Strontium's presence "does tell us something interesting about the composition of the material that was released during the merger," says Brian Metzger, a Columbia University astrophysicist who was not involved in the work.

The material must have had an unusually low neutron density compared with matter typically found in a neutron star. An extremely neutron-rich environment would have created much heavier elements, with many neutrons in their nuclei, rather than lightweights like strontium. The material probably underwent some other interaction — like bombardment with subatomic particles called neutrinos from the merger — that destroyed neutrons, Metzger says. ■

ATOM & COSMOS

Strange tempests spotted on Saturn

Scientists see midsize storms on the planet for the first time

BY MARIA TEMMING

Saturn saw some weird weather last year. Telescope images reveal a newfound type of storm activity that raged near Saturn's north pole in 2018, researchers report October 21 in *Nature Astronomy*.

Until now, astronomers had seen only two kinds of Saturnian storms: relatively small ones about 2,000 kilometers across that appear for a few days and Great White Spots that are 10 times as large and last for months. The newly seen weather disturbance was a series of four midsize storms. Each was several thousand kilometers across and lasted between about 1.5 weeks and seven months.

Saturnian storms are thought to originate in clouds hundreds of kilometers below the planet's visible upper cloud cover. Studying such storms can offer a window into deep atmospheric goings-on that aren't directly observable, says Agustín Sánchez-Lavega, who studies planetary atmospheres at the University of the Basque Country in Bilbao, Spain.

Sánchez-Lavega and colleagues analyzed hundreds of images taken by amateur astronomers, as well as pictures from Spain's Calar Alto Observatory and NASA's Hubble Space Telescope. From March to October 2018, four bright spots appeared in Saturn's atmosphere, between the latitudes of 67° N and 74° N.

Computer simulations indicate that each storm required about 10 times as much energy as a small storm to get going, but only about one-hundredth the energy required to brew up a Great White Spot.

The timing of the storm sequence hints at a failed Great White Spot. Such planetary-scale storms have been seen six times since 1876; those few data points seem to indicate that Great White Spots form around the same latitudes once every 60 years or so. The last time Saturn had a far-north Great White Spot was in 1960. Perhaps a 2010 Great White Spot farther south siphoned so much atmospheric energy that there was only enough left to fuel a few middling storms in 2018, Sánchez-Lavega says.

Planetary scientist Robert West is skeptical. Gas swirling in Saturn's atmosphere at different latitudes tends to stay in its own lane. West, of Caltech and NASA's Jet Propulsion Laboratory in Pasadena, Calif., suspects that the storms were not a failed Great White Spot, but "a whole different thing." ■

In 2018, telescopes found a series of storms, each several thousand kilometers wide, near Saturn's north pole (white spots at arrows). Not all of the storms are visible in each image.

A. SÁNCHEZ-LAVEGA *ET AL*/*NATURE ASTRONOMY* 2019

LIFE & EVOLUTION

How spider webs resist rotting

Bacteria key to decomposition can't get to the silk's nitrogen

BY PRIYANKA RUNWAL

From spooky abandoned houses to dark forest corners, spider webs have an aura of eternal existence. In reality, the silk threads last hours to weeks without rotting. The material endures because bacteria that would aid decomposition are unable to access the vital nutrient nitrogen in the silk, a study suggests.

Previous research had hinted that spider webs have antimicrobial properties that outright kill bacteria. But subjecting the webs of three spider species to four types of bacteria revealed that the spiders use a resistance strategy instead, researchers report online October 23 in the *Journal of Experimental Biology*.

The scientists "challenge something that has gone significantly overlooked," says Jeffery Yarger, a biochemist at Arizona State University in Tempe. "We just assumed [the silk] has some kind of standard antimicrobial property."

Spiders spin strings of silk to trap food, wrap their eggs and rappel. Webs can sport leaf debris for camouflage amid tree canopies or leftover dead insects for a meal later. These bits and bobs lure bacteria and fungi involved in decomposition to the web, exposing the protein-rich web silks to the microbes.

"But [the microbes] don't seem to affect spider silk," says study coauthor Dakota Piorkowski, a biologist at Tunghai University in Taichung, Taiwan.

The researchers placed threads from three tropical spider species — giant golden orb weaver (*Nephila pilipes*), lawn wolf spider (*Hippasa holmerae*) and dome tent spider (*Cyrtophora moluccensis*) — in petri dishes and grew four types of bacteria in perpendicular lines across the silk. "If the silk has antibacterial properties, you should see no growth between the piece of silk and ... bacteria," Piorkowski says.

There was no evidence of a "clear zone" of dead bacteria in spots where the bacteria came in direct contact with the silk, the researchers found. The team tested if the silk kept bacteria at bay by blocking them from nitrogen reserves. When extra nitrogen was applied to all three types of spider silk via nutrient solutions, bacteria readily grew. So bacteria seem capable of growing on and possibly decomposing the silk, as long as the threads aren't the only source of nitrogen. The researchers hypothesize that an outer coating of fat or complex protein on the silk may block bacteria's access to nitrogen.

Biologist Randy Lewis of Utah State University in Logan cautions against ruling out antibacterial features in all spider silks. Tarantulas' underground webs, for example, which exist in environments rife with microbes compared with webs made by aerial web-spinning spiders, may need the extra protection, he says. ■

A lawn wolf spider's web is long-lasting because it stops bacteria from getting to nitrogen in the silk threads, researchers contend.

LIFE & EVOLUTION

Egg color linked to a bird's climate

Darker shells in colder areas may help keep chicks warm

BY JONATHAN LAMBERT

Bird eggs come in a dizzying array of colors. But that diversity follows a simple pattern — the colder the climate, the darker the egg, a new study shows.

Darker eggs absorb more heat than lighter ones, which could help developing chicks stay warm while their parents forage, scientists report October 28 in *Nature Ecology & Evolution*.

Biologists have long tried to suss out the selective forces that shape and color a specific species's eggs. Those forces include keeping eggs hidden from predators, protecting eggs from bacteria, signaling egg quality and maintaining warmth. But scientists weren't sure whether any of these factors were important in determining egg diversity in birds in general around the world.

Using museum collections, researchers compiled data on eggs from 634 species from 36 of the 40 orders of living birds. The team then analyzed the data against a global map. Egg color and brightness were closely linked with average annual temperature, even after correcting for egg color similarities between closely related species.

Birds in "the far north, which tends to be colder, had darker, browner eggs," says study coauthor and biologist Daniel Hanley of Long Island University Post in Brookville, N.Y. Eggs became lighter and slightly bluer closer to the equator, though egg colors were generally more variable in the tropics.

The trend may reflect adaptation to the cold: A dark egg, like a dark car parked in the sun, absorbs more thermal radiation from the sun than lighter eggs do. To test the idea, the researchers exposed white, brown and blue chicken eggs to direct sunlight and tracked heat retention. Brown eggs warmed up faster and cooled down more slowly than the lighter eggs.

"In the Arctic, parents have to go out to forage and get back to their eggs quickly," Hanley says. "If you can buy them five extra minutes, that can actually be really beneficial for them."

Biologist Mary Caswell Stoddard of Princeton University welcomes the study's attention to the role of egg color in temperature regulation. "That's part of what makes this study, and the discovery that birds living in colder habitats tend to lay darker eggs, so exciting," she says, though undoubtedly there are other selective factors at play. ■

PERSON HUANG

The rotifer *Rotaria rotatoria* (shown in a microscope image) produces a molecule that paralyzes larval worms that cause schistosomiasis.

LIFE & EVOLUTION

Molecule stops parasitic worms

Aquatic invertebrates could help combat schistosomiasis

BY SOFIE BATES

Tiny invertebrates, once a nuisance to scientists studying schistosomiasis, may actually hold the key to fighting the spread of the tropical disease.

Schistosomiasis, also known as snail fever, is caused by several species of freshwater parasitic worms that penetrate human skin to enter the blood. The parasites must first infect aquatic snails before developing into larvae, the life cycle stage that infects people. For decades, scientists have studied the parasites as they infested snails and have grown frustrated when specimens were contaminated by microscopic invertebrates called rotifers. Somehow, the presence of rotifers paralyzes the larvae, preventing them from infecting other organisms.

Now, scientists have identified a molecule secreted by rotifers as the cause of paralysis. Larvae of *Schistosoma mansoni* worms became paralyzed within 30 seconds of being submerged in water containing the molecule. Paralyzed larvae could not infect mice whose tails were placed in the water, the team reports October 17 in *PLOS Biology*.

S. mansoni is one of several species that causes schistosomiasis, which affects more than 200 million people worldwide and can cause fever, liver damage, abdominal pain and anemia. The worms live inside blood vessels, feasting on proteins and laying eggs that hatch and travel through the bloodstream. Many of the eggs end up in the liver — where they cause inflammation — while some are excreted in feces. Other people can become infected by coming into contact with water contaminated by those feces.

In the new study, researchers grew the rotifer species *Rotaria rotatoria*. When *S. mansoni* larvae were put in the same water in which rotifers had grown, the larvae couldn't move, suggesting that the rotifers had secreted something that caused paralysis. The researchers identified a molecule, which they named schistosome paralysis factor, or SPF, as the likely cause.

Mice exposed for 30 minutes to worm-infested water without SPF picked up an average of 83 larval worms, and the livers of those mice had holes where worm eggs had embedded. But when the same water contained SPF, mice didn't pick up any worms, and mouse livers looked normal.

It's unclear why rotifers have SPF or how it causes paralysis. But further study of the molecule, part of which resembles the neurotransmitter serotonin, may lead to new ways of treating or preventing schistosomiasis. "Hopefully, we can come up with ways to prevent people from getting infected," says study coauthor and developmental biologist Phil Newmark, a Howard Hughes Medical Institute investigator at the University of Wisconsin–Madison.

The medication used to treat schistosomiasis, called praziquantel, kills adult worms but not larvae. Some researchers have voiced concern about possible drug resistance. "Identifying new targets and molecules is essential to ensure we have new drugs in the pipeline," says Jonathan Marchant, a cell biologist at the Medical College of Wisconsin in Milwaukee who was not involved in the study. The research illustrates how chemicals made by animals and plants have the power to supplement human medicine, Marchant says. "It's an important reminder of the power of nature's synthetic arsenal." ■

ATOM & COSMOS

Planetary safety rules are outdated

Policies to avoid contamination need nuance, NASA panel says

BY MARIA TEMMING

Some policies for protecting the moon, Mars and other places in the solar system from contamination by visiting space probes, or even humans, may be too strict.

That's the conclusion of a 12-expert panel commissioned by NASA to review voluntary international guidelines for keeping space missions from polluting other worlds with earthly life, and vice versa. These guidelines are recommendations from the international scientific organization COSPAR, which for decades has set and revised policies for space-faring nations (*SN: 1/20/18, p. 22*).

With NASA planning to send a sample-collection mission to Mars next year, and countries and private companies preparing for trips to the moon, guidelines "are in urgent need of updating," Thomas Zurbuchen, associate administrator for NASA's Science Mission Directorate, said October 18 in a news conference coinciding with the review's release. "We want to respect the integrity of the places we go and protect our home planet" from contaminants that may be brought back. But current rules may make future missions unnecessarily complex or expensive.

For instance, current guidelines treat the whole moon as a possible site to investigate the origins of life. But apart from a few regions, such as the lunar south pole, which may have water ice, the moon holds little interest for studying the chemical evolution of life, panel chair and planetary scientist Alan Stern of the Southwest Research Institute in Boulder,Colo., said in the news conference. Many places may not need protection.

At least one astrobiologist, however, cautions against relaxing guidelines too much. Spacecraft landing in areas deemed sterile could still contaminate areas that are potentially interesting for astrobiology, says John Rummel of the

NEWMARK LAB

SETI Institute in Mountain View, Calif. If a probe crashes on the moon's surface, "you end up with material that's taken into the lunar atmosphere and deposited in the cold traps at the south and north anyway," he says. "You don't even have to land at the south pole to affect [it]."

The review panel also recommended reassessing contamination risks across Mars. Mars missions have been designed to meet rigorous sterilization standards that often involve exposing spacecraft components to heat, chemicals or harsh radiation. But studies have suggested that Earth microbes probably would struggle to survive on many parts of Mars. So such deep cleaning may not be needed.

Specific areas of Mars should be identified as high-priority zones for seeking past or present life, the report states. Other areas could be designated as human exploration zones, where microbes brought by astronauts wouldn't pose such a problem.

Cornell University astrobiologist Alberto Fairén welcomes adding nuance to the guidelines. In *Advances in Space Research* in March, he and colleagues recommended a few high-priority astrobiology zones on Mars, including lakes of liquid water possibly hidden under ice.

> "Earth and Mars have been exchanging meteorites for billions of years with absolutely no planetary protection."
>
> ALAN STERN

Rummel takes a more conservative view. He acknowledges that there are probably places on Mars where Earth microbes won't grow. But "we don't know enough about Mars, in my opinion, [to categorize] most of it."

The report also considers rules for bringing samples home. Current guidelines stipulate that Mars rocks should be sterilized or undergo biohazard testing before they can be handed out for analysis. Such precautions "lack a fully rational basis," the report states.

"Earth and Mars have been exchanging meteorites for billions of years with absolutely no planetary protection," Stern said.

NASA will consider the report in updating its standards, but the process for incorporating the suggestions into COSPAR guidelines "is not well-defined," the report states. ■

BODY & BRAIN

Sleep may trigger a wash of the brain

Waves of cerebrospinal fluid could clean out harmful proteins

BY LAURA SANDERS

Every 20 seconds, a wave of fresh cerebrospinal fluid rolls into a sleeping person's brain. These slow, rhythmic blasts, described for the first time in the Nov. 1 *Science*, may help explain why sleep is so important for brain health.

Studies of lab animals have shown that the fluid, also called CSF, can wash harmful proteins, including those implicated in Alzheimer's disease, out of the brain. The new results give heft to the idea that a similar power wash happens in people.

Researchers studied 13 healthy, young people in an MRI scanner as they fell into non-REM sleep, the type of slumber that takes up most of the night. At the same time, the scientists monitored different sorts of activity in participants' heads. Electrodes measured the activity of large collections of nerve cells, and functional MRI measured the presence of oxygenated blood that keeps those nerve cells fed.

By using a form of rapid fMRI, the team also measured the movements of CSF in the brain. This fMRI revealed waves of fresh CSF flowing rhythmically into the sleeping brains, a pattern that was obvious — and big, says study coauthor Laura Lewis, a neuroscientist and engineer at Boston University. "I've never had something jump out at me to this degree," she says. "It was very striking."

Awake people have small, gentle waves of CSF that are largely linked to breathing patterns. In contrast, the sleep waves were tsunamis that spread in the brain. "The waves we saw during sleep were much, much larger, and higher velocity," Lewis says.

Those CSF waves were tied to other types of waves in the brain, the researchers found. First, a slow wave of nerve cells' electrical activity — the sort that indicates non-REM sleep — swept the brain. Then, levels of oxygen in the brain's blood fell, representing an outflow of blood. And finally, possibly to take the place of the exiting blood, the wave of CSF rolled into the brain.

The study "elegantly links a number of seemingly unrelated topics in neuroscience, including sleep, brain waves, cerebrospinal fluid flow and blood flow, together," says Maiken Nedergaard, a neuroscientist at the University of Rochester Medical Center in New York.

It's not yet clear exactly how the various waves are related to each other. Lewis and colleagues plan on testing whether one event causes the others.

Spotting these powerful CSF waves in the sleeping brain raises the possibility that they clear harmful waste products from the brain (*SN: 7/21/18, p. 22*). Nedergaard and colleagues have found that CSF coming into mice's brains can carry away amyloid-beta, a sticky protein that accumulates in Alzheimer's disease. When mice are asleep, more CSF comes into the brain, and more A-beta gets cleared away. Finding an influx of CSF in sleeping humans "is really a significant move," Nedergaard says.

Studying the strong CSF waves in people with Alzheimer's might reveal new aspects of the disorder, Lewis says. Slow waves of nerve cells' electrical activity during sleep are known to decline with age, and the decline is particularly severe in people with Alzheimer's. As a result, the CSF waves might be diminished in these people, too, Lewis says, an absence that could leave more toxic proteins sticking around. ■

BODY & BRAIN

Alzheimer's may scramble metabolism

Mouse study links the disease, sleep and blood sugar responses

BY LAURA SANDERS

CHICAGO — Wide swings in blood sugar can mess with sleep. Food's relationship with sleep gets even more muddled when signs of Alzheimer's disease are present, a study of mice suggests.

The results, presented in a news conference October 20 at a meeting of the Society for Neuroscience, show that metabolism, sleep and brain health "don't happen in isolation," says neuroscientist Shannon Macauley of Wake Forest School of Medicine in Winston-Salem, N.C.

Macauley and colleagues figured out a way to simultaneously measure how much sugar the brain consumes, the rate of nerve cell activity and how much time mice spend asleep. Injections of glucose into the blood, to mimic food intake, led to changes in the brain: a burst of metabolism, a bump in nerve cell activity and more time awake. A dip in blood sugar, caused by insulin injections, also led to more nerve cell action and wakefulness. "You can have it go up high or go down low, and it was just really bad either way," Macauley says.

The researchers did similar analyses in mice genetically engineered to have one of two key signs of Alzheimer's. Some of the mice had clumps of amyloid-beta protein between nerve cells; others had tangles of tau protein inside nerve cells.

Both groups slept less than normal. And while both types of mice had abnormal reactions to high and low blood sugar, those reactions differed. In mice with A-beta, higher blood sugar led to a slight rise in brain metabolism, but not nearly as much as in a normal mouse. In mice with tau, high blood sugar didn't increase brain metabolism. In both cases, nerve cell activity no longer had big responses to blood sugar.

A-beta and tau "might be affecting the sleep-wake circuit in very different ways," Macauley says.

Globs of amyloid-beta protein (orange in this illustration) between nerve cells alter how mice respond to changes in blood sugar. These globs are a hallmark of Alzheimer's in people.

Neuroscientist Steve Barger of the University of Arkansas for Medical Sciences in Little Rock cautions that some of the findings come from mice engineered to make lots of A-beta quickly. That is "quite distinct from the way that most people get Alzheimer's disease."

Still, sleep often suffers in Alzheimer's patients. Study coauthor and neurologist David Holtzman of Washington University School of Medicine in St. Louis and others have found that sleep problems can precede other symptoms. ■

BODY & BRAIN

Drug's effect on autism questioned

Prozac didn't lessen children's obsessive-compulsive behavior

BY JONATHAN LAMBERT

Prozac, a commonly prescribed medication for children and teens with autism, is no more effective than a placebo at treating obsessive-compulsive behavior, a small study finds.

Those results, published in the Oct. 22 *JAMA*, cast doubt on the widespread practice of prescribing antidepressants known as selective serotonin reuptake inhibitors, or SSRIs, to treat children with autism."We really don't have any good medications that have yet been studied in children with autism for these behaviors," says Ann Neumeyer, medical director of the Massachusetts General Hospital Lurie Center for Autism in Lexington, who wasn't involved in the study.

Autism spectrum disorders encompass a range of symptoms, including obsessive-compulsive behaviors. Individuals can become hyperfocused on ideas or objects and engage in ritualistic behaviors, such as hand-waving or rocking. These symptoms can interfere with everyday functioning.

About half of kids and teens with autism receive medication, and about a quarter to a third of that half are given SSRIs, according to Dinah Reddihough, a pediatrician at Murdoch Children's Research Institute in Melbourne, Australia. "Despite their widespread use, there is no evidence of effectiveness of SSRIs for autism spectrum disorders in children."

Reddihough and colleagues recruited 109 participants for a clinical trial of Prozac, also known as fluoxetine, to test whether the drug was effective for children with autism. Children and teens, ages 7½ to 18, were randomly assigned to receive either a low dose of up to 20 or 30 milligrams per day of fluoxetine or a placebo for four months. Obsessive and compulsive symptoms were tracked before and after treatment.

At first, the fluoxetine group appeared to show a slight easing of symptoms after four months compared with the placebo group. But after controlling for factors including age, sex and the severity of symptoms at the trial's start, the difference vanished. Fluoxetine did no better than the placebo.

The relatively small sample size could have limited the ability to detect a benefit, Neumeyer says. "It's possible that, with higher numbers, they would've found subgroups who benefit from SSRIs." Still, she says, the study helps show that "SSRIs are not the medication clinicians should go to first" for treating obsessive-compulsive behavior in children and teens with autism. ■

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HUMANS & SOCIETY

Humans' maternal origins pinpointed

Controversial study places the motherland in southern Africa

BY BRUCE BOWER

Humankind's maternal roots extend back about 200,000 years to what was then a lush region of southern Africa, a group of scientists claims.

But the question of how, when and where *Homo sapiens* originated remains far from settled, other researchers say.

Examining variations in a type of maternally inherited DNA, the scientists concluded that the founding maternal line of *H. sapiens* arose in what's now Botswana. Then about 130,000 years ago, some members of that group migrated in two waves to East Africa via a vegetated corridor created by increased rainfall, the team reports. Those migrants may have given rise to early herding and farming groups in East Africa.

Another population pulse out of the maternal homeland moved southwest, all the way to the southern tip of Africa, by about 110,000 years ago, geneticist Vanessa Hayes and colleagues report online October 28 in *Nature*. Southern migrants became specialists in hunting and gathering along the coast, the scientists speculate.

"Everyone alive today goes back genetically to one maternal starting point in southern Africa," Hayes, of the Garvan Institute of Medical Research in Sydney, said October 24 in a news conference.

But much is still unknown about human origins. Hayes' team examined only mitochondrial DNA, which represents a tiny fraction of human ancestry, says archaeologist Eleanor Scerri of the Max Planck Institute for the Science of Human History in Jena, Germany.

Ancient folks who possessed forms of mitochondrial DNA that managed to get passed to people today were not the only people living in Africa 200,000 years ago or earlier, Scerri says. So only studies of entire genomes, or at least analyses including nuclear DNA, can provide reliable glimpses of ancient human origins, she argues. In contrast to mitochondrial DNA, nuclear DNA is inherited from both parents.

Researchers will also need to extract DNA from ancient human fossils to determine whether southern African foraging groups today are related to people who lived in the same region, say, 50,000 or 200,000 years ago, says geneticist Sarah Tishkoff of the University of Pennsylvania. And the numbers of East African foragers today are so small that mitochondrial DNA can't resolve the age and location of their maternal roots, leaving a big question mark about humankind's maternal evolution, Tishkoff says.

Taking archaeological, fossil and DNA evidence into account, present-day *H. sapiens* probably originated from mating among human groups all across Africa that had different mixes of skeletal traits (*SN: 12/23/17 & 1/6/18, p. 24*), beginning about 300,000 years ago, Scerri argues.

"It's possible, even likely, that [multiple] geographic centers contributed portions of their heritage to build our genome, which cannot be addressed by mitochondrial diversity alone," agrees Rebecca Cann, a geneticist at the University of Hawaii at Manoa.

But the study provides support for evidence that the roots of human mitochondrial DNA go back to as early as 200,000 years ago in sub-Saharan Africa, Cann says. She and colleagues reported initial evidence for that scenario in 1987. But it was unclear where that maternal line originated and how subsequent migrations from there might have occurred.

Hayes' team studied a rare form of mitochondrial DNA known as L0, which is today largely restricted to the Khoisan people of southern Africa. Khoisan people consist of populations of herder-gatherers and hunter-gatherers who speak languages containing "click" consonants. Researchers have determined that L0 has far-more-ancient roots than other forms of mitochondrial DNA that have been inherited by living people.

The researchers collected L0 mitochondrial DNA from 198 indigenous people living in southern Africa, mainly Khoisan. Adding in previously published samples, Hayes' group analyzed L0 mitochondrial DNA from 1,217 people.

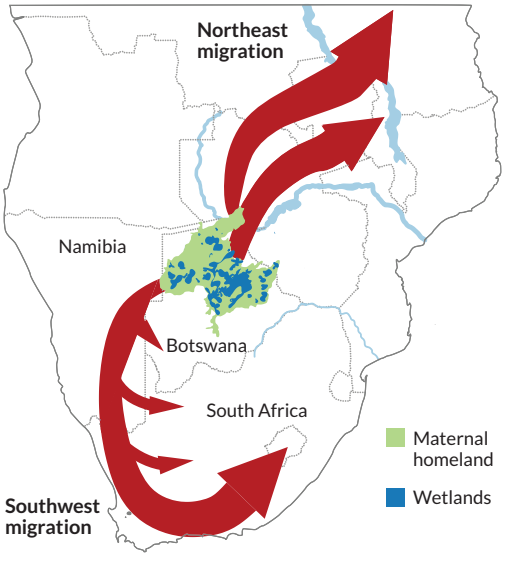
Mitochondrial DNA accumulates changes slowly over many generations. Based on the number of mitochondrial DNA alterations in samples from different parts of southern Africa, the scientists calculated how long ago and approximately where each L0 variant originated.

Comparisons with geologic data and computer simulations of the ancient climate corroborated the genetic evidence for the migrations' timing, the team says.

While the proposed homeland region is more arid and is sparsely populated today, it had small lakes and abundant vegetation that supported a variety of animals along with humans between 200,000 and 130,000 years ago, Hayes says. ■

Leaving home DNA analyses suggest that, around 200,000 years ago, a founding maternal line of *Homo sapiens* emerged in a lush region (green) of what's now Botswana. People then migrated northeast and southwest of that area between 130,000 and 110,000 years ago.

Proposed migrations from the homeland



E.K.F. CHAN *ET AL*/*NATURE* 2019

Derrick "Strawberry" Cox (left) regularly meets with Devonte Paulk in Washington, D.C. Cox is an HIV-positive mentor to people who are newly diagnosed.

MATTHEW RAKOLA

A NEW OUTLOOK FOR AN HIV DIAGNOSIS

For people with HIV, undetectable means untransmittable

By Aimee Cunningham

In October 1995, George Kerr III tested positive for HIV. "I was terrified," he remembers. "I thought my life was over." That year, more than 50,000 people in the United States died from AIDS, the disease that ravages the body when the human immunodeficiency virus goes unchecked. It was the highest number of AIDS deaths the United States would experience in a single year.

Kerr was 29 at the time. He started treatment and suffered through nausea, diarrhea and night sweats. Sometimes, the medication made him pass out. "At one time I was taking 27 pills a day," Kerr says, some with meals, some without. The regimen was so disruptive, sometimes he didn't take his medications as prescribed.

Today, he takes only three pills a day to keep the virus under control. "It's easier," Kerr says. There are even one-pill formulations that combine the drugs necessary to treat HIV. The many available drugs — collectively called antiretroviral therapy, or ART — do more than cut down on pills and side effects. ART is also a kind of prevention (*SN Online: 7/12/16*). There is no cure for HIV, but a person consistently taking

ART can almost make HIV disappear. The virus's presence in the blood becomes so vanishingly small that the virus can't be transmitted sexually. The concept is called undetectable = untransmittable, or U=U, and it has changed everything.

People with HIV who stick to their medications no longer have to fear passing the virus to a sexual partner. "The person that I am seeing today is HIV-negative," says Kerr, a community activist in Washington, D.C. "I know without a doubt that I will not be infecting him." With U=U, he says, HIV-positive people "can have the same dreams and goals as any other person in the world."

George Kerr III, diagnosed with HIV in 1995, says treatments are easier than they used to be.

People who are HIV-negative also have a prevention option in pre-exposure prophylaxis, or PrEP, a combination of antiretroviral drugs that can ward off an infection. Taken regularly, PrEP, sold as Truvada, is highly effective at preventing new infections in those at risk of exposure to HIV (*SN: 11/14/15, p. 14*). In October, the U.S. Food and Drug Administration approved a new PrEP option, called Descovy, but only for certain populations.

If everyone who needs treatment and preventive medicines could take these drugs, "you can theoretically end the epidemic as we know it, and that is our goal," Anthony Fauci, director of the National Institute of Allergy and Infectious Diseases in Bethesda, Md., said during a February news briefing about a new federal initiative against HIV.

But the medications can't subdue HIV while sitting on a shelf. The hard work of taming the epidemic comes in reaching everyone who is positive or at risk, and there are still formidable barriers to surmount. Many people can't access medical care, due to poverty or homelessness. The HIV epidemic in the United States hits some groups harder than others. Men who have sex with men account for the majority of new diagnoses, and black and Latino men in this group bear the brunt. Among women who have heterosexual sex, black women are affected more than others.

And stigma around HIV has not subsided. "A lot of people that I've known, unfortunately, have been thrown away" by their family, friends or church community "just because they're now positive," says Derrick "Strawberry" Cox, who mentors people dealing with a new HIV diagnosis in Washington, D.C.

The nation's capital has one of the highest rates of new HIV diagnoses in the country, at 46.3 per 100,000 people in 2017, according to the U.S. Centers for Disease Control and Prevention. The city is home to Whitman-Walker Health, a nonprofit health center that has been providing HIV care since the 1980s, when the AIDS crisis first emerged in the United States. The day-to-day HIV outreach and care offered in the city demonstrate the successes and the challenges of making HIV treatment and prevention available to all who need it.

"We have the science, we have the medications," says Amanda Castel, an HIV medical epidemiologist at the George Washington University Milken Institute School of Public Health in Washington, D.C. "We know what we need to do, but we have to get people to come in the door and stay in the door."

Stalled progress

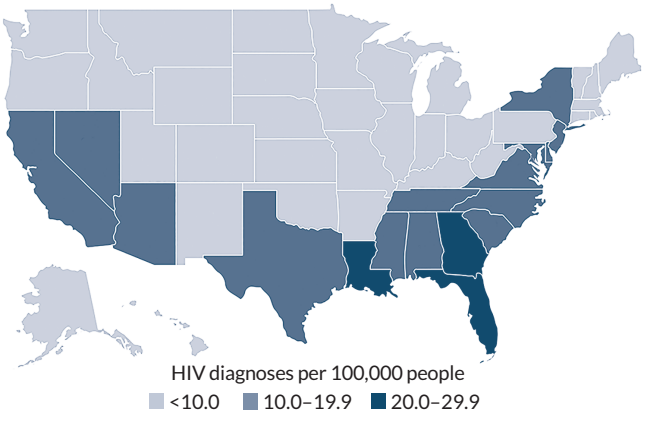
It's a breezy spring day at a busy street corner in Washington, D.C., and the pamphlets won't stay put. Community health educator Miguel Mejia and two colleagues from Whitman-Walker are stationed here for a free HIV testing event. Mejia occasionally chases after the soaring papers, which provide information on safe sex practices, PrEP and HIV.

As soon as Mejia and colleagues set up their table in front of the mobile clinic and lay out free samples, people approach. A group of young men help themselves to condoms. A young woman stops to take an HIV test, then a young man. An older man picks up an oversized, bright blue capsule-shaped key chain. "What's this?" he asks. The metal capsule is a convenient way to carry PrEP pills, he learns. It's also a conversation starter, a way for Mejia and the other educators to connect with people.

In 2018, 12,322 D.C. residents, or 1.8 percent of the population, were HIV-positive. An estimated 78 percent of those living with HIV were in treatment, and of that group, 85 percent were undetectable, according to the city's 2019 health department report on HIV and other infectious diseases. Those percentages are encouraging. But they suggest that 1 in 5 HIV-positive residents in D.C. are not in treatment, and among those who are, 15 percent haven't suppressed the virus, probably because they are not consistently taking their medications.

The last decade has seen a tremendous drop in new cases in D.C. The health department report, released in August, counted 360 new cases in 2018, a 74 percent decrease from the 1,374 new diagnoses in 2007. But it's only 13 fewer than in 2017, a slowing in line with the country's stalled progress: New diagnoses nationwide have stubbornly lingered at around 40,000 annually, with around half of those occurring in the South. Georgia, Florida

U.S. rates of HIV diagnoses, 2017



The South is hit hard In 2017, people newly diagnosed with HIV in the United States predominantly lived in the South, which accounted for 52 percent of the 38,739 diagnoses. SOURCE: CDC

FROM TOP: SHERYL ADAMS; C. CHANG

Community health educator Miguel Mejia drives a mobile clinic (top) to neighborhoods in Washington, D.C., to offer free HIV testing. He and colleagues also offer free condoms, PrEP keychains and educational materials on HIV (bottom).

and Louisiana are among the states with the highest rates of HIV diagnoses.

Education is key to bringing cases down further, says Mejia, who fits in as much information as he can during his encounters at the table and with test-takers. "When we forget to add education to prevention, to testing ... we kind of, like, get stuck."

A reason to come in the door

For many people, there's a lot to learn about where things stand with HIV, such as U=U. The slogan was launched in 2016, but the science supporting the equation has grown out of studies from the last two decades or so.

Researchers have conducted large clinical trials of couples, heterosexual and gay, in which one member was HIV-positive and the other was negative. When HIV-positive partners consistently took ART, they brought their viral loads — the amount of virus present in the blood — down below what could be detected by laboratory tests. Positive partners with undetectable viral loads did not transmit the virus to negative partners. Treatment was also prevention.

The most recent evidence that undetectable equals untransmittable came in May, when researchers reported in the *Lancet* results of a clinical trial of 782 gay couples. After more than 76,000 reported instances of anal sex without a condom, HIV had not spread from a positive to a negative partner in any couple. U=U holds true after a person has been undetectable for six months.

Clinical trials published in the last decade have also evaluated PrEP as a prevention option for HIV-negative people. PrEP is most effective when taken daily. If started the correct number of days before exposure and used consistently, PrEP can reduce the risk of HIV by as much as 90 percent for vaginal sex and up to 99 percent for anal sex. For preventing transmission among people who use injection drugs, another important risk factor, PrEP is up to 74 percent effective.

With ART and PrEP, health officials feel the time is right to tackle HIV anew. Early in 2019, the U.S. Department of Health and Human Services unveiled a plan to reduce new infections, now at roughly 40,000 annually, by 75 percent in the next five years and by 90 percent in 10 years.

Of the approximately 1.1 million people with HIV in the United States in 2016, about 160,000, or 1 in 7, were unaware they were infected. Mejia and his fellow health educators regularly visit various D.C. neighborhoods to reach people who are missing out on treatment.

The mobile clinic offers two HIV tests, one that swabs the gums and gives results in roughly 20 minutes and a 60-second test that uses blood from a finger stick. In the prelude to a test and while people await their results, Mejia gets to know the test-takers: whether they've been tested before, what they know about HIV, the last time they had unprotected sex. Making that first connection friendly and nonjudgmental is crucial to helping a person make and keep an appointment for treatment if the test comes back positive. "How you welcome your client at the time when you're counseling is how the client is going to respond," he says.

Once someone is in the door, Whitman-Walker staff accompany that person through each step of that first appointment, from learning about HIV and understanding the test results to prescribing medication and exploring insurance options, says Heather Alt, deputy director of nursing at Whitman-Walker. The patient-centered focus extends to figuring out a medication ritual, Alt says, whether it's setting a cell phone alarm or filling a pillbox together. "If you're more comfortable taking your meds in front of me, we can do it that way too," she says.

Whitman-Walker, which in 2017 provided services to more than 20,000 people, about 3,600 of whom were living with HIV, has been a prominent part of Washington, D.C.'s efforts to temper its HIV epidemic. The same goes for the D.C. Health Department, which offers HIV testing and needle exchange, and runs public health campaigns. The city supports people living with HIV through the federally funded Ryan White HIV/AIDS Program, which provides services to more than half of HIV-positive people nationwide.

FROM TOP: MATTHEW RAKOLA; A. CUNNINGHAM

But even with D.C.'s many HIV services — as Mejia puts it, "our area is very blessed" — not everyone who needs help is getting it, the city's annual reports reveal.

Castel, of George Washington University, and colleagues study a large group of HIV-positive patients called the D.C. Cohort. People traveling five miles or more to get care were 30 percent less likely, on average, to be keeping their virus levels in check, Castel and colleagues reported in 2018 in *AIDS and Behavior*. Most members of the cohort who had to bridge this distance lived in the southeast quadrant of D.C., where there are fewer HIV-care options, and where many residents contend with additional barriers, such as poverty and homelessness.

No assumptions

Martha Sichone-Cameron has worked with women and girls living with or at risk for HIV in the city, many from Southeast D.C., at The Women's Collective, a community health organization. The stigma that prevails comes through in the stories of the clients she's served. A lot of the women who were HIV-positive hadn't told their families. Sometimes, the husband also was positive but wasn't willing to go to the doctor. In one case, Sichone-Cameron says, "the guy used to take the medication away from the woman for himself."

Sichone-Cameron grew up in Zambia, one of several sub-Saharan countries in Africa hit hard in the 1990s by the AIDS epidemic. She nearly died of AIDS in 2003, but through her work with a nonprofit organization caring for orphans, she was able to travel to the United States for medical advice. With a change in medication, she became undetectable within a year.

Through her advocacy, Sichone-Cameron has seen how the high prevalence of HIV in D.C., along with the poverty, violence and drug use that plagues some neighborhoods, puts women at high risk for infection. "Give them the power of education," she says. "Give them the tools that are there, like PrEP." PrEP is a discreet option for women seeking protection but facing resistance or violence from a partner, she says. "Put it in a vitamin bottle, you take one a day, nobody will know."

PrEP's power to stem HIV hasn't fully been realized. Many people don't know about PrEP, studies show, and its use is low. Around 1.1 million people in the United States were considered candidates for PrEP in 2015 due to their risk for acquiring HIV, according to the CDC. But only about 100,000 people used PrEP in 2017, based on a study of a national prescription database reported in 2018 in the *Annals of Epidemiology*.

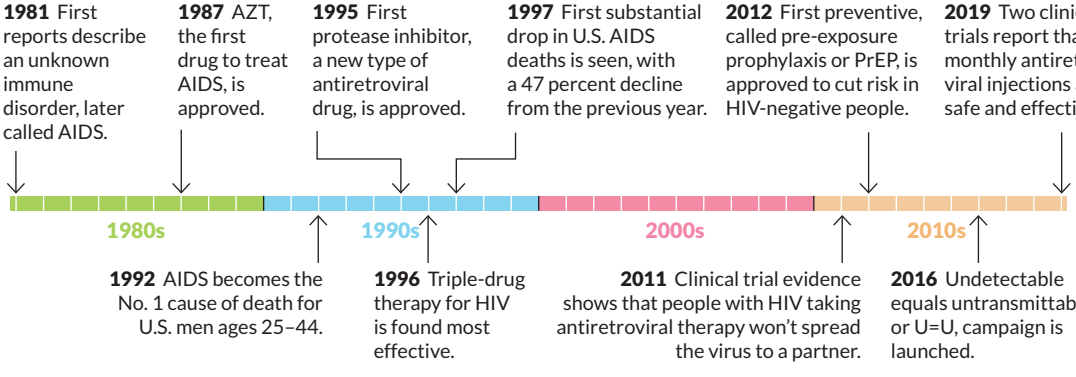
Martha Sichone-Cameron (third from left, shown with her husband, sons and daughter) almost died from AIDS in 2003. But with a change in medication, levels of HIV in her blood became undetectable in less than a year. She advocates for women with HIV and those at risk.

The U.S. Public Health Service's clinical guidance for PrEP recommends using PrEP for risky behaviors, such as condomless sex between men or heterosexuals, sex with an HIV-positive partner, sex with a high number of partners or injecting drugs. But to Sichone-Cameron, the women she's worked with were vulnerable simply because of where they lived. "You don't need to ask them about their behavior," she says. "All you have to do is ask them their address and zip code, and that should make you prescribe PrEP."

Discussing PrEP routinely with all patients could be a way to democratize its reach. "Risk prediction is an imperfect process," says Sarah Calabrese, an HIV prevention researcher at George Washington University. "It's the patient who knows the most about their sex life and their intentions." And if health care providers prefaced that conversation by saying, " 'Listen, this is something we talk about with all of our patients,' then that avoids patients feeling stigmatized," she says.

FROM TOP: COURTESY OF M. SICHONE-CAMERON; C. CHANG

Milestones in HIV treatment in the United States



38 years

Through decades of drug development and testing in patients, HIV has changed from a death sentence to a manageable health condition for people who consistently take their medications.

SOURCES: CDC; NIH; PREVENTION ACCESS CAMPAIGN; VIIV HEALTHCARE

Washington, D.C., has begun using a "status-neutral" approach to HIV care, to make PrEP a more likely part of the conversation. In the past, if a person tested negative, the response was often, "you're HIV-negative, have a nice day," says Michael Kharfen, senior deputy director of the HIV/AIDS, Hepatitis, STD and TB Administration in the D.C. Department of Health.

"That's not sufficient any longer," he says. A discussion of overall sexual health and wellness, including HIV prevention and an offer of PrEP, should follow a negative result.

An eye-opener

Cox, who volunteers at Whitman-Walker, unintentionally learned he was positive in 2011 when he took his best friend to the doctor so the two could get tested together. "She thought she had something.... It just came back that she had a yeast infection," he says. But the doctor nonchalantly informed Cox that he was HIV-positive. Cox was 21. The doctor "assumed that I already knew," he says.

His trusted primary care provider confirmed the results and discussed next steps. "She made sure I was legitimately OK physically and mentally." She has also worked with Cox to find one-pill formulations that work for him. He is leery of pills, having once choked on Skittles. But today the pill he takes is so small, "I just throw it to the back of my neck and just drink something real quick."

He motivates himself to take his pill each night at 11 p.m. with a signature phone alarm: an ear-piercing scream, the kind uttered as an ax murderer approaches. Cox wanted something jarring to be "forceful with myself, like, take it now!" Today, eight years after his diagnosis, "I still remain undetectable."

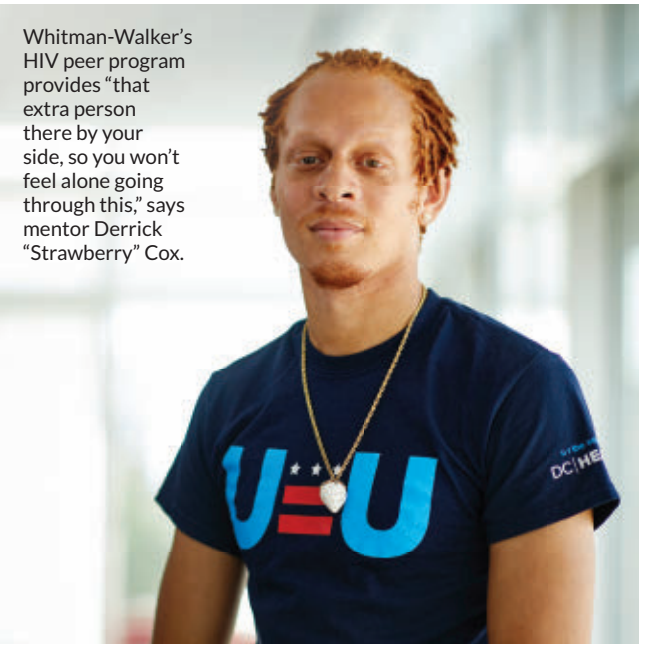
Cox mentors people newly diagnosed with HIV. His mentee Devonte Paulk learned he was HIV-positive in April 2018. Paulk was living in Atlanta at the time. "I instantly broke down, didn't really tell anybody," Paulk says. He didn't feel like he had his family's support.

"Because of their perception of gay people, period, you know, we're just automatically going to have AIDS," he says. "I was scared of the 'I told you's' and 'I tried to warn you.'" Paulk started treatment when he learned his status, but during the tumult of that time, he became depressed, used drugs to cope and fell off his meds. He moved to the Washington, D.C., area in November 2018, where he met Cox while hanging out with a high school friend.

"We just ended up talking that day," says Cox, sitting with Paulk at Whitman-Walker Health, "and he just came out with a lot of things." Cox told Paulk about the peer program, and that by joining, even if he wasn't ready for the group sessions, it would mean Cox could help him as a mentor.

"My main thing was to get him on Medicaid and then get him back on his meds. His health came first," Cox says. Paulk credits Cox for the fact that he's back on his medication. "And I am currently undetectable," Paulk says.

The first time Paulk came to the group, he was pretty quiet, Cox remembers. There are 20 to 30 people, young adults to octogenarians. The group includes gay, heterosexual and transgender people. Cox likes mixing the ages so that long-term survivors can share their stories with newly diagnosed members, "letting them know that it's going to be OK." The second time Paulk attended the group, "he opened up more," Cox says.



Whitman-Walker's HIV peer program provides "that extra person there by your side, so you won't feel alone going through this," says mentor Derrick "Strawberry" Cox.

MATTHEW RAKOLA

"I realized I wasn't alone," Paulk says.

New members of the peer program often express shock and despondence over the diagnosis. Paulk described feeling dirty, a sentiment others have shared. Many say they feel unwanted, Cox says, "like they're not going to be accepted at all, like 'who will love me now that I have HIV?'"

Even in D.C., with comprehensive HIV services and a proud, active LGBTQ community, people can still feel shame. The stigma can stop some from going to Whitman-Walker, Cox says, since it has a reputation for treating HIV-positive people.

Cox talks to mentees about U=U to "let them know that it's OK to be positive as long as you're staying on top of your health." The realization that they won't spread the virus to a partner can "help people be back at peace." By taking care of you, you're taking care of partners too, he says.

Paulk says he's breaking out of his shell more and more. "I called HIV a 'situation' for a long time," he says. "I could not say HIV, it was always 'my situation.'" Now he shares his status more freely. "I like to just go ahead and get it over with at the beginning," he says. "It's not everybody's business, true, but it makes me more comfortable to be able to just come out like that without hesitating.

"Being here ... it's been an eye-opener, and for good reasons," Paulk says. "I feel like a normal person." ■

Explore more

■ District of Columbia Department of Health. "Annual epidemiology & surveillance report." Released August 2019.

GEOLOGIC ROAD TRIP OF THE MONTH

MOUNT SHASTA

So far as can be told, Shasta began its career sometime around 600,000 years ago. The mountain appears to have grown during four major eruptive periods, each of which produced a large andesite volcano. So the massive bulk of Shasta is really a huddled cluster of volcanic cones.

Although the southern flank of Shasta is deeply eroded, most of the mountain is not. Obviously, it has been active enough to repair most of the scars of ice age glaciation. Radiocarbon dates suggest that Shasta has erupted, on average, once every 600 to 800 years since the last ice age. It erupted ash flows about 1,100 and 750 years ago, a hot mudflow about 800 years ago, and modest quantities of ash and hot mudflows in 1786.

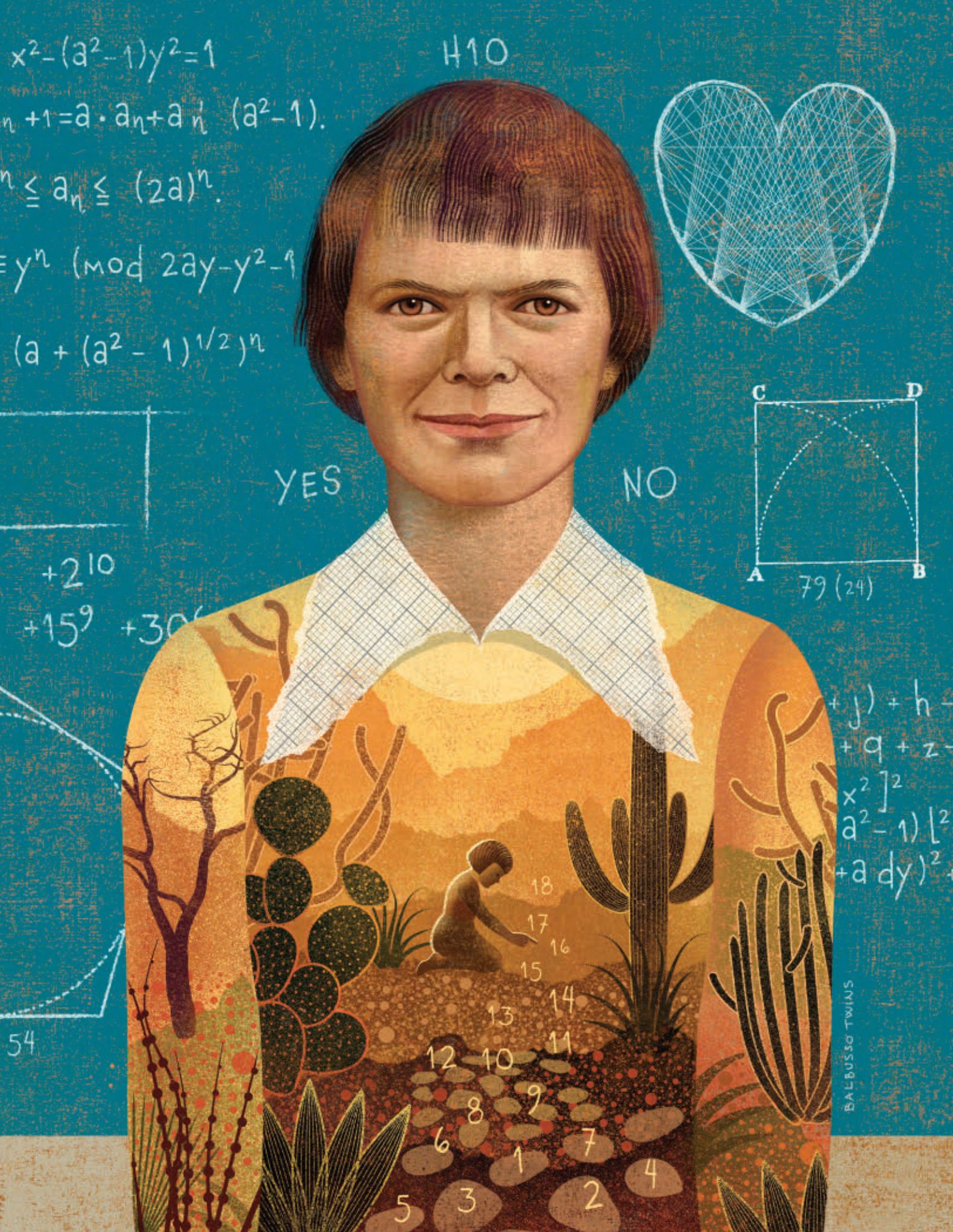
Shastina, the satellite cone on the west flank of Shasta, is a substantial volcano in its own right, one of the larger of the High Cascades. Its smooth slopes show no sign of glacial erosion. A detailed series of radiocarbon dates on charcoal associated with its lavas show that the entire cone grew during an episode of vigorous activity between 9,700 and 9,400 years ago. Ash flows poured down the west side of Shastina as it was growing, and across more than 40 square miles of countryside west of the mountain, including the sites of Weed and Mount Shasta city. It has not erupted since.

The Hotlum Cone on the summit of Shasta appears to have been the source of most of the activity since Shastina went out of business. It apparently erupts at least once every thousand years, probably more frequently. Steam vents in the Hotlum Cone show that hot rock still exists within the volcano.

The French explorer La Perouse and his crew briefly glimpsed what they thought was a distant volcanic eruption while they were sailing along the coast of California at the latitude of Shasta in 1786. It was almost certainly the Hotlum Cone on the summit of Shasta—a minor eruption that scattered a thin layer of brown pumice across part of the mountain. The same eruption also sent an ash flow and several hot and cold mudflows about 7 miles down the valley of Ash Creek, on the east slope of Shasta, and sent a hot mudflow some 12 miles down the valley of Mud Creek.

Gravity surveys reveal evidence of a large volume of abnormally light rock at shallow depth beneath Shasta and the surrounding area. Earthquake waves passing beneath the area of the gravity anomaly lose much of their shear wave motion, which means that they are passing through a liquid. It must be magma. No one actually knows what kind of magma, but pale andesite or rhyolite seem a good bet because they commonly come in large volumes. Also, the small eruption of 1786 produced pale andesite. If that magma lurking beneath Shasta really is a large mass of rhyolite or pale andesite, and if it contains steam, it could cause a horrifying eruption. The potential may exist for a catastrophe of the kind that quickly converted Oregon's Mazama, a volcano on the scale of Shasta, into Crater Lake.

Shasta from the southwest. Shastina on its left. (41.324203, -122.305614)


$x^2-(a^2-1)y^2=1$
H10
$a_{n+1}=a\cdot a_n+a_n$ (a^2-1).
$a^n \leqq a_n \leqq (2a)^n$.
$\equiv y^n \pmod{2ay-y^2-1}$
$(a+(a^2-1)^{1/2})^n$
YES
NO
C
D
A
B
79 (24)
$+2^{10}$
$+15^9$
54
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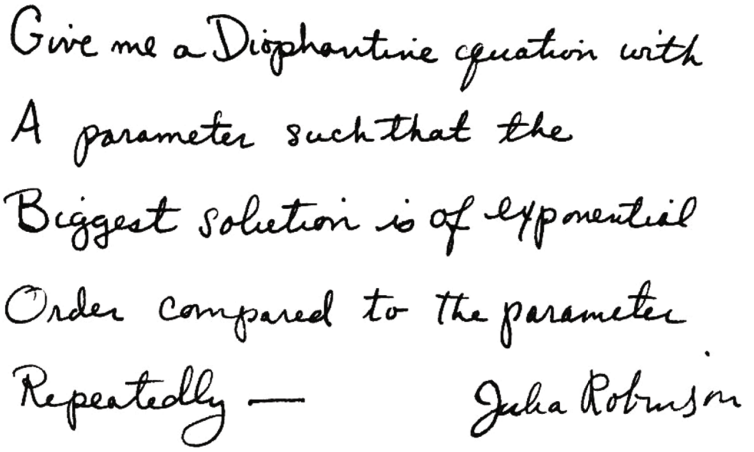


Known for the Unknowable

Julia Robinson helped define the limits of mathematical understanding

By Evelyn Lamb

Every December 8 for years, Julia Robinson blew out the candles on her birthday cake and made the same wish: that someday she would know the answer to Hilbert's 10th problem. Though she worked on the problem, she did not care about crossing the finish line herself. "I felt that I couldn't bear to die without knowing the answer," she told her sister.

In early 1970, just a couple of months after her 50th birthday, Robinson's wish came true. Soviet mathematician Yuri Matiyasevich announced that he had solved the problem, one of 23 challenges posed in 1900 by the influential German mathematician David Hilbert.

Matiyasevich was 22 years old, born around the time Robinson had started thinking about the 10th problem. Though the two had not yet met, she wrote to Matiyasevich shortly after learning of his solution, "I am especially pleased to think that when I first made the conjecture you were a baby and I just had to wait for you to grow up!"

The conjecture Robinson was referring to was one of her contributions to the solution to Hilbert's 10th problem. Matiyasevich put the last piece into the puzzle, but Robinson and two other American mathematicians did crucial work that led him there. Despite the three weeks it took for their letters to reach each other, Robinson and Matiyasevich started working together through the mail in the fall of 1970. "The name of Julia Robinson cannot be separated from Hilbert's 10th problem," Matiyasevich wrote in an article about their collaboration.

Robinson was the first woman to be elected to the mathematics section of the National Academy of Sciences, the first woman to serve as president of the American Mathematical Society and a recipient of a MacArthur Fellowship. She achieved all of this despite not being granted an official faculty position until about a decade before her death in 1985.

OPPOSITE: THE BALBUSSO TWINS; THIS PAGE: C. REID, COURTESY OF NEIL REID

The life of Julia Robinson After a challenging childhood, Robinson pursued a life of mathematics, setting the foundation for a solution to Hilbert's 10th problem.

1919
Julia Bowman is born on December 8 in St. Louis.

1922
Julia's mother dies. Julia and her sister, Constance, move to Arizona, where their father and his new wife later join them.

1925
The family moves to Point Loma on San Diego Bay.

ca. 1929
Julia comes down with scarlet fever and then rheumatic fever.

1936
Julia enrolls in San Diego State College (now University).

1937
Julia's father dies by suicide.

1939
Julia transfers to UC Berkeley, where she takes five math courses in her first year, including one taught by Raphael Robinson.

1941
Julia and Raphael Robinson marry on December 22.

Robinson never thought of herself as a brilliant person. In reflecting on her life, she focused instead on the patience that served her so well as a mathematician, which she attributed in part to a period of intense isolation as a child. At age 9, while living with her family in San Diego, she contracted scarlet fever, followed by rheumatic fever.

Penicillin had just been discovered and was not yet available as a treatment. Instead, she lived at the home of a nurse for a year, missing two years of school.

Even after she rejoined her family, attended college and married, complications from rheumatic fever led to lifelong health problems, including the inability to have children. After a much-wanted pregnancy ended in miscarriage, doctors told her another pregnancy could kill her. She had a heart operation when she was around 40 years old that improved her health, but she was never able to have the family she deeply desired.

Diagnosed with scarlet fever and then rheumatic fever at age 9, Julia lived away from home with a nurse. In the image above, she has returned home for a visit.

Despite her accomplishments, Robinson was reluctant to be in the spotlight, only consenting to tell her story for publication near the end of her life. The quotes attributed to Robinson in this article come from that record, an "autobiography" written by her older sister, Constance Reid, in close consultation with Robinson.

The 10th problem

Hilbert issued the first of his 23 challenges to the mathematics community during a lecture in Paris at the 1900 International Congress of Mathematicians. The questions, which helped guide the course of mathematics research for the next century and through the present day, spanned several disciplines in mathematics, probing everything from the logical foundations of various branches of mathematics to very specific problems relating to number theory or geometry.

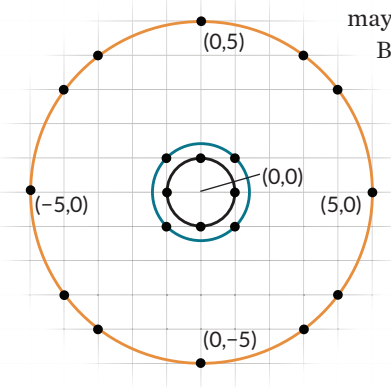
The 10th problem is a deep question about the limitations of our mathematical knowledge, though initially it looks like a more straightforward problem in number theory. It concerns expressions known as Diophantine equations. Named for Diophantus of Alexandria, a third century Hellenistic mathematician who studied equations of this form in his treatise *Arithmetica*, a Diophantine equation is a polynomial equation with any number of variables and with coefficients that are all integers. (An integer is a whole number, whether positive, negative or zero.)

Examples of Diophantine equations include everything from simple linear equations such as $5x+y=7$ (the variables are x and y, and their coefficients are 5 and 1) to the Pythagorean distance formula $a^2+b^2=c^2$ (the variables are a, b and c, and their coefficients are all 1) to towering monstrosities in googols of variables.

Mathematicians are interested in whether Diophantine equations have solutions that are also integers. For example, Pythagorean triples — sets of numbers such as 3, 4 and 5 or 5, 12 and 13 — are solutions to the equation $a^2+b^2=c^2$. Some Diophantine equations have integer solutions, and some do not. While $a^2+b^2=c^2$ has infinitely many integer solutions, the similar equation $a^3+b^3=c^3$ has none (except for solutions including zeros, which mathematicians consider uninteresting).

If an equation does have integer solutions, you do not need to be particularly clever to find them — you just need to be patient. A brute-force search will eventually give you numbers that work. (Of course, being cleverer may mean you can be less patient.) But if you do not know whether the equation can be solved in integers, you will never know whether your failure to find a solution is because none exists or because you have not been patient enough.

Earlier this fall, mathematicians Andrew Booker of the



All about integers The three circles to the right represent the Diophantine equations $x^2+y^2=1$ (black), $x^2+y^2=2$ (blue) and $x^2+y^2=25$ (orange). All three have integer solutions (marked as black dots where the circles cross intersections of grid lines). Yet there are some Diophantine equations with no integer solutions. And for others, mathematicians don't yet know if integer solutions exist.

FROM TOP: C. REID, COURTESY OF NEIL REID; T. TIBBITTS

University of Bristol in England and Andrew Sutherland of MIT announced that they had used a mix of clever algorithms and a powerful supercomputer to find that $42=-80{,}538{,}738{,}812{,}075{,}974^3+80{,}435{,}758{,}145{,}817{,}515^3+12{,}602{,}123{,}297{,}335{,}631^3$. In other words, the Diophantine equation $x^3+y^3+z^3=42$ has an integer solution.

This is one case of the more general question of which integers n can be written as the sum of three integer cubes: $x^3+y^3+z^3=n$. Forty-two was the last two-digit number for which mathematicians didn't know whether there was a solution, but infinitely more numbers await integer solutions, if they exist.

What Hilbert wondered in his 10th problem was how to tell whether an equation has integer solutions or not. Is there an algorithm — a terminating process yielding a yes-or-no answer — that can determine whether any given Diophantine equation has such a solution?

A large part of the appeal of the 10th problem and related questions is sheer curiosity. Do these often very simple polynomials have integer solutions? Why or why not? The answers generally do not have concrete practical applications, but the area of research is related in deep ways to theoretical computer science and the limits of what computer programs can do.

Unknowability

Robinson's interest in Hilbert's 10th problem started fairly early in what was an atypical mathematical career. She married Raphael Robinson, a mathematician at the University of California, Berkeley, not long after graduating from the university with a bachelor's degree in mathematics. UC Berkeley's antinepotism rules prohibited her from working in his department. (Her situation was not uncommon for women in academia in the 1940s and 1950s.) After earning her Ph.D. in math in 1948, also at UC Berkeley, she worked in industry and outside her field for a few years and volunteered for Democratic candidate Adlai Stevenson's presidential campaigns. She also worked as an unofficial member of the UC Berkeley math department, using Raphael's office and occasionally teaching classes.

Shortly after getting her bachelor's degree from UC Berkeley, Julia married mathematician Raphael Robinson. They are shown here beside their first home.

C. REID, COURTESY OF NEIL REID

Although she did not have the stability or salary of an official faculty position, she published in mathematics journals, both individually and with collaborators, and presented her work at conferences, often bringing a bicycle along. She'd become an avid cyclist after her heart surgery, delighted by her ability to exercise after years of being perpetually short of breath.

When she was elected to the National Academy of Sciences in 1976, the university press office had to call the mathematics department to ask who Julia Robinson was. UC Berkeley quickly made her a full professor. Robinson writes, "In fairness to the university, I should explain that because of my health, even after the heart operation, I would not have been able to carry a full-time teaching load."

Shortly after she graduated with her Ph.D., her adviser, Alfred Tarski, mentioned a problem to Raphael, who in turn told Julia. This particular problem involved Diophantine sets, groups of integers that when substituted for one variable in some Diophantine equation would allow integer solutions in the other variables. Consider the equation $c-x^2=0$, which has integer solutions for x only when c is a perfect square. Thus the perfect squares form a Diophantine set. The problem Raphael told Julia about was to determine whether the powers of 2 — 2, 4, 8, 16 and so on — form a Diophantine set. Through her work on that question, she found her way to the 10th problem.

Robinson first met Martin Davis, then an instructor at the University of Illinois at Urbana-Champaign, in 1950. "It started with our working on the same problem but from absolutely opposite directions," says Davis, now age 91. Both researchers had been looking at Diophantine sets. Davis was starting generally, trying to show that all sets with a particular property called listability were Diophantine. Robinson was starting from the particular, trying to show that a few special sets — including prime numbers and the powers of 2 she had been working on — were Diophantine.

In 1959, Robinson and Davis started working together. With Hilary Putnam of Princeton University, they kept pushing on the problem. Eventually

1948
Robinson defends her Ph.D. and begins work on Hilbert's 10th problem.

1952
Robinson publishes "Existential definability in arithmetic," which will prove essential to solving Hilbert's 10th problem.

1961
Robinson and colleagues publish "The decision problem for exponential Diophantine equations," which shows the need for a "Goldilocks" equation.

1961
Robinson has open-heart surgery.

1970
Yuri Matiyasevich answers Hilbert's 10th problem. He and Robinson begin collaborating.

1976
Robinson is the first female mathematician elected to the National Academy of Sciences.

1983
Robinson becomes president of the American Mathematical Society and receives a MacArthur Fellowship.

1985
Robinson dies on July 30, at age 65.

3. No – except for 1 semester or two when the nepotism rule was enforced. Also there was one case when both my husband and I were invited to a conference and the committee decided it would be unfair to pay expenses for both of us because the other families would have to pay for the wives. We didn't particularly care and perhaps they were right.

In response to a questionnaire that asked whether she had ever faced discrimination as a student or professional, Robinson (pictured above a couple of weeks before her death) shared this response, describing her experience as a woman in math.

they showed that all they needed was what Davis describes as a "Goldilocks" equation. "The solutions aren't supposed to grow too fast, and they aren't supposed to grow too slowly," he says. But that equation eluded them for almost a decade.

In the U.S.S.R., Matiyasevich had tried to tackle Hilbert's 10th problem as a college student but abandoned it around the time he graduated in 1969. Then a new paper from Robinson sucked him back in. "Somewhere in the Mathematical Heavens there must have been a god or goddess of mathematics who would not let me fail to read Julia Robinson's new paper," he wrote.

He was asked to review it — a mere five pages about the relative growth of solutions to certain Diophantine equations in two variables. Her ideas immediately sparked new ideas for him, and he was able to produce the needed "Goldilocks."

"It's such a romantic thing — in the wider sense of the word romantic — that the four of us, such different people with different backgrounds, all together produced this piece of work," Davis says.

Together, they had shown that no all-purpose algorithm exists to determine whether an arbitrary Diophantine equation has integer solutions.

But that isn't the end of the story. Building on the work of Robinson and her colleagues, mathematicians continue to probe the boundary between knowability and unknowability. "Her work is still very relevant today," says Kirsten Eisenträger of Penn State, a number theorist whose research is related to the 10th problem.

If Robinson were still alive on her 100th birthday this December, what problem would she be thinking about as she blew out her candles? The fact that there is no general algorithm for all Diophantine equations leaves many tantalizing questions open. For example, does an algorithm exist for Diophantine equations of a certain form, say, multivariable cubic equations?

Mathematicians are also looking at what happens if you change the types of solutions sought for Diophantine equations. One change is to ask the question for rational numbers: Is there a way to determine whether a polynomial equation with integer coefficients has any solutions that are rational numbers? (A rational number is the ratio of two whole numbers; 1/2 and −14/3 are two examples.) Most experts believe that the answer is no, but mathematicians are far from a proof. One potential path to a solution involves building on work Robinson did in her Ph.D. thesis over 70 years ago.

In 1984, during her term as president of the American Mathematical Society, Robinson was diagnosed with leukemia. During a remission the next spring, while cycling with her sister, Robinson decided that Reid would write her life story, "The autobiography of Julia Robinson." Weeks later, the cancer had returned. Reid finished writing the record of Robinson's life as her sister's health deteriorated. Robinson died on July 30, 1985, at age 65.

"What I really am is a mathematician," Reid writes on behalf of Robinson on the closing page. "Rather than being remembered as the first woman this or that, I would prefer to be remembered, as a mathematician should, simply for the theorems I have proved and the problems I have solved." ■

Explore more

■ Constance Reid. "The autobiography of Julia Robinson." *The College Mathematics Journal*. January 1986.

Evelyn Lamb is a freelance writer based in Salt Lake City. A disclosure to the reader: She began her science writing career through a fellowship sponsored by the American Mathematical Society and still occasionally writes for the organization.

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EXHIBIT

Meet your extended family at a new human evolution exhibition

Karabo, a hominid skeleton dating to nearly 2 million years ago, is now on display in Dallas.

For the next few months, visitors to the Perot Museum of Nature and Science in Dallas will have a rare opportunity to see fossils of ancient hominids up close.

A new exhibition, "Origins: Fossils from the Cradle of Humankind," open through March 22, brings to the museum *Australopithecus sediba* and *Homo naledi*. The discoveries of these South African species over the last decade have raised new questions about humans' family tree.

Almost as amazing as the fossils themselves is the fact that they traveled to the United States. "Origins" marks the first time these fossils have been displayed outside of South Africa, and Dallas is their only scheduled stop.

"Origins"
THROUGH MARCH 22, 2020
PEROT MUSEUM OF NATURE AND SCIENCE | *Dallas*

"There's something really distinct in our modern world about being able to see something ... that's authentic, that really is 2 million years old or 300,000 years old, and you're there just inches from it rather than seeing it in virtual reality or on your computer screen," says Becca Peixotto, director of the museum's Center for the Exploration of the Human Journey.

"Origins" focuses primarily on two specimens. First there's Karabo, the male *A. sediba* skeleton that paleoanthropologist Lee Berger's 9-year-old son Matthew discovered at a site called Malapa in 2008. Karabo, at the time of his death, about 1.97 million years ago, was close to Matthew's age. Then there's Neo, one of over a dozen *H. naledi* individuals found deep in the Rising Star cave system near Johannesburg in 2013 (*SN: 10/3/15, p. 6*). Neo, an adult male, lived about 300,000 years ago, about the time *H. sapiens* emerged (*SN: 6/10/17, p. 6*).

The exhibition encourages visitors to compare the mix of physical traits that these hominids had, in the same way scientists might as they piece together where species fit in humans' evolutionary story. A panel points out how *A. sediba* had hands, feet, teeth and hips similar to modern people's, yet also had small brains and long, apelike arms. In analyzing *A. sediba*'s features, Berger, of the University of the Witwatersrand in Johannesburg, has argued that *A. sediba* is a contender for a direct ancestor of the genus *Homo* (*SN: 8/10/13, p. 26*).

As scientists have discovered more and more fossils, it has become clear that the traditional view of human evolution as a "march of progress," with a straight line of species leading to *H. sapiens*, is too simplistic, says Berger, who oversaw the discoveries of *A. sediba* and *H. naledi*. "What we're seeing, as we get a clearer picture, is that we grossly underestimated the complexity of hominids in the past."

What "Origins" does best is showcase the process of science — to the point of putting actual working scientists on display. Researchers can apply to study the fossils during the exhibition's run — "as long as they do it in front of the public," says Linda Silver, the museum's chief executive officer. About halfway through the exhibition is a glass-enclosed lab where researchers can work while visitors watch.

One way of getting people to trust science, Berger says, is to understand its process — and to see the real deal.

For visitors, coming face-to-face with the real deal begins with Karabo, whose skeleton is roughly 30 percent complete, according to Berger. A nearby case displays a rocky sphere that probably contains the rest of Karabo's bones, allowing visitors to see how the fossils are typically found.

Visitors have several opportunities to learn about the process of science. In one section, a "video tree" describes *H. naledi*'s discovery and shows scientists from different specialties talking about their work on the species. A map and 3-D model of the Rising Star cave system are also on display. Visitors can attempt to squeeze through the tiny opening — 18 centimeters wide — of a life-size model of the entrance to the chamber where Peixotto and five other scientists dropped 12 meters down to excavate *H. naledi* fossils.

After visitors see Neo's skeleton, the exhibition concludes with a re-created dig site, where visitors become paleoanthropologists and search through a large box of sand containing 15 fossil models. After photographing their finds with iPads, visitors can go to a science tent for a guided analysis of the images. "It's kind of realistic because one of the things we're starting to do is leave more [fossils] in place" in the field, Peixotto says.

But Neo's and Karabo's excavated bones are meant to inspire visitors. "Just being able to see those real things," Peixotto says, "there's a sense of awe and an emotional connection that's really important for us in understanding that these are our common roots as a species." — *Tara Haelle*

PEROT MUSEUM OF NATURE AND SCIENCE

SOCIETY UPDATE

Educators in the driver's seat

200 teachers attend Research Teachers Conference

Two hundred high school teachers from across the United States and its territories gathered September 27–29 in Washington, D.C., for Society for Science & the Public's fifth annual High School Research Teachers Conference, sponsored by Regeneron. The teachers discussed key science education issues, such as using big data in student research, biosafety and supporting underserved students.

"At the High School Research Teachers Conference, we put educators in the driver's seat, enabling them to provide input into the agenda and teach one another about best practices and what is most effective in the classroom," says Maya Ajmera, President and CEO of the Society and Publisher of *Science News*. "We hope that teachers will leave our conference inspired and excited to implement new and innovative ideas in their own classrooms so that they can provide their students with high-quality STEM experiences."

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SEPTEMBER 28, 2019

SOCIAL MEDIA

Many moons

In 2018, scientists reported five additional moons orbiting Jupiter, bringing the planet's total to 79. The International Astronomical Union named the new moons after descendants or consorts of the Greek god Zeus, **Lisa Grossman** reported in "By Zeus! Newfound moons of Jupiter get names" (*SN: 9/28/19, p. 4*). On Facebook, **Anthony Barcellos** jokingly decried the planet's plethora of moons: "I memorized the names of Jupiter's moons when I was in elementary school — and there were only *twelve*. I give up!!!"

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Chip off the old carbon block

*Scientists built the first microprocessor that uses thousands of carbon nanotube transistors, **Maria Temming** reported in "Computer chip milestone reached" (SN: 9/28/19, p. 7).*

Reddit user **SchwarzerKaffee** asked about the environmental impact of producing carbon-based microprocessors versus standard silicon-based ones.

Making microelectronics from silicon "is very energy intensive," says materials scientist **Michael Arnold** of the University of Wisconsin–Madison. But carbon nanotube microprocessors would also require many of the same components and take about as many steps to make as silicon ones, he says. "The energy consumption, water usage and by-products all associated with the fabrication of microprocessors likely will not be drastically different."

Dishing on brain organoids

*Brain organoids fired coordinated electrical signals similar to those seen in human babies' brains, **Laura Sanders** reported in "Cells in lab dishes form brain waves" (SN: 9/28/19, p. 12).*

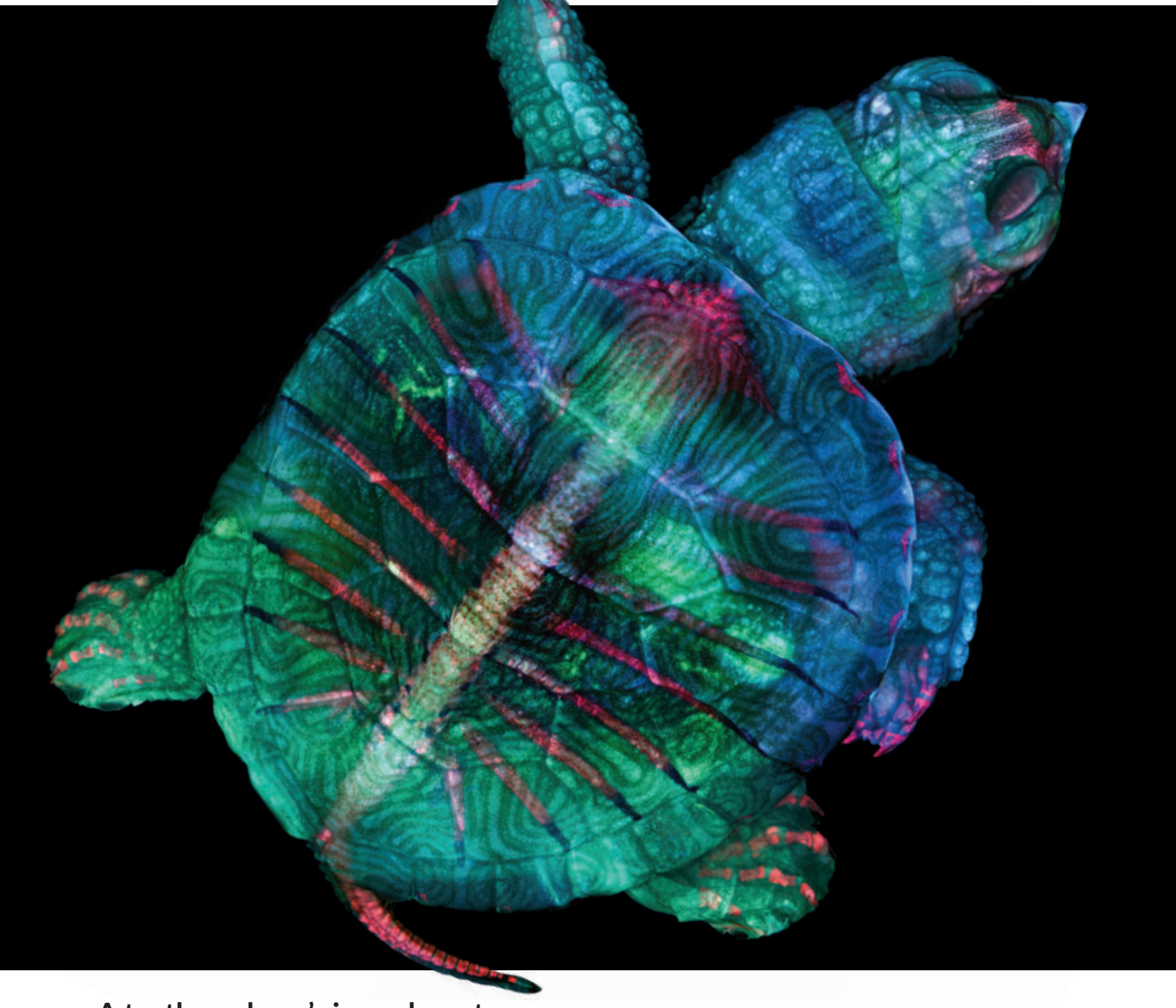
Reader **Steve Hieronymus** wondered what possibilities this research holds for Alzheimer's and Parkinson's disease.

These small clumps of stem cells have offered some interesting insights, **Sanders** says. "Scientists have grown organoids from cells of people with an inherited form of Alzheimer's and watched related proteins accumulate," she says. "And organoids grown from people with Parkinson's have key defects in nerve cells that make dopamine, a chemical messenger involved in the disease." One big caveat: The organoids lack many important features of a real human brain, including the full repertoire of cells and blood vessels.

Correction

"Predicting premature birth" (*SN: 11/9/19, p. 14*) incorrectly stated that 150 Detroit women in a study to identify biomarkers of preterm labor gave birth prematurely. Of the 150 women, 71 women experienced preterm birth.

JPL-CALTECH/NASA, SWRI, MSSS, KEVIN M. GILL



A turtle embryo's inner beauty

As scientists scour the natural world in search of truth, they often capture its beauty. Such was the case for microscopy technician Teresa Zgoda and micro-photographer Teresa Kugler. While at the Marine Biological Laboratory in Woods Hole, Mass., the pair used fluorescence microscopy and stereomicrography to create a vivid portrait of a turtle embryo (above, stained to capture different tissues, such as some bones in pink, and shown at five times magnification).

Because the embryo was more than 2.5 centimeters long, Zgoda, now at Brigham and Women's Hospital in Boston, and Kugler, a recent graduate from the Rochester Institute of Technology in New York, couldn't capture it all in such detail in one image. Instead, they stitched together hundreds of images focused on different locations and layers of the turtle to create a composite of the entire embryo. The pair's turtle image won first place in the annual Nikon Small World photomicrography competition.

"Microscopy lets us zoom in on the smallest organisms and building blocks that comprise our world — giving us a profound appreciation for the small things in life that far too often go unnoticed," Kugler said in an Oct. 21 news release announcing the results of the contest. — *Jonathan Lambert*

T. ZGODA AND T. KUGLER/NIKON SMALL WORLD

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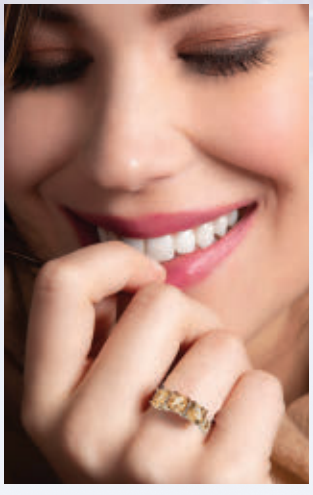

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