Can Monkeypox Be Contained? | Recycling Urban Heat

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ AUGUST 13, 2022

Martian Wanderers

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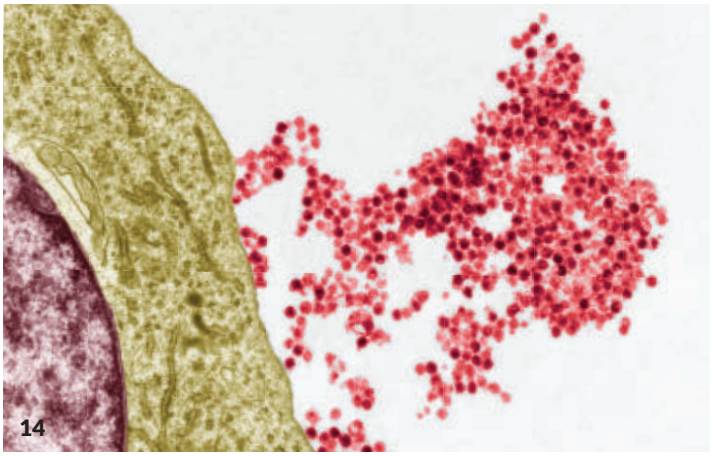
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COVER Much of what scientists know about Mars is thanks to a succession of rolling robot explorers. *Cornelia Li*


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FROM TOP: STEVE GSCHMEISSNER/SCIENCE SOURCE; NASA, ESA, CSA, STSCI; ROB LAVINSKY/ARKENSTONE

Our enduring fascination with outer space

The glowing dots in the night sky have enthralled for as long as people could look skyward. Our desire to figure out what makes the stars blaze and why some of the celestial bodies move in strange ways has sparked centuries of conjecture, observation and exploration, from the simple telescope Galileo used to observe Mars in the early 1600s to the new James Webb Space Telescope, a 14,300-pound behemoth with a mirror so big it had to be folded up to fit into the launch vehicle.

Count us here at *Science News* among those fascinated by space. We've covered it from the 1920s, when astronomer Edwin Hubble started making his big discoveries, through the launch of the first satellite, Sputnik, in 1957, and the "space race" that put people on the moon in 1969. Now, increasingly sophisticated robots are independently exploring other planets and even the sun, and reporting back to us here on Earth.

This issue's cover story celebrates the 25th anniversary of rovers on the surface of Mars, starting with the arrival of tiny Sojourner on July 4, 1997. Three rovers are currently hard at work probing the Red Planet's surface and atmosphere (Page 20). Those machines, NASA's Curiosity and Perseverance — the SUVs of Mars vehicles — and China's smaller Zhurong, are greatly expanding Mars exploration, contributor Alexandra Witze writes. Perseverance is collecting rock samples that future missions can return to Earth. It even serves as home base for the tiny helicopter dubbed Ingenuity that has buzzed around dozens of times, outliving its anticipated life span and delighting its creators and the public alike.

That's not the only space news worth noting. In July, NASA revealed the first images delivered by the James Webb Space Telescope, and they are mind-blowing. They look back in time more than 13 billion years to reveal swarms of never-before-seen galaxies (Page 30). The idea of building a giant telescope and shooting it into space was audacious when it was dreamed up in the 1980s. And the project was plagued by years of delays and massive cost overruns. Even after its successful launch in December, scientists and engineers held their breaths, fearing that the craft would fail to complete the complicated task of unfolding its mirror and five-layered sunshield. After all that, seeing these radiant images and knowing there will be many more (and more new discoveries) on the way, it seems worth the wait.

And why stop there? This issue also covers how months in space affect astronauts' bone health, which is bad news for those of us who would like to travel to Mars and also stand upright afterward (Page 4). We report the results of the latest efforts to find elusive dark matter (Page 11). And we also relay how quantum messaging might help aliens communicate with us on Earth. Here's hoping that they'll be more like E.T. than like the creature in the *Alien* movies (Page 5).

If it feels like there's an abundance of amazing stuff happening in astronomy, cosmology and astrophysics these days, you're right. To help you keep up, we've launched a space newsletter. Sign up at www.sciencenews.org/newsletters and you'll get our latest coverage rocketing into your inbox every other Friday.

— Nancy Shute, Editor in Chief

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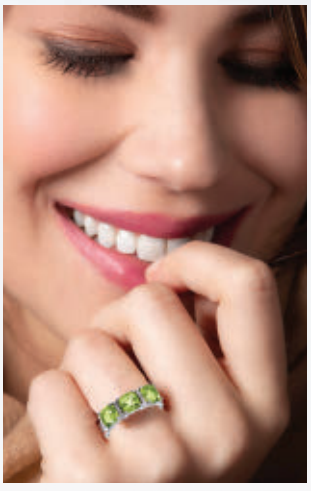

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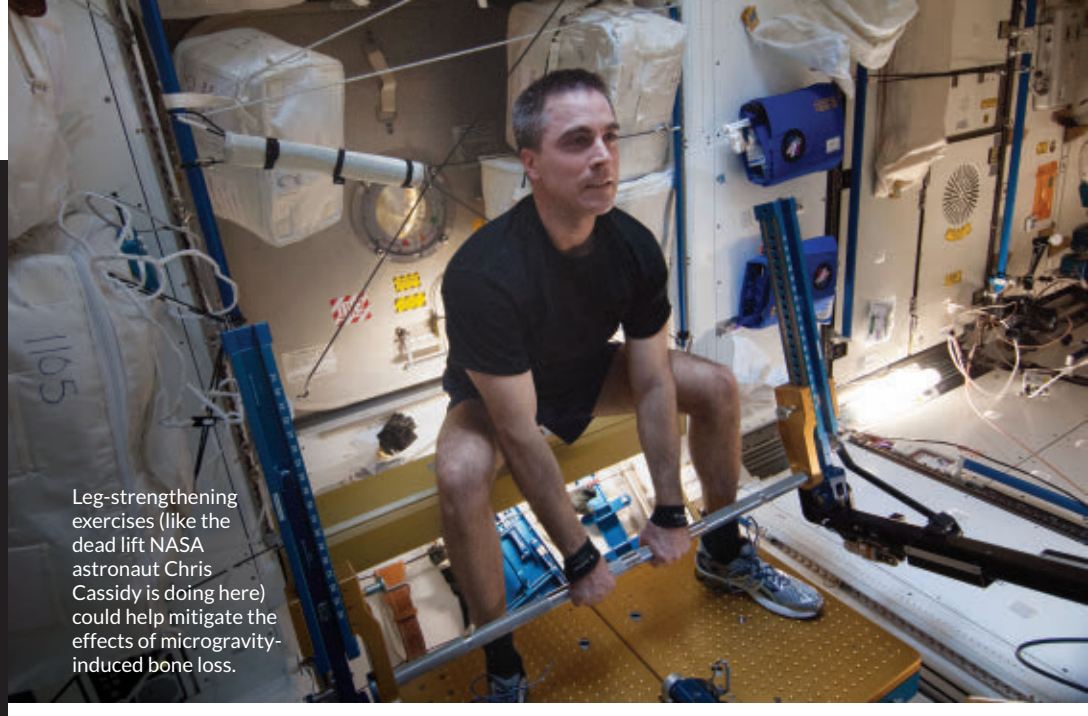
50 YEARS AGO

The icy world of organ freezing

If whole organs could be frozen and stored… surgeons would be able to perform far more transplants…. For all their efforts, though, cryobiologists (biologists who study the effects of cold on life) have not been very successful with organ freezing…. Nobody to date has cooled whole mammalian hearts any lower [than −20° Celsius] or longer [than six hours] and revived them.

UPDATE: Scientists still struggle to keep donor hearts on ice for longer than six hours, but it is now possible to store a different organ — the liver — at below-freezing temperatures for more than a day. The challenge has been figuring out how to stop ice from crystallizing and damaging cells. In 2019, scientists reported successfully warming up several human livers after supercooling them for 27 hours (*SN: 10/12/19 & 10/26/19, p. 10*). This and other preservation methods such as freezing at high pressures or thawing using nanoparticles aren't yet ready for the operating room, but they have the potential to keep thousands of lifesaving organs from going to waste each year.



Leg-strengthening exercises (like the dead lift NASA astronaut Chris Cassidy is doing here) could help mitigate the effects of microgravity-induced bone loss.

SCIENCE STATS

Six months in space ages bones by 20 years

You might want to bring your dumbbells on that next spaceflight.

During space missions lasting six months or longer, astronauts can experience bone loss equivalent to two decades of aging. A year of recovery in Earth's gravity rebuilds about half of that lost bone strength, researchers report June 30 in *Scientific Reports*.

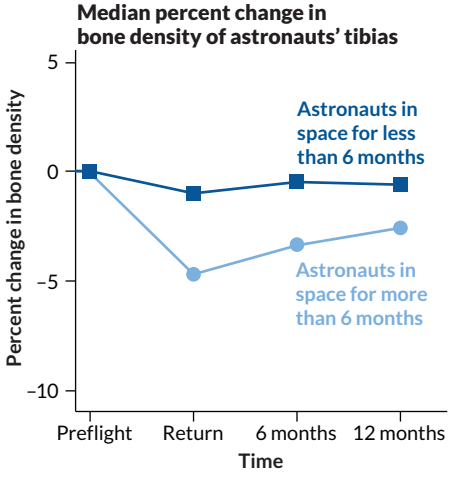
Bones "are a living organ," says exercise scientist Leigh Gabel of the University of Calgary in Canada. "They're alive and active, and they're constantly remodeling." But without gravity, bones can't maintain their density and thus lose strength.

Gabel's team tracked 17 astronauts — 14 men and three women with an average age of 47 — who spent from four to seven months in space. The researchers imaged the bone structure of the tibia in the lower leg and the radius in the lower arm using high-resolution peripheral quantitative computed tomography. This technology can measure 3-D bone microarchitecture on scales of 61 micrometers, roughly the thickness of a human hair.

The team took images at four points in time — before spaceflight, when the astronauts returned from space, and then six months and one year later — and used the data to calculate bone density (see graph, below left) and strength.

Astronauts in space for less than six months (dark blue) nearly recovered their preflight bone density and strength after a year back in Earth's gravity. But those in space for more than six months (light blue) still had bone loss in their tibias equivalent to a decade of aging. The lower arm bones showed almost no loss, probably because the bones aren't weight-bearing, Gabel says.

Doing more weight lifting exercises in space could help alleviate bone loss, says coauthor Steven Boyd, an exercise scientist also at the University of Calgary. "A whole bunch of struts and beams all held together give your bone its overall strength," Boyd says. "Those struts or beams are what we lose in spaceflight." Once these microscopic tissues are gone, you can't rebuild them, but you can strengthen the remaining ones, he says. — *Liz Kruesi*



FROM TOP: NASA; L. GABEL *ET AL*/*SCIENTIFIC REPORTS* 2022. ADAPTED BY E. OTWELL

INTRODUCING

A newfound dinosaur's puny arms were no joke

Tyrannosaurus rex's tiny arms have launched a thousand sarcastic memes: I love you this much; can you pass the salt?; row, row, row your … oh. But back off, snarky jokesters. A newfound species of big-headed carnivorous dinosaur suggests small arms weren't just an evolutionary punch line. Arm reduction — alongside giant heads — evolved independently in different dinosaur lineages, paleontologist Juan Canale and colleagues report July 7 in *Current Biology*.

Meraxes gigas was a distant relative of *T. rex* that lived between 100 million and 90 million years ago in Argentina, says Canale, of the country's CONICET research network. The specimen described by Canale's team is about 11 meters long and has a skull decorated with crests and hornlets, which probably helped attract mates.

Why *M. gigas* and *T. rex* had such tiny arms is an enduring mystery. They weren't for hunting: Both dinosaurs used their giant heads to kill prey. But *M. gigas*' unusually muscular arms suggest that the limbs weren't useless, Canale says. They may have aided mating somehow — perhaps showing a mate some love. — *Carolyn Gramling*

Meraxes gigas (illustrated) was a massive predatory dinosaur with tiny, muscular arms that may have been used in mating, scientists speculate.

FUTUROLOGY

E.T. might be able to pass quantum notes to Earth

An intelligent alien civilization could beam quantum messages to Earth. Particles of light, or photons, could be transmitted over vast interstellar distances without losing their quantum nature, researchers report in the June 15 *Physical Review D*. So scientists searching for extraterrestrial signals could also look for quantum messages.

Researchers are currently developing Earth-based quantum communication, a technology that uses quantum particles to securely send information (SN: 8/5/17, *p.* 14). Extraterrestrials, if they're out there, may have also adopted quantum communication, say theoretical physicists Arjun Berera and Jaime Calderón Figueroa, both of the University of Edinburgh.

A major obstacle to quantum communication is decoherence, in which a quantum particle loses its quantumness as it interacts with its surroundings. Since the average density of matter in space is much less than on Earth, particles could be expected to travel farther before succumbing to decoherence. So the pair calculated how far X-ray photons could travel unscathed through interstellar space. These photons could more than traverse the Milky Way, potentially traveling hundreds of thousands of light-years, the researchers found. One type of quantum dispatch to search for, they say, could be quantum teleportation. In this technology, a distant particle's properties transfer to another. Since the technology requires quantum *and* standard signals, scientists could look for concurrent signals to ID alien missives. — *Emily Conover*

TEASER

Neck patch could help detect concussions

A flexible sensor applied to the back of the neck could help detect concussions in athletes.

The sensor, described June 23 in *Scientific Reports*, is sleeker and more accurate than some instruments currently in use, says electrical engineer Nelson Sepúlveda of Michigan State University in East Lansing. For instance, accelerometers in helmets help monitor for concussions in football players but can give false readings when helmets slide.

Sepúlveda and colleagues' patch is made of two electrodes on a thin film and adheres to the nape. When the head and neck move, the patch generates and sends electric pulses to a computer. Scientists can analyze the signals to assess sudden movements that can cause concussion. The team tested the patch on a human-like figure, dropping it from a height of 60 centimeters. Scientists also packed the figure's head with sensors to get a baseline level of neck strain. Data from the patch and the internal sensors aligned more than 90 percent of the time. "My hope is that [the patch] will lead to earlier diagnosis," Sepúlveda says. — *Nikk Ogasa*

Scientists have created a patch that could help detect head injuries caused by football tackles.

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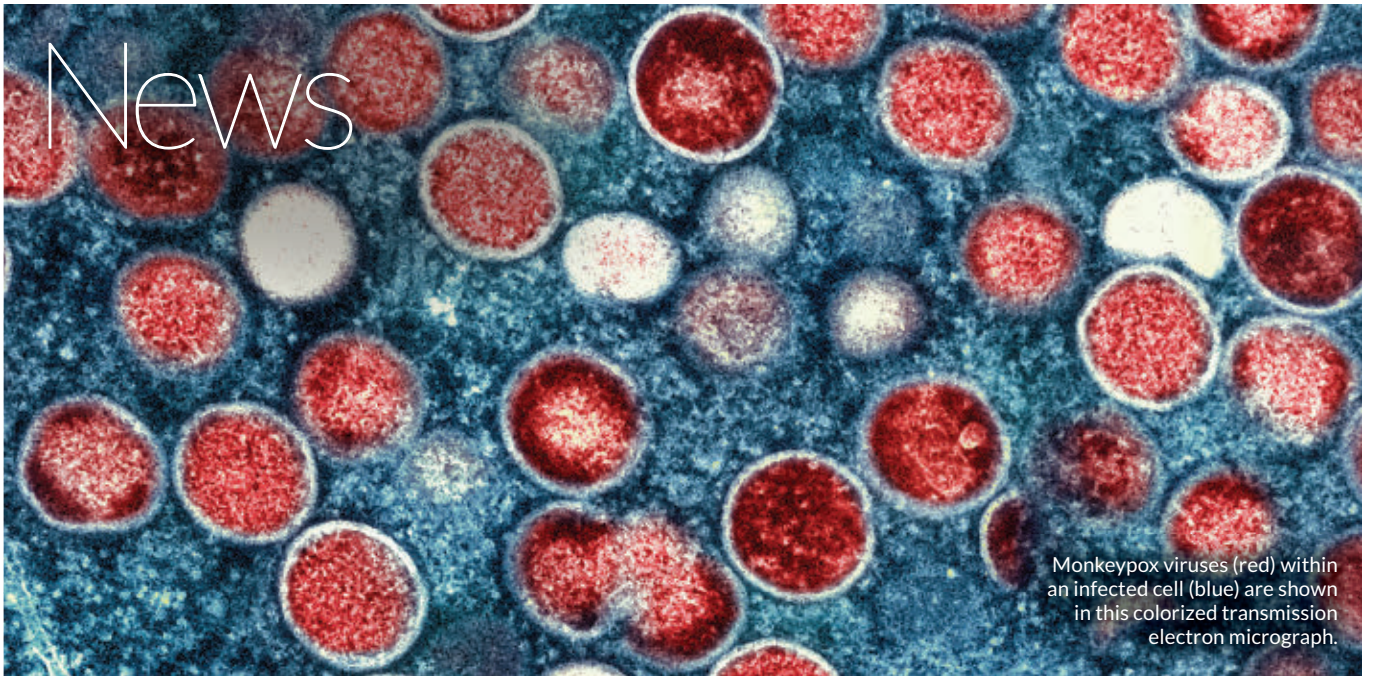


Monkeypox viruses (red) within an infected cell (blue) are shown in this colorized transmission electron micrograph.

NIAID

BODY & BRAIN

Monkeypox is a global health crisis

A lack of coordinated containment efforts is fueling its spread

BY TINA HESMAN SAEY

It may soon be too late to end the global monkeypox epidemic.

"We are losing the window to be able to contain this outbreak," Boghuma Titanji, an infectious diseases doctor and virologist at Emory University in Atlanta said July 21 during a seminar sponsored by the Harvard Kennedy School's Belfer Center for Science and International Affairs.

On July 23, director-general of the World Health Organization Tedros Adhanom Ghebreyesus declared that the global outbreak is a public health emergency of international concern, the organization's highest state of alert. The WHO committee evaluating the matter was split on whether the outbreak constitutes an international emergency, but Ghebreyesus decided that enough conditions were met to warrant the designation.

Monkeypox has infected more than 18,000 people since the beginning of May, according to the WHO (SN: 6/18/22, *p.* 6). More than 3,500 cases have been reported in the United States as of July 26, the U.S. Centers for Disease Control and Prevention reports.

"Although I am declaring a public health emergency of international concern, for the moment this is an outbreak that is concentrated among men who have sex with men, especially those with multiple sexual partners," Ghebreyesus said in a statement. "That means that this is an outbreak that can be stopped with the right strategies in the right groups."

Monkeypox has caused outbreaks for decades in some parts of Africa, Anne Rimoin, an epidemiologist at the UCLA Fielding School of Public Health, said at the Harvard seminar. But the virus "has been neglected by the global health community." Monkeypox "has been giving us warning signals" for years in Congo, Nigeria and other parts of West Africa, but has only gotten attention once it recently started causing cases outside of the continent, Rimoin said.

There has been no concerted global effort to contain the virus, which is related to smallpox, Titanji said. Each country has been left to set its own policies.

That has led to disparities. Well-resourced countries have had at least some access to testing, vaccines and medications, which may help limit the spread of the virus or the severity of the disease. Resource-poor nations often lack that access, leaving them with limited ability to track or control the virus.

Continued spread of monkeypox in resource-poor countries could leave places that do manage to contain an initial outbreak vulnerable to reintroductions, Jay K. Varma, director of the Cornell Center for Pandemic Prevention and Response in New York City, said in the seminar. The WHO emergency declaration may lead to a more concerted international effort that could make more resources available to contain the spread.

Even for the wealthiest countries, containing the outbreak is a challenge. Questions abound about how the virus is transmitted, and whether vaccines and treatments — when people can get them — can halt its spread. Even diagnosing the disease can be tricky, with testing often hard to come by and missed diagnoses potentially leading to more cases.

Who's affected

The vast majority of cases in the global outbreak have been among men who have sex with men. Of 528 people infected in 16 countries, 98 percent identified as gay or bisexual men, researchers report July 21 in the *New England Journal of Medicine*.

In some countries with outbreaks, "gay men are criminalized," Kai Kupferschmidt, a correspondent for *Science* magazine, said during the seminar. There, "people cannot access good information to help them keep from getting infected and cannot access health care if they do get infected. In these countries, it becomes really difficult to even see the problem," he said.

In the statement, Ghebreyesus urged all countries to "work closely with communities of men who have sex with men, to design and deliver effective information and services, and to adopt measures that protect the health, human rights and dignity of affected communities.

"Stigma and discrimination can be as dangerous as any virus," he said.

Doctors might also miss cases because of the unusual presentation of the illness in this outbreak, compared with earlier outbreaks. For instance, in the NEJM study, only a quarter of patients had monkeypox lesions on their faces, and only 10 percent had the sores on their palms or soles of their feet. Those body parts have been among some of the most affected in other outbreaks.

Instead, 73 percent of people in the study had lesions in the anal and genital regions and 55 percent on the trunk, arms or legs. Some people also had lesions in their mouth and throat. Most of the people in the study had fewer than 10 lesions, with 54 people having only a single lesion on their genitals, making confusion with herpes or syphilis possible.

Seventy people in the study were admitted to the hospital. Of those, 21 were hospitalized because of pain, mostly severe rectal pain. Others had eye lesions, kidney damage, inflammation of the heart or throat swelling that prevented the people from drinking.

Those complications fit with what health officials across the United States have seen. "While the mortality appears very low, which is great, the morbidity is actually much higher than any of us expected," Mary Foote, medical director of the New York City Department of Health and Mental Hygiene, said July 14 in a news briefing sponsored by the Infectious Diseases Society of America.

"A lot of people with this infection are really suffering, and some actually may be at risk for permanent damage and scarring. We've seen many people with symptoms that are so severe that they are unable to go to the bathroom, urinate or eat without excruciating pain," Foote said.

How it spreads

Monkeypox typically spreads among people through close contact with infected people or with clothing, bedding or towels used by people with the disease. People can get infected through droplets given off by infected people during close face-to-face interactions, such as close conversation, kissing or during medical exams. But patterns of infection clearly indicate that monkeypox isn't airborne the way the virus that causes COVID-19 or other respiratory viruses are, Kupferschmidt said.

> People "are really suffering, and some actually may be at risk for permanent damage and scarring."
> MARY FOOTE

A small number of women and children have also gotten monkeypox in the outbreak. Two children in the United States have been diagnosed, CDC director Rochelle Walensky said July 22 in an interview with the *Washington Post*. Both children were social contacts of men that have sex with men, she said.

"I don't think it's surprising that we are occasionally going to see cases in individuals who are not gay, bisexual or other men who have sex with men. The social networks we have as humans mean we have contact with a lot of different people," Jennifer McQuiston, deputy director of the CDC's Division of High Consequence Pathogens and Pathology said July 22 during a White House news briefing.

In the Netherlands, a child who had no contact with anyone known to be infected with the virus also got monkeypox, researchers report July 21 in *Eurosurveillance*. That boy's case raises the possibility that monkeypox may be spreading undetected more broadly in communities than realized. How the boy became infected is a matter of speculation. Examination of viral DNA showed that the boy isn't connected to any of the known cases in the Amsterdam region. He traveled to Turkey in June and may have gotten infected there or while traveling.

The boy has very low levels of IgA antibodies, which patrol mucous membranes and help prevent infections there. Low levels of the antibodies could make him vulnerable to respiratory infections.

Other details of how monkeypox spreads are still unknown. For instance, researchers don't know whether the virus can be transmitted through semen as a sexually transmitted disease. Researchers have found evidence of viral DNA in semen, saliva, urine and feces, but that may be inactive remnants. So far, no researchers have reported finding infectious virus in genital body fluids that might be exchanged during sex. Also unknown is whether getting infected through mucous membranes during sexual contact would shield against catching the virus later, Rimoin said.

Scientists are questioning whether the monkeypox virus has changed or whether it has simply found a niche social-sexual network among gay and bisexual men that may enable the virus to spread more efficiently, Titanji said. It may be that there are different transmission patterns in historically affected countries and newly affected countries that require different strategies to stop the spread, she said.

Researchers also need to do good studies to figure out how well vaccines and therapeutics work and under what circumstances, Rimoin said. The WHO emergency declaration includes recommendations for increasing testing and surveillance and for speeding up research on vaccines, treatments and other virus containment measures.

One thing is clear, Rimoin said. "We're giving this virus room to run like it never has before." The global health community hasn't paid enough attention to monkeypox, she said. Now, "it's everybody's problem to solve." ■

LIFE & EVOLUTION

Flower shape may impact bee health

Long, narrow blooms lessen the risk of catching a gut parasite

BY RACHEL CROWELL

Bees that land on short, wide flowers can fly away with an upset stomach.

Common eastern bumblebees (*Bombus impatiens*) are more likely to catch a diarrhea-inducing gut parasite from purple coneflowers (*Echinacea purpurea*), black-eyed Susans (*Rudbeckia hirta*) and other similarly shaped flora than from other flowers, researchers report in the July *Ecology*. Because parasites and diseases contribute to bee decline, the finding could help researchers create seed mixes that are more bee-friendly and inform gardeners' and land managers' decisions about which flower types to plant.

The parasite (*Crithidia bombi*) is transmitted when the insects accidentally ingest contaminated bee feces, which "tends to make the bees dopey and lethargic," says Rebecca Irwin, a community and evolutionary ecologist at North Carolina State University in Raleigh. "It isn't the number one bee killer out there," but bees sickened by the gut parasite can struggle with foraging.

In laboratory experiments involving caged bees and 16 plant species, Irwin and colleagues studied how different floral attributes affected *C. bombi* transmission. The team focused on three factors: the amount of poop landing on flowers when bees fly and forage, how long the parasite survives on the plants and how easily the parasite is transmitted to new bees. Together, these three factors show the overall transmission rate.

Compared with plants with long, narrow flowers such as phlox (*Phlox* spp.) and bluebeards (*Caryopteris* spp.), short, wide flowers had more feces land on them. Parasites didn't survive long on these blooms, probably because the open floral shapes increase exposure to ultraviolet light, speeding up the drying out of parasite-laden fecal droplets, Irwin says. Still, these flowers transmitted the parasite more easily to pollinators, thus increasing the overall transmission rate.

Bumblebees that land on coneflowers (one shown) and other short, wide blooms are more likely to contract a gut parasite than bees that land on longer, narrower flowers, scientists say.

The findings support a new theory suggesting that traits, such as flower shape, are better predictors of disease transmission than individual species of plants, says Scott McArt, an entomologist focusing on pollinator health at Cornell University who wasn't involved with the study. "You don't need to know everything about every plant species when designing your pollinator-friendly garden or habitat restoration project."

Instead, to limit parasite transmission among bees, it's best to choose plants that have long, narrow flowers, he says. "Wider and shorter flowers are analogous to the small, poorly ventilated rooms where COVID is efficiently transmitted among humans."

If ripping out coneflowers or black-eyed Susans isn't palatable, don't fret. Irwin recommends continuing to plant a diversity of flower types, which helps if one type of flower is "a high-transmitting species," she notes.

In the future, Irwin plans to conduct field experiments examining other factors that could influence parasite transmission, such as whether bees are driven to visit certain types of flowers more often than others in nature. ■

ATOM & COSMOS

Fermi bubbles trap galaxy scraps

Clouds within carry stuff from the Milky Way's disk and halo

BY LISA GROSSMAN

Huge bubbles of plasma billowing out from the Milky Way's center might contain scraps from all over the galaxy — and beyond.

A new look at gas clouds in the Milky Way's Fermi bubbles shows that the clouds contain stuff from the galaxy's starry disk and from some mysterious other source. The finding could shed light on how galaxies in general live and die, astronomers report July 18 in *Nature Astronomy*.

The Fermi bubbles are giant blobs of plasma, tens of thousands of light-years tall, that extend on either side of the Milky Way's galactic disk. When the bubbles were discovered in 2010, astronomers thought they could have been formed by simultaneously exploding stars (SN: 12/4/10, p. 18). These days, many astronomers are instead convinced the bubbles could have been blown by a massive, long-ago burp emitted from the galaxy's supermassive black hole.

In the years that followed the discovery, astronomers also spotted clouds of relatively cool gas that seem to flit around within the bubbles, high above the starry disk. "We call them high-velocity clouds, because we're not very good at naming things," says astrophysicist Trisha Ashley of the Space Telescope Science Institute in Baltimore.

Scientists thought the clouds had been ripped from the Milky Way's bright starry disk and sent flying when the Fermi bubbles formed. That assumption has been used to calculate things like the age of the bubbles, which could offer a clue to their origins. "It made sense, it was a logical assumption," Ashley says. "But no one had ever tested the origin of these clouds."

Now Ashley and colleagues have made a first effort to figure out where the clouds come from — and found a surprising answer.

Using new and archived data from several telescopes, she and her team measured the metal content—the abundances of all the elements heavier than helium—in 12 high-velocity clouds entrenched in the Fermi bubbles. Then the researchers compared the clouds' chemistries with those of stars in the Milky Way's disk. If the clouds really did come from the disk, then they should have metal contents similar to the sun and other disk stars, Ashley says. If not, the clouds' metal contents should be lower.

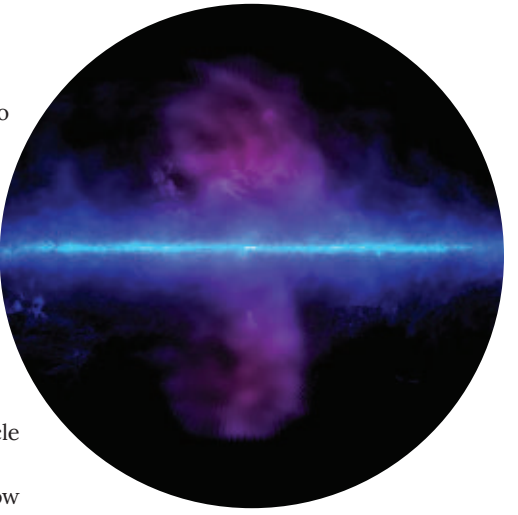
The team found a wide range of metal contents in the clouds, from less than a fifth of the sun's to more than the sun's. That means "these clouds have to originate in both the disk of the Milky Way and the halo of the Milky Way," she says, referring to the chaotic cloud of gas and dust that surrounds the galaxy and provides it with fuel for new stars (SN: 7/21/18, *p.* 16). "We haven't figured out any other explanation."

How those clouds got into the halo in the first place is still an open question, says Jessica Werk, an astronomer at the University of Washington in Seattle who was not involved in the study.

"There's a number of ways these clouds can be produced, a number of origins and a number of fates," Werk says. The clouds could have condensed within the halo on their own, or they could have been ripped from smaller galaxies cannibalized by the Milky Way, or a number of other origin stories (SN: 7/27/02, *p.* 52). "This cycle in general is a very messy process."

That messiness could help predict how the Milky Way's star formation could change in the future. Cold gas clouds like these are the fuel for future star formation. If these clouds were born in the Milky Way's gaseous halo but are being buoyed up by the Fermi bubbles instead of falling into the disk to form stars, that could eventually slow down the galaxy's star-forming factories.

But if the gas clouds do end up falling into the disk and forming new stars, that could mean the Milky Way is building new stars from a variety of cosmic sources.



Giant plasma bubbles (purple) in the Milky Way contain clouds made of material from its disk (blue) and halo, a study suggests.

"Ultimately what people are interested in is, how does the Milky Way sustain its star formation for a long time?" Werk says. "This tells you it's not just one thing."

Studying these bubbles and clouds can help astronomers understand other galaxies, too. "We can see these things going on in other galaxies," Ashley says. "But we have a front-row seat to this one." ■

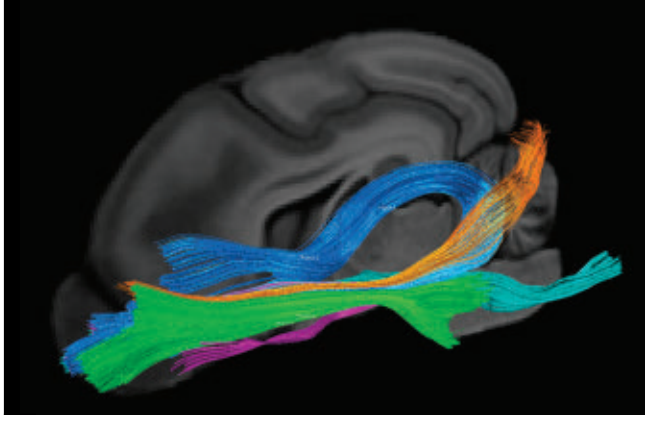
FROM TOP: FERMI LAT COLLABORATION, DOE, NASA; P. JOHNSON, GENERATED USING TRACKVIS SOFTWARE

LIFE & EVOLUTION

New nose-to-brain link ID'd in dogs

A dog's brain is wired for smell. Now, a new map shows just how extensive that wiring is.

Powerful nerve connections link the dog nose to wide swaths of the brain, researchers report July 11 in the *Journal of Neuroscience*. One of these canine connections, a hefty link between areas that handle smell and vision, hasn't been seen before in any species, including humans. The results offer a first-of-its-kind anatomical description of how dogs "see" the world with their noses. The new brain map is "awesome, foundational work," says Eileen Jenkins, a retired army veterinarian and expert on working dogs. "It's going to revolutionize how we understand cognition in dogs."



Dogs are superb sniffers. Their noses hold between 200 million and 1 billion odor molecule sensors, compared with the estimated 5 million receptors in a human nose. And the canine olfactory bulb, a brain structure that sits behind the eyes and is an early stop for odor information, can be up to 30 times larger than a human's. Pip Johnson, a veterinary radiologist and neuroimaging expert at Cornell University College of Veterinary Medicine, wanted to know how smell information wafts beyond the obvious sniffing equipment.

The map (left), based on brain data from 20 mixed-breed dogs and three beagles, contains some familiar paths. It shows the tracts of white matter fibers that carry signals from the olfactory system (bottom left) to brain areas associated with memory and emotion (blue), instinctual behaviors (turquoise), odor perception (green) and memory (pink). But one road (orange), which connects the olfactory bulb to the occipital lobe, the part of the dog brain that handles vision, is totally new.

The connection suggests dog sight and smell are intricately linked. Perhaps that explains why smell can often compensate when a dog loses its sight, Johnson says. "Blind dogs can still play fetch." —*Laura Sanders*

EARTH & ENVIRONMENT

A new look at the 'mineral kingdom'

Classification system might transform the search for life

BY ASA STAHL

If every mineral tells a story, then geologists now have their equivalent of *The Arabian Nights*.

For the first time, scientists have cataloged every different way that every known mineral can form and put all of that information in one place. This collection of mineral origin stories hints that Earth could have harbored life earlier than previously thought, quantifies the importance of water as the most transformative ingredient in geology and may change how researchers look for signs of life and water on other planets.

"This is just going to be an explosion," says Robert Hazen, a mineralogist and astrobiologist at the Carnegie Institution for Science in Washington, D.C. "You can ask a thousand questions now that we couldn't have answered before."

For more than 100 years, scientists have defined minerals by their structure and chemistry. But that can make for an incomplete picture. For instance, though all diamonds are a kind of crystalline carbon, three different diamonds might tell three different stories, Hazen says. One could have formed 5 billion years ago in a distant star, another may have been born in a meteorite impact and a third could have been baked deep below Earth's crust.

So Hazen and colleagues set out to define a different approach to mineral classification. This new angle focuses on thinking about minerals as things that evolve out of the history of life, Earth and the solar system, he and his team report in a pair of studies in the July issue of *American Mineralogist*. The team defined 57 main ways that the "mineral kingdom" forms, with options ranging from condensation out of the space between stars to precipitation in the excrement of bats.

The information in the catalog isn't new, but it was previously scattered throughout thousands of scientific papers. The "audacity" of the work, Hazen says, was to compile all that information for the more than 5,600 known types of minerals. That makes the catalog a one-stop shop for anyone who wants to use minerals to understand the past.

The compilation also allowed the team to think about mineral evolution from a broader perspective. Patterns immediately popped out. One of the new studies shows that more than 60 percent of all known mineral kinds form in ways that ought to have been possible on the newborn Earth. The implication: Of all the geologic environments that scientists have considered as potential crucibles for the beginning of life on Earth, most could have existed as early as 4.3 billion years ago. Life, therefore, may have formed almost as soon as Earth did, or at the very least, had more time to arise than most scientists have thought. The oldest known rocks with traces of life date to roughly 3.7 billion years ago (SN: 4/1/17, p. 6).

"That would be a very, very profound implication—that the potential for life is baked in at the very beginning of a planet," says Zachary Adam, a paleobiologist at the University of Wisconsin–Madison who was not involved in the new studies.

But the exact timing of when conditions ripe for life arose is based on "iffy" models, says Frances Westall, a geobiologist at the Center for Molecular Biophysics in Orléans, France, who was also not part of Hazen's team. Westall thinks that scientists need more data before they can be sure. But, she says, "the principle is fantastic."

The new results also show how essential water has been to making most of the minerals on Earth. Roughly 80 percent of known mineral types need H_2O to form, the team reports.

"Water is just incredibly important," Hazen says, adding that the estimate is conservative. "It may be closer to 90 percent." Taken one way, this means that if researchers see water on a planet like Mars, they can guess that it might have a rich mineral ecosystem. But flipping this idea may be more useful: Scientists could identify what minerals are on the Red Planet and then use the new catalog to work backward and figure out what its environment was like in the past. A group of minerals, for example, might be explainable only if there had been water, or even life.

Right now, scientists do this sort of detective work on just a few minerals at a time. But if researchers want to make the most of the samples collected on other planets, something more comprehensive is needed, Adam says, like the new study's framework.

And that's just the beginning. "The value of this [catalog] is that it's ongoing and potentially multigenerational," Adam says. "We can go back to it again and again and again for different kinds of questions."

There is a lot more that scientists can do, agrees Carnegie mineralogist Shaunna Morrison, a coauthor of the new studies. "We're just scratching the surface." ■

Calcite can form in at least 17 different ways, more than almost any other mineral. This calcite formed in a cave and got its distinctive shape from changing water levels.

ROB LAVINSKY/ARKENSTONE

ATOM & COSMOS

New detector joins dark matter hunt

The LZ experiment finds no sign of the elusive substance — yet

BY EMILY CONOVER

The next generation of dark matter detectors has arrived.

A massive new effort to detect the elusive substance has reported its first results. Following a time-honored tradition of dark matter hunters, the experiment, called LZ, didn't find dark matter. But it has found nothing better than ever before, physicists reported July 7 in a virtual webinar and in a paper posted July 8 at arXiv.org. With several additional years of data collection planned for LZ and similar experiments, physicists are hopeful they'll finally get a glimpse of the stuff.

"Dark matter remains one of the biggest mysteries in particle physics today," LZ spokesperson Hugh Lippincott, a physicist at the University of California, Santa Barbara, said during the webinar.

LZ, or LUX-ZEPLIN, aims to discover the unidentified particles that are thought to make up most of the universe's matter. Although no one has ever conclusively detected dark matter, its influence can be seen in the motions of stars and galaxies.

About 1.5 kilometers underground at the Sanford Underground Research Facility in Lead, S.D., the LZ detector is filled with 10 metric tons of liquid xenon. If any dark matter particles crash into nuclei of the xenon atoms, they would produce flashes of light that the detector would pick up.

> "Dark matter remains one of the biggest mysteries in particle physics today."
>
> HUGH LIPPINCOTT

The experiment is one of a new generation of bigger, badder detectors based on liquid xenon, which also includes XENONnT at Gran Sasso National Laboratory in Italy and PandaX-4T at the China Jinping Underground Laboratory. All three experiments aim to detect a theorized type of dark matter called weakly interacting massive particles, or WIMPs. Scientists scaled up the search to improve the chance of spying WIMPs; each detector contains multiple tons of liquid xenon.

Using only about 60 days of data, LZ has already surpassed earlier efforts to pin down WIMPs, setting a stricter limit on the probability that a WIMP will interact with a nucleus (SN: 6/23/18, *p.* 13). "It's really impressive what they've been able to pull off," says theoretical physicist Dan Hooper of Fermilab in Batavia, Ill.

Though the search came up empty, "the way something's going to be discovered is when you have multiple years in a row of running," says LZ collaborator Matthew Szydagis, a physicist at the University at Albany in New York. LZ is expected to run for about five years. That data may provide a better chance to find the particles. ■

EARTH & ENVIRONMENT

Automation builds a better ice tower

Ice stupas can help communities cope with climate change

BY NIKK OGASA

There's a better way to build a glacier.

During winter in India's mountainous Ladakh region, some farmers use pipes and sprinklers to construct building-sized cones of ice. These towering, humanmade glaciers, called ice stupas, slowly release water as they melt during the dry spring months for communities to drink or irrigate crops. But the pipes often freeze when it gets too cold, stifling construction.

Now, early results show that an automated system can prevent frozen pipes, using local weather data to control when and how much water is spouted. What's more, the system uses a lot less water than the usual method, researchers reported June 23 at the Frontiers in Hydrology meeting in San Juan, Puerto Rico.

"This is one of the technological steps forward that we need to get this innovative idea to the point where it's realistic as a solution," says glaciologist Duncan Quincey of the University of Leeds in England who was not part of the research.

Ice stupas were invented in 2013 as a way for typically alpine communities to cope with shrinking glaciers due to human-caused climate change. Glacial meltwater that would otherwise be lost is piped into gravity-driven fountains that sprinkle continuously in the winter. The drizzle freezes, creating frozen cones that can store millions of liters of water.

It's simple but inefficient. More than 70 percent of the spouted water may flow away instead of freezing, says glaciologist Suryanarayanan Balasubramanian of the University of Fribourg in Switzerland. So he and his team connected an ice stupa's fountain to a computer system that automatically adjusts the flow rate based on local temperatures, humidity and wind speed. The fountain activates only when conditions are right for the spouted water—not water in the pipes—to freeze.

In India's Ladakh region, some communities store water for later use by creating giant cones of ice, known as ice stupas.

In tests of the system in Switzerland, a continuously sprinkling fountain spouted about 1,100 cubic meters of water and amassed 53 cubic meters of ice after four months, with pipes freezing once. The automated system sprayed around 150 cubic meters of water but formed 61 cubic meters of ice, and no frozen pipes.

Next comes making the system more affordable. "We eventually want to reduce the cost so that it is within two months of salary of the farmers in Ladakh," says Balasubramanian. "Around $200 to $400." ■

EARTH & ENVIRONMENT

Reusing the heat beneath our feet

Recycling heat leaked into earth could warm buildings

BY NIKK OGASA

The secret to efficiently heating some buildings might lurk beneath our feet, in heat inadvertently stored underground.

Just as cities warm the surrounding air, giving rise to urban heat islands, so too does human infrastructure warm the underlying earth (SN: 4/11/09, p. 26). An analysis of groundwater well sites across Europe and parts of North America and Australia now reveals that roughly a couple thousand of those locations possess excess underground heat that could be recycled to warm buildings for a year, researchers report July 8 in *Nature Communications*.

What's more, even if humans managed to remove all this accumulated thermal pollution, existing infrastructure at about a quarter of the locations would continue to warm the ground enough that heat could be harvested for many years to come. That could reduce reliance on fossil fuels and help mitigate climate change.

"There's a lot of untapped potential out there," says Grant Ferguson, a hydrogeologist at the University of Saskatchewan in Saskatoon, Canada, who was not involved in the study.

Groundwater warmed by all that trapped heat and piped to the surface could heat buildings, says Susanne Benz, an environmental scientist at Dalhousie University in Halifax, Canada, providing some communities with a reliable and low-energy means to warm homes. "And if we don't use it, it will just continue to accumulate," Benz says.

She and colleagues analyzed population density, heating demand and groundwater temperature at more than 6,000 locations, most in Europe. About 43 percent—mostly in or near highly populated areas—had accumulated enough heat in the top 20 meters of earth to satisfy a year's worth of the local heating demand. At about 25 percent of the 6,000 locations, heat continuing to leak from existing infrastructure could be harvested. That ongoing harvesting could satisfy at least a quarter of demand at 18 percent of locales.

Constructing systems to take advantage of human heat pollution today could one day help residents harvest heat from climate change, the researchers say.

Using climate projections, the team explored the feasibility of extracting underground heat in a warmer world. In a best-case scenario that assumes greenhouse gas emissions peak at about the year 2040, climate change would warm the ground enough by the end of the century that underground heat recycling at 81 percent of the locales could meet more than a quarter of local heating demand. ■

S. BALASUBRAMANIAN/ICESTUPA PROJECT

LIFE & EVOLUTION

How dinos survived Triassic cold snaps

Feathers may have offered insulation during volcanic winters

BY CAROLYN GRAMLING

Widespread volcanic eruptions around 202 million years ago triggered a mass extinction that killed off three-fourths of the planet's species, including many large reptiles. Yet dinosaurs, somehow, survived.

Dinosaurs are often thought of as heat-loving, well suited to the steamy Triassic Period. But their secret to survival may have been adaptation to the cold. Their warm coats of feathers could have helped them weather relatively brief but intense bouts of volcanic winter associated with the massive eruptions, researchers report July 1 in *Science Advances*.

"We've known for a while that there were probably volcanic winters" associated with the massive eruptions, says paleontologist Paul Olsen of the Lamont-Doherty Earth Observatory at Columbia University. Along with carbon dioxide, volcanoes spew sulfur particles into the atmosphere that can darken skies for years and lower global temperatures.

In the new study, Olsen and colleagues present the first physical evidence that not only did such winters occur at the end of the Triassic, but also that dinosaurs were there to weather them. At a site called the Junggar Basin, which was high in the Arctic Circle at the close of the Triassic, the team identified rock fragments that could only have been deposited by ancient ice alongside the footprints of dinosaurs.

PAINTING BY LARRY FELDER

A feathered theropod dinosaur snags a snack amid a volcanic winter in this artist's rendition.

"There is a stereotype that dinosaurs always lived in lush tropical jungles," says Stephen Brusatte, a paleontologist at the University of Edinburgh not involved in the new study. "But this new research shows convincingly that the higher latitudes would have been freezing and even covered in ice during parts of the year" at the beginning of the rise of the dinosaurs.

> "There is a stereotype that dinosaurs always lived in lush tropical jungles."
>
> **STEPHEN BRUSATTE**

The Triassic ended with a bang beginning about 202 million years ago, as supercontinent Pangaea began to break apart. Massive volcanic eruptions burst forth as the crust split, opening up a basin that became the Atlantic Ocean. The hardened lava from those eruptions now spans 7 million square kilometers across Africa, Europe and North and South America, forming a rock sequence known as the Central Atlantic Magmatic Province, or CAMP.

Carbon dioxide levels were very high in the late Triassic and early Jurassic, much of it now thought to have been pumped into the atmosphere by those eruptions. Earth has been assumed to have been in a steamy greenhouse state, with thick forests extending into polar regions.

The Junggar Basin, in what's now northwestern China, was covered with forests of conifers and deciduous trees growing alongside a massive ancient lake. Dinosaurs certainly lived there: No bones have yet been discovered, but footprints are preserved in the shallow-water siltstones and sandstones that formed at the bottom of the lake.

The new data suggest that—despite the extremely high CO_2 levels—this region also experienced harsh, frigid winters, with the lake at least partially freezing over. Analyzing the distribution of grain sizes in the same rocks that bear the footprints, the researchers determined that a large portion of the grains weren't part of the original lake mud, but had been carried there from elsewhere.

The most likely explanation, Olsen says, is that these grains are "ice-rafted debris"—a well-known phenomenon in which bits of rock freeze to the base of ice along a shoreline, and then hitch a ride as the ice eventually drifts into open water. As the floating ice melts, the bits of rock sink, deposited in new territory.

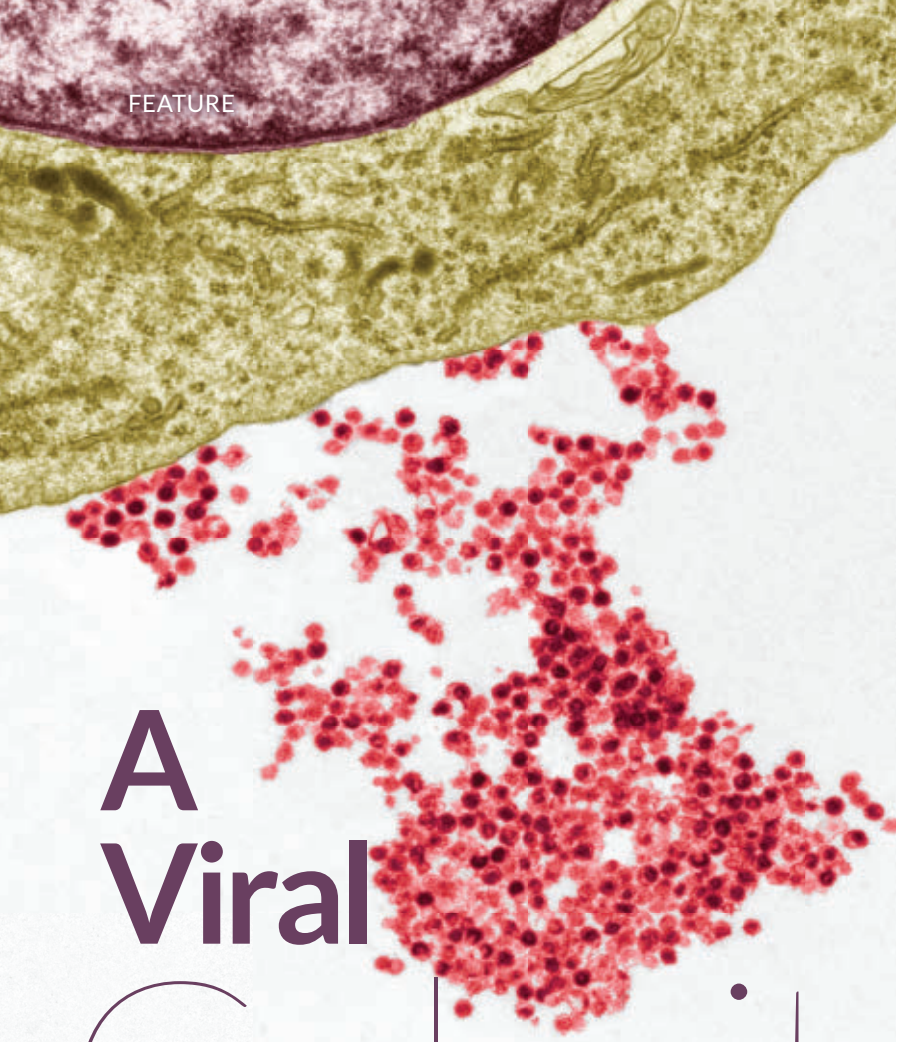
Volcanic winters might last for tens or even hundreds of years, Olsen says. The huge sheets of lava linked to the CAMP eruptions point to at least tens of thousands of years of eruption pulses, maybe even a million years. That could have kept the winters going long enough to drive many less-well-insulated reptiles off the face of the Earth, he adds. Episodes of those freezing conditions may have even extended all the way to the tropics, the team says.

Evidence of feathers has been found in the fossils of many types of dinosaurs. Recent reports that flying reptiles called pterosaurs also had feathers suggest that the insulating fuzz may have appeared as early as 250 million years ago.

Thanks to those insulating feathers, dinosaurs were able to survive the lengthy winters that ensued during the end-Triassic mass extinction, Olsen and colleagues say. Dinosaurs might then have been able to spread rapidly during the Jurassic, occupying niches left vacant by less hardy reptiles.

That dinosaurs living in the far north were able to survive due to feathery insulation makes sense, says paleontologist Randall Irmis of the University of Utah in Salt Lake City, who was not connected with the study. But whether a volcanic winter could have frozen the tropics too—giving dinosaurs a similar advantage there—isn't yet clear.

Feathers are probably just one of many reasons why dinosaurs diversified and spread rapidly, Irmis says. "There's a lot that plays into why they became such a successful group." ■



A Viral Culprit for Multiple Sclerosis

Researchers pivot to drugs and vaccines against Epstein-Barr virus

By Erin Garcia de Jesús

As Tanina Agosto went through her normal morning routine in July 2007, she realized something was wrong. The 29-year-old couldn't control her left side, even her face. "Literally the top of my head to the bottom of my foot on the left side of my body could not feel anything."

Epstein-Barr viruses (red) emerge from an immune system B cell in this colorized electron micrograph.

The next day, Agosto spoke with a doctor at the New York City hospital where she works as a medical secretary. He told her that she probably had a pinched nerve and to see a chiropractor.

But chiropractic care didn't help. Months later, Agosto needed a cane to get around, and moving her left leg and arm required lots of concentration. She couldn't work. Numbness and tingling made cooking and cleaning difficult. It felt a bit like looping a rubber band tightly around a finger until it loses sensation, Agosto says. Once the rubber band comes off, the finger tingles for a bit. But for her, the tingling wouldn't stop.

Finally, she recalls, one chiropractor told her, "I'm not too big of a person to say there's something very wrong with you, and I don't know what it is. You need to see a neurologist." In November 2008, tests confirmed that Agosto had multiple sclerosis. Her immune system was attacking her brain and spinal cord.

Agosto knew nothing about MS except that a friend of her mother's had it. "At the time, I was like, there's no way I've got this old lady's condition," she says. "To be hit with that and know that there's no cure—that was just devastating."

Why people develop the autoimmune disorder has been a long-standing question. Studies have pointed to certain gene variations and environmental factors. For decades, a common virus called Epstein-Barr virus has also been high on the list of culprits.

Now recent studies paint a clearer picture that Epstein-Barr virus instigates MS when the central nervous system gets caught in the cross hairs of an immune response to the virus's attack. This recognition opens new options for treatment, or even vaccines. Perhaps therapies that target Epstein-Barr itself—or remove the cells in the body where the virus camps out—could jettison the virus before damage is done.

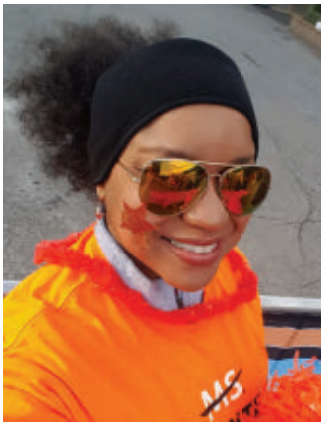
Vaccines might one day "make multiple sclerosis become a historical disease like polio," says Lawrence Steinman, a neurologist at Stanford University. "The trials will be arduous," Steinman says. Still, "I think we might be able to put MS in the rearview mirror."

For now, there's a lot to learn, including how exactly the virus triggers MS, says Francesca Aloisi, a neuroscientist at the Italian National Institute of Health in Rome.

For many people with MS, even with current therapies, the disease can progress. Right now, Agosto's symptoms are largely under control. Thanks to physical therapy, an anti-inflammatory diet and medication, she has about 90 percent function on the left side of her body. "Things like long-distance running are out of the question," she says. Carrying grocery bags with her left arm is a challenge.

STEVE GSCHMEISSNER/SCIENCE SOURCE

Studying the virus's role in MS "will be an amazing game changer," says Agosto, who is a patient advocate with the National Multiple Sclerosis Society's New York City chapter. If Epstein-Barr virus is driving her disease, she wants to know: "How do we get this virus out of the driver's seat?"



Tanina Agosto, diagnosed with multiple sclerosis in 2008, is now an advocate for people with the disease. Her symptoms are currently under control.

A familiar virus

Multiple sclerosis is an uncommon disease, affecting nearly 3 million people globally. Yet Epstein-Barr virus is almost everywhere.

The virus, discovered in 1964, infects an estimated 90 percent of people around the world. People infected as young children might have a mild cold or show no symptoms. Teenagers or young adults may experience a bout of debilitating fatigue called infectious mononucleosis, or mono, that can last weeks or months.

These symptoms eventually fade. But Epstein-Barr infections hang on. The virus belongs to the herpesvirus family — a group known for instigating lifelong infections. The herpesviruses behind cold sores, genital herpes and chicken pox also stick around for life, usually staying quiet for long stretches. For example, varicella-zoster virus, which causes chicken pox, goes latent inside nerve cells but can resurface to cause the painful disease shingles (SN: 3/2/19, p. 22).

In the body, Epstein-Barr virus slips into the epithelial cells that line the surface of the throat, allowing the virus to spread to other people via saliva — hence mono's nickname, "the kissing disease." The virus also infects a type of immune cell called B cells, where it enters viral hibernation.

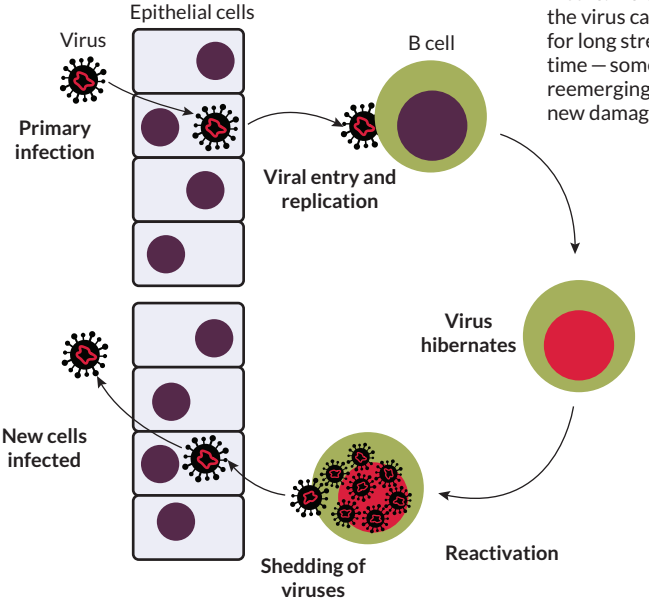
Epstein-Barr virus can cause problems long after the initial infection. People who had mono are more likely to develop cancers such as Hodgkin's lymphoma than people who didn't. And they are more likely to be diagnosed with MS. A teenage case of mono doesn't mean long-term problems are inevitable. But avoiding mono-related fatigue doesn't guarantee an escape from risk either. Agosto, for instance, doesn't recall ever having mono.

Establishing the link

In March 2000, epidemiologist Alberto Ascherio of the Harvard T.H. Chan School of Public Health published research exploring the link between Epstein-Barr virus and MS. With colleague Mette Munch of the University of Aarhus in Denmark, Ascherio analyzed data from eight studies suggesting that MS patients are more likely to have had an Epstein-Barr infection than those without MS. Studies over the next 20 years continued to hint that the virus plays a role, but "the problem is to go from a suggestion or suspicion to proof," says Ascherio. Getting that proof is difficult, because nearly everyone has been infected with Epstein-Barr virus, or EBV, yet very few have MS.

"If it's true that EBV causes MS, then you would expect to find that those individuals who are not infected with EBV, they will not get MS," Ascherio says. "It's very simple." He and colleagues needed to follow a large group of young adults who had never been infected.

The researchers found such a group in the U.S. military. Through the Department of Defense Serum Repository, the team had access to repeated blood samples from more than 10 million individuals, taken when active-duty members were screened for diseases such as HIV at the start of their service and then every two years. Using blood samples taken between 1993 and 2013, Ascherio and colleagues could identify people who had never been infected with Epstein-Barr virus, track new infections and learn when people who



Lifelong infection
Epstein-Barr virus infects the throat's epithelial cells and the immune system's B cells. Inside B cells, the virus can hibernate for long stretches of time — sometimes reemerging and doing new damage.

FROM TOP: ADRIAN AGOSTO; T. TIBBITTS

developed MS started showing symptoms.

Over that 20-year span, 801 people whose blood was tested were diagnosed with MS. Thirty-five of those people had no signs of Epstein-Barr virus infection in their first blood sample. But all but one became infected before their MS diagnosis. People infected with the virus were 32 times as likely to develop MS as uninfected people. What's more, the researchers found that blood concentrations of a nervous system protein that is a signal of nerve damage rose after Epstein-Barr virus infection, before an MS diagnosis. The results prompted Ascherio and his team to make a bold claim in *Science* in January: "These findings cannot be explained by any known risk factor for MS and suggest EBV as the leading cause of MS."

It is still possible that infection with Epstein-Barr virus is a time stamp for something else, perhaps not yet identified, that's also relevant for MS, says Mark Allegretta, vice president of research at the National Multiple Sclerosis Society. "The way we talk about it now is that it's very strong evidence that it's necessary for development of MS, but it's insufficient on its own."

Ascherio isn't deterred. "After 20 years of talking about EBV and MS, it's quite exciting that we've finally nailed it down," he says. "There was a lot of skepticism until now and that is fading away."

32
times
Increased chance of developing MS if infected with Epstein-Barr virus, in one study
SOURCE: K. BJORNEVIK *ET AL*/ *SCIENCE* 2022

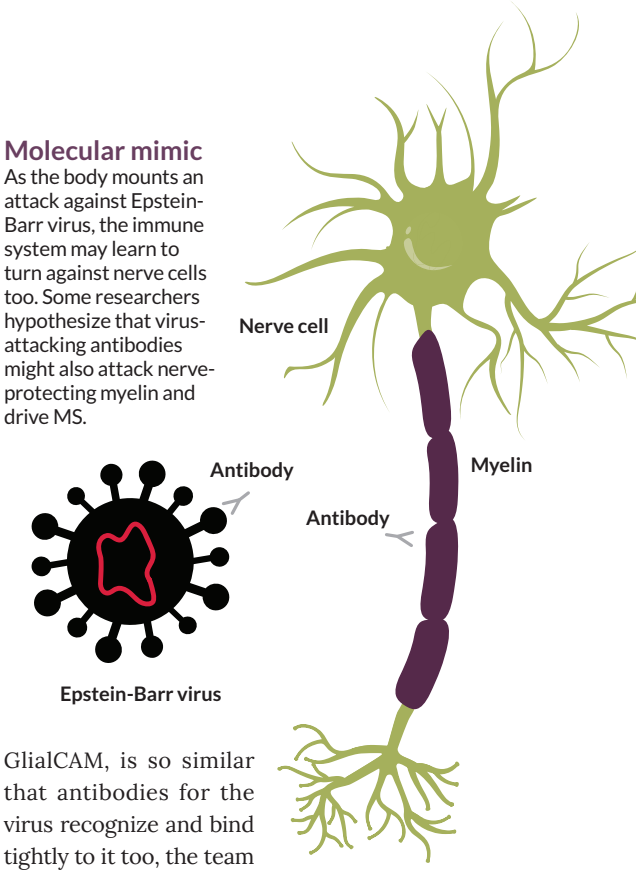
A skeptic convinced

The fact that Epstein-Barr virus is implicated in so many diseases had many researchers skeptical of its link to MS, says Tobias Lanz, a neurologist at Stanford University. "It's involved in tumors, it's involved in MS, it's involved in lupus, it's in chronic fatigue syndrome. Somehow, people link it to everything and that makes us reasonably suspicious."

Lanz's mentor, Stanford rheumatologist William Robinson, was one of those skeptics. Once Lanz, Robinson and their colleagues found hints of how Epstein-Barr virus could spark nerve damage, however, Robinson became a believer.

The team discovered that immune proteins called antibodies from some MS patients attach to a key Epstein-Barr virus protein, as well as to a protein from the central nervous system. This finding, described in the March 10 *Nature*, suggests that as the immune system learns how to recognize the virus, it may also learn to attack nerve cells.

The viral protein, called EBNA1, helps Epstein-Barr virus persist in the body for life, hidden away inside B cells. Its molecular twin in the central nervous system, a portion of a protein called GlialCAM, is so similar that antibodies for the virus recognize and bind tightly to it too, the team found in lab experiments.



Molecular mimic
As the body mounts an attack against Epstein-Barr virus, the immune system may learn to turn against nerve cells too. Some researchers hypothesize that virus-attacking antibodies might also attack nerve-protecting myelin and drive MS.

W.H. ROBINSON AND L. STEINMAN/SCIENCE 2022; T. TIBBITTS

"That really changed everything," Robinson says, calling it "an in-your-face result that you can't dismiss as not being real." In addition to adding to the evidence that Epstein-Barr virus causes MS, the finding also provides a hint of a possible mechanism: GlialCAM is found in glial cells, which support nerve cells and form the insulating layer myelin that helps nerve cells send signals (SN: 8/22/15, p. 18). Myelin is the very thing that is destroyed in MS.

About a quarter of patients in the study had antibodies that recognize both EBNA1 and GlialCAM. The similarities between the two proteins, called molecular mimicry, means that EBNA1 may not be a good viral protein to include in vaccines to curb diseases related to Epstein-Barr virus, says Steinman, the Stanford neurologist, who was also involved with the research. If the virus indeed sparks an autoimmune reaction, vaccines that target this viral protein or other mimics could harm myelin and spur MS.

Viral damage

Several studies support the idea that molecular mimicry causes MS damage. But other hypotheses are on the table.

Those B cells, for instance, where Epstein-Barr viruses hide out, produce antibodies. One possibility is that B cells infected with Epstein-Barr virus transform in ways that encourage the immune system to attack the body's own tissues.

Aloisi, the neuroscientist in Rome, backs a different hypothesis: Perhaps the immune system's attack on the virus itself is behind the damage.

"The biology of the virus is so similar to the biology of the disease," Aloisi says. For some people, MS can go through phases of silence where the disease is stable, no better, no worse. The disease then reactivates, producing new brain lesions and worsening symptoms. Epstein-Barr virus can similarly come out of latency, perhaps causing a surge of problems before returning to hibernation inside host cells.

In 2007, Aloisi and colleagues discovered unexpected clusters of B cells within the membranes that cover and protect the brain. In all but one of 22 patients studied, some of those B cells were infected with Epstein-Barr virus.

The finding "was like a bomb in the field," Aloisi says, "because nobody ever thought about this possibility." Other researchers initially failed to replicate the results. But "little by little other work came out [in support]," she says. "It's difficult to find these [clusters of B cells] in the brain because people with MS don't have large, inflamed brains. It's small spots here and there."

> "We need something that targets the EBV-infected cells, not all of the B cells."
>
> **FRANCESCA ALOISI**

It's possible that the central nervous system becomes a stronghold for the virus, Aloisi says. Immune cells called T cells, which can either coordinate an attack or kill infected cells, rush in. Some virus-infected B cells die, but the immune system can't eliminate the virus. Myelin gets caught in the cross fire. "This creates a situation that is extremely detrimental to the tissue," she says.

Treatment tactics

Regardless of whether Epstein-Barr virus drives MS symptoms directly or causes the body's immune response to go haywire, the big question is what to do about it.

One obvious path is to develop MS drugs that go after the virus, Aloisi says. Some drugs that block hepatitis B virus and HIV have shown potential against Epstein-Barr virus in lab-grown cells, says Ascherio, the Harvard epidemiologist. But those results are very preliminary.

Another option is to go after the infected cells. A few MS therapies may do that already. The existing MS therapy natalizumab already prevents B and T cells from crossing into the central nervous system. Fingolimod may do that as well. Another drug called ocrelizumab, approved for patients with MS in 2017, is an antibody that attaches to a protein on B cells and triggers cell death. The drug helps patients, like Agosto, who have relapsing-remitting MS, but it's less effective for people with a progressive form of the disease, who have fewer treatment options (SN: 12/9/17, *p.* 20).

Researchers thought the drug dampened faulty immune responses by depleting B cells, Lanz says. "But it could also well be that we're hitting those particular pathogenic B cells that are infected with Epstein-Barr virus. So the B cell depletion might actually be an anti-EBV drug and nobody appreciated that."

Aloisi agrees. "Now we need something that targets the EBV-infected cells, not all of the B cells," she says. Indiscriminately killing B cells puts patients at risk for other infections. One way to get around that could come in the form of T cell therapies that go after only infected cells. Such therapies are already in clinical trials in MS patients.

Some researchers suspect that antiviral treatments would probably make the most sense when used early on, before the immune system eats away at the myelin around the nerve cells. Once the virus has kick-started an immune response to attack the nervous system, "the train may already be out of the station," says neuroimmunologist Emily Harrington of Ohio State University's Wexner Medical Center in Columbus.

A vaccine

Even better than stopping the infection once it starts would be to build defenses before the virus invades, or to stop it from reawakening. Enter vaccines.

The widespread impact of mono and Epstein-Barr virus's links to cancer and autoimmune disease had already spurred vaccine research, so a few potential shots are already in the pipeline. But Epstein-Barr virus has a complex way of invading the body, says vaccinologist Javier Gordon Ogembo of City of Hope, a cancer care center in Duarte, Calif. The virus uses at least five viral proteins to invade both epithelial cells and B cells. A vaccine would need to drive an immune response that blocks the virus's entry into both cell types to prevent infection. "This is the reason, I think, why there has not been a vaccine so far," Ogembo says.

Pharmaceutical company GlaxoSmithKline took

Vaccine options
Recent studies suggest that vaccines being developed to prevent diseases related to Epstein-Barr virus, or EBV, such as mononucleosis or cancer, might also work for multiple sclerosis.

Vaccine	How it works	Developed for	Stage of development
Moderna mRNA vaccine	Uses mRNA to teach the body to recognize four viral proteins that help EBV enter epithelial and B cells	Mononucleosis	Phase I clinical trial
NIH nanoparticles vaccine	Teaches the body to attack a protein called gp350, which EBV uses to infect B cells	Mono and cancer	Phase I clinical trial
City of Hope modified virus vaccine	Delivers DNA to cells so the cells can make and teach the immune system to recognize five viral proteins that help EBV enter epithelial and B cells	Mono and cancer	Animal studies
BioNTech mRNA vaccine	Blocks myelin attack	MS	Animal studies

one vaccine candidate to clinical trials in the early 2000s. It seemed to stop people from developing mono, but it didn't meet the original goal of preventing infection overall. So the company abandoned the vaccine.

Moderna, the biotechnology company made famous for its effective COVID-19 vaccine, recently launched a clinical trial of an mRNA vaccine for Epstein-Barr virus. The shot teaches the body to recognize four of the five viral proteins that help the virus invade both cell types, says viral immunologist Katherine Luzuriaga of the University of Massachusetts Chan Medical School in Worcester, who is involved in the trial. For now, the team is testing whether the vaccine sparks a strong immune response and getting a sense for whether it might curb cases of mono.

In March, the U.S National Institutes of Health launched a clinical trial to test a vaccine that uses nanoparticles to teach the body to recognize the virus and get rid of it. Ogembo and colleagues at City of Hope are developing another vaccine that uses a modified virus as the immune system's instructor.

Although clinical trials could reveal within the next few years whether the vaccines can control mono, it will be decades before researchers learn anything about the potential impact on cancer or MS, Luzuriaga and Ogembo say. The hope is to see an outcome like the vaccines for human papillomaviruses, Luzuriaga says, which reduce the number of HPV infections and led to a dramatic reduction in cervical cancers.

Developing therapeutic vaccines for people who already have MS may also be possible, Ascherio says. The aim would be to stop the virus from emerging from its slumber inside B cells. It would be akin to the shingles vaccine, which prevents the painful reactivation of varicella-zoster virus in nerve cells.

That is Steinman's aim as well, but he envisions a shot that would put a check on the undesirable immune response. Steinman and colleagues have tested such a vaccine to try and teach MS patients' immune systems to ignore and not harm a protein called myelin basic protein, which helps add myelin to nerves. There were hints the vaccine might have been effective, but the team ultimately stopped the project.

"If it weren't for other very powerful therapies becoming approved in that same time frame, we may have continued," Steinman says. Now, he wants to make a vaccine that helps MS patients tolerate, rather than attack, the central nervous system protein GlialCAM.

Researchers at BioNTech, also famous for developing a COVID-19 vaccine, are working on something similar. In mice with a disease close to MS, the company showed that an mRNA vaccine could keep the immune system from attacking myelin proteins, the team reported in January 2021 in *Science*.

Time will tell how effective any of these shots might be. But with studies providing more and more evidence that Epstein-Barr virus is linked to many diseases, Ogembo says, "it's time to make a vaccine and get rid of it." ■

Explore more

- Gabriela M. Escalante *et al*. "Four decades of prophylactic EBV vaccine research: A systematic review and historical perspective." *Frontiers in Immunology*. April 14, 2022.
- Kjetil Bjornevik *et al*. "Longitudinal analysis reveals high prevalence of Epstein-Barr virus associated with multiple sclerosis." *Science*. January 13, 2022.

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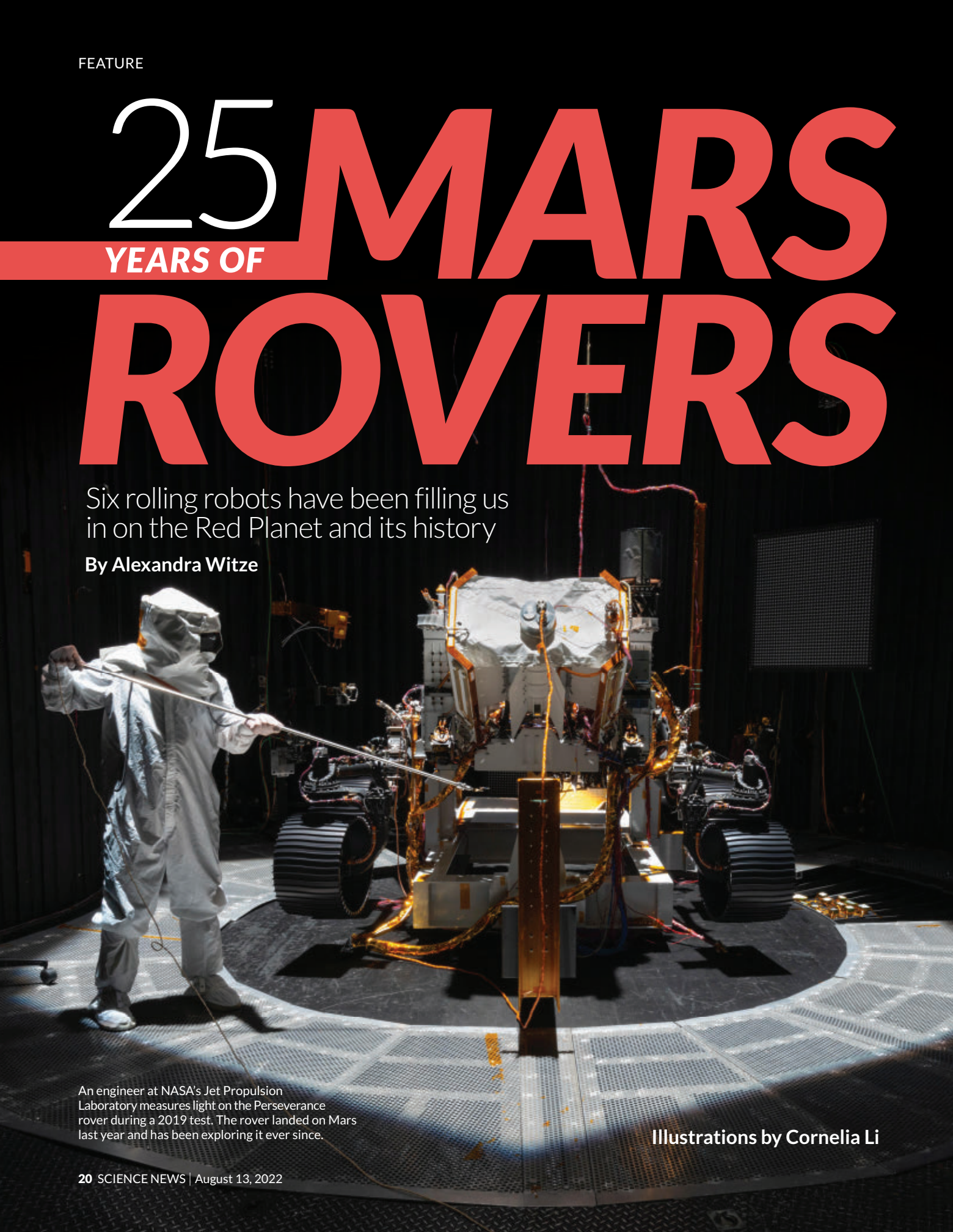
25 YEARS OF MARS ROVERS

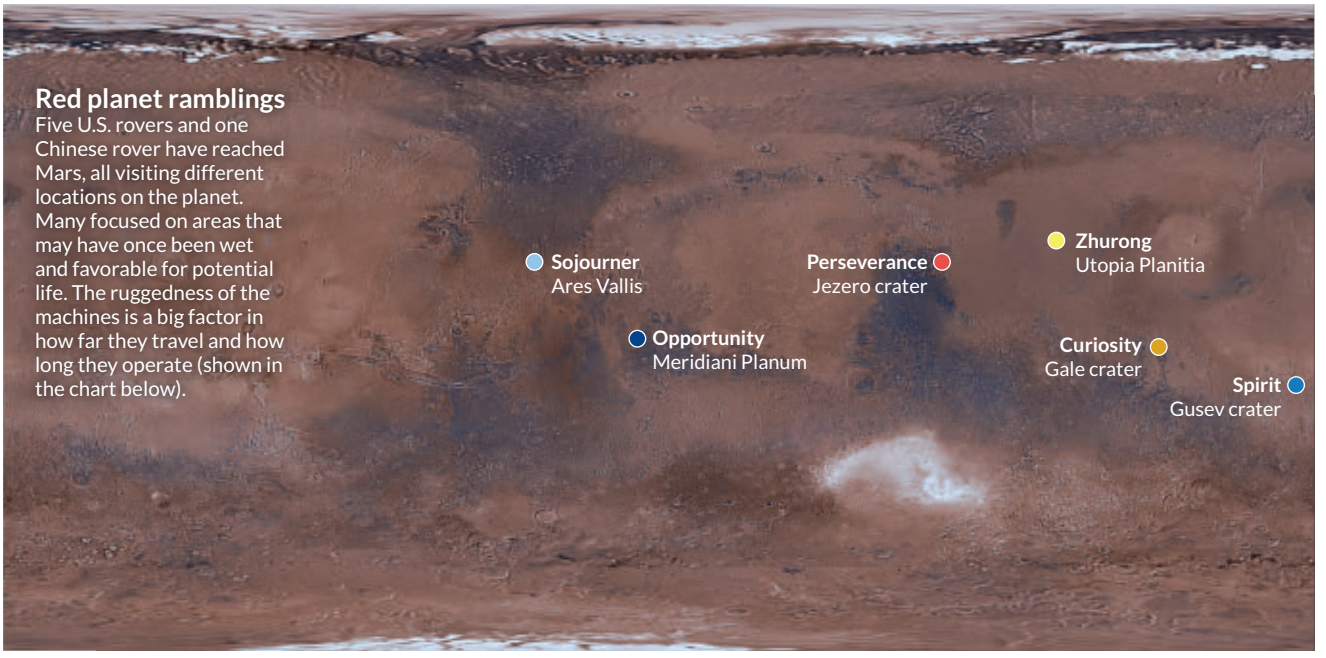
Six rolling robots have been filling us in on the Red Planet and its history

By Alexandra Witze



An engineer at NASA's Jet Propulsion Laboratory measures light on the Perseverance rover during a 2019 test. The rover landed on Mars last year and has been exploring it ever since.

Illustrations by Cornelia Li



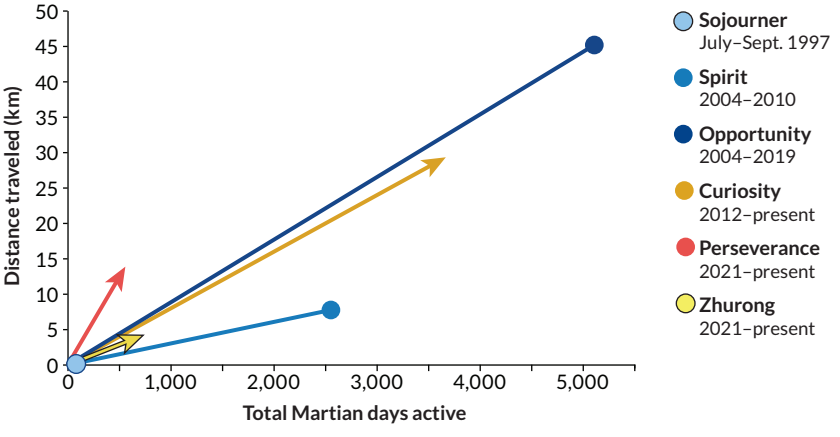
Few things are harder than hurling a robot into space — and sticking the landing. On the morning of July 4, 1997, mission controllers at the Jet Propulsion Laboratory in Pasadena, Calif., were hoping to beat the odds and land a spacecraft successfully on the Red Planet.

Twenty-five years ago that little robot, a six-wheeled rover named Sojourner, made it — becoming the first in a string of rovers built and operated by NASA to explore Mars. Four more NASA rovers, each more capable and complex than the last, have surveyed the Red Planet. The one named Curiosity marked its 10th year of cruising around on August 5. Another, named Perseverance, is busy collecting rocks that future robots are supposed to retrieve and bring back to Earth. China recently got into the Mars exploring game, landing its own rover, Zhurong, last year.

Other Mars spacecraft have done amazing science from a standstill, such as the twin Viking landers in the 1970s that were the first to photograph the Martian surface up close and the InSight probe that has been listening for Marsquakes shaking the planet's innards (*SN Online*: 2/24/20). But the ability to rove turns a robot into an interplanetary field geologist, able to explore the landscape and piece together clues to its history. Mobility, says Kirsten Siebach, a planetary scientist at Rice University in Houston, "makes it a journey of discovery."

Each of the Mars rovers has gone to a different place on the planet, enabling scientists to build a broad understanding of how Mars evolved over time. The rovers revealed that Mars contained water, and other life-friendly conditions, for much of its history.

How far and long have Mars rovers gone?



That work set the stage for Perseverance's ongoing hunt for signs of ancient life on Mars.

Each rover is also a reflection of the humans who designed and built and drove it. Perseverance carries on one of its wheels a symbol of Mars rover tracks twisted into the double helix shape of DNA. That's "to remind us, whatever this rover is, it's of human origin," says Jennifer Trosper, an engineer at the Jet Propulsion Lab, or JPL, who has worked on all five NASA rovers. "It is us on Mars, and kind of our creation."

The little microwave that could

Sojourner, that first rover, was born in an era when engineers weren't sure if they even could get a robot to work on Mars. In the early 1990s, then-NASA Administrator Daniel Goldin was pushing the agency to do things "faster, better and cheaper" — a catchphrase that engineers would mock by saying

Sojourner

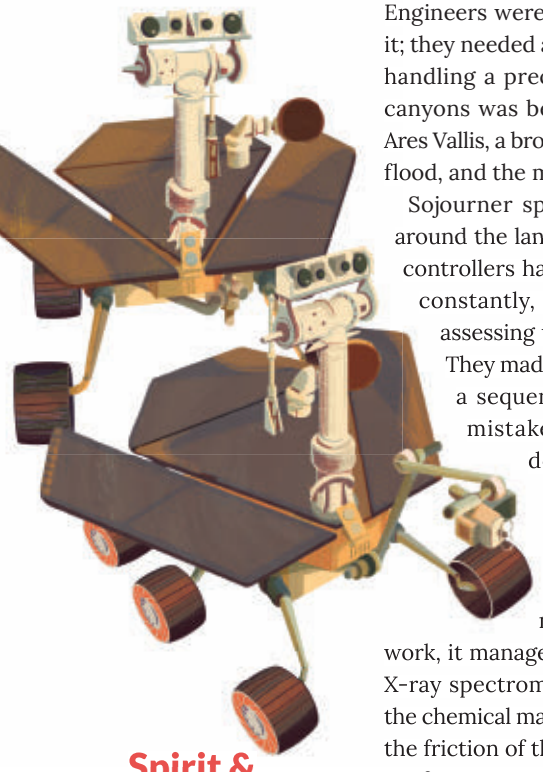
SIZE: Microwave oven

FUN FACTS: Had to stay close to its lander to communicate with Earth

Analyzed 15 Martian rocks

OPPOSITE PAGE: JPL-CALTECH/NASA; THIS PAGE, FROM TOP: NASA MARS TREK; E. OTWELL

In 1997, NASA's first rover, Sojourner, rolled down a landing ramp and became the first mobile Mars robot. Solar panels provided power throughout its 12-week mission.



Spirit & Opportunity

SIZE: Golf cart

FUN FACTS: Spirit spotted minerals possibly left by an ancient hot spring

Opportunity found the first definitive evidence of ancient water on Mars

Spirit perished when it got stuck in a sand pit

Opportunity died in a dust storm, which cut off solar power

only two of those three things were possible at the same time. NASA had no experience with interplanetary rovers. Only the Soviet Union had operated rovers — on the moon in 1970 and 1973.

JPL began developing a Mars rover anyway. Named after the abolitionist Sojourner Truth, the basic machine was the size of a microwave oven. Engineers were limited in where they could send it; they needed a large flat region on Mars because handling a precision landing near mountains or canyons was beyond their abilities. NASA chose Ares Vallis, a broad outflow channel from an ancient flood, and the mission landed there successfully.

Sojourner spent nearly three months poking around the landscape. It was slow going. Mission controllers had to communicate with Sojourner constantly, telling it where to roll and then assessing whether it had gotten there safely. They made mistakes: One time they uploaded a sequence of computer commands that mistakenly told the rover to shut itself down. They recovered from that stumble and many others, learning to quickly fix problems and move forward.

Although Sojourner was a test mission to show that a rover could work, it managed to do some science with its one X-ray spectrometer. The little machine analyzed the chemical makeup of 15 Martian rocks and tested the friction of the Martian soil.

After surviving 11 weeks beyond its planned one-week lifetime, Sojourner ultimately grew too cold to operate. Trosper was in mission control when the rover died on September 27, 1997. "You build these things, and even if they're well beyond their lifetime, you just can't let go very easily, because they're part of you," she says.

Twin explorers

In 1998 and 1999, NASA hurled a pair of spacecraft at Mars; one was supposed to orbit the planet and another was supposed to land near one of the poles. Both failed. Stung from the disappointment, NASA decided to build a rover plus a backup for its next attempt.

Thus were born the twins Spirit and Opportunity. Each the size of a golf cart, they were a major step up from Sojourner. Each had a robotic arm, a crucial development in rover evolution that enabled the machines to do increasingly sophisticated science. The two had beefed-up cameras, three spectrometers and a tool that could grind into rocks to reveal the texture beneath the surface.

But there were a lot of bugs to work out. Spirit and Opportunity launched several weeks apart in 2003. Spirit got to Mars first, and on its 18th Martian day on the surface it froze up and started sending error messages. It took mission controllers days to sort out the problem — an overloaded flash-memory system — all while Opportunity was barreling toward Mars. Ultimately, engineers fixed the problem, and Opportunity landed safely on the opposite side of the planet from Spirit.

Both rovers lasted years beyond their expected three-month lifetimes. And both did far more Martian science than anticipated.

Spirit broke one of its wheels early on and had to drive backward, dragging the broken wheel behind it. But the rover found plenty to do near its landing site of Gusev crater, home to a classic Mars landscape of dust, rock and hills. Spirit found rocks that appeared to have been altered by water long ago and later spotted a pair of iron-rich meteorites. The rover ultimately perished in 2010, stuck in a

The pale rock at center, seen beneath the Opportunity rover's robotic arm in 2013, was one of many at the rover's landing site that held long-awaited evidence that liquid water once flowed on Mars.

FROM TOP: JPL-CALTECH/NASA; JPL-CALTECH/NASA, CORNELL UNIV., ARIZONA STATE UNIV.

sand-filled pit. Mission controllers tried to extract it in an effort dubbed "Free Spirit," but salts had precipitated around the sand grains, making them particularly slippery.

Opportunity, in contrast, became the Energizer Bunny of rovers, exploring constantly and refusing to die. Immediately after landing in Meridiani Planum, Opportunity had scientists abuzz.

"The images that the rover first sent back were just so different from any other images we'd seen of the Martian surface," says Abigail Fraeman, a planetary scientist at JPL. "Instead of these really dusty volcanic plains, there was just this dark sand and this really bright bedrock. And that was just so captivating and inspiring."

Right at its landing site, Opportunity spotted the first definitive evidence of past liquid water on Mars, a much-anticipated and huge discovery (*SN: 3/27/04, p. 195*). The rover went on to find evidence of liquid water at different times in the Martian past. After years of driving, the rover reached a crater called Endeavour and "stepped into a totally new world," Fraeman says. The rocks at Endeavour were hundreds of millions of years older than others studied on Mars. They contained evidence of different types of ancient water chemistry.

Opportunity ultimately drove farther than any rover on any extraterrestrial world, breaking a Soviet rover's lunar record. In 2015, Opportunity passed 26.2 miles (42.2 km) on its odometer; mission controllers celebrated by putting a marathon medal onto a mock-up of the rover and driving it through a finish line ribbon at JPL. Opportunity finally died in 2019 after an intense dust storm obscured the sun, cutting off solar power, a must-have for the rover to recharge its batteries (*SN: 3/16/19, p. 7*).

The twin rovers were a huge advance over Sojourner. But the next rover was an entirely different beast.

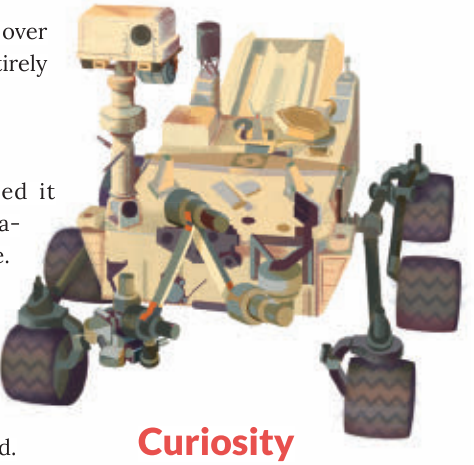
The SUV of rovers

By the mid-2000s, NASA had decided it needed to go big on Mars, with a mega-rover the size of a sports utility vehicle. The one-ton Curiosity was so heavy that its engineers had to come up with an entirely new way to land on Mars. The "sky crane" system used retro-rockets to hover above the Martian surface and slowly lower the rover to the ground.

Against all odds, in August 2012, Curiosity landed safely near Mount Sharp, a 5-kilometer-high pile of sediment within the 154-kilometer-wide Gale crater (*SN: 8/25/12, p. 5*). Unlike the first three Mars rovers, which were solar-powered, Curiosity runs on energy produced by the radioactive decay of plutonium. That allows the rover to travel farther and faster, and to power a suite of sophisticated science instruments, including two chemical laboratories.

Curiosity introduced a new way of exploring Mars. When the rover arrives in a new area, it looks around with its cameras, then zaps interesting rocks with its laser to identify which ones are worth a closer look. Once up close, the rover stretches out its robotic arm and does science, including drilling into rocks to see what they are made of.

When Curiosity arrived near the base of Mount Sharp, it immediately spotted rounded pebbles shaped by a once-flowing river, the first closeup look at an ancient river on Mars. Then mission controllers sent the rover rolling away from the mountain, toward an area in the crater

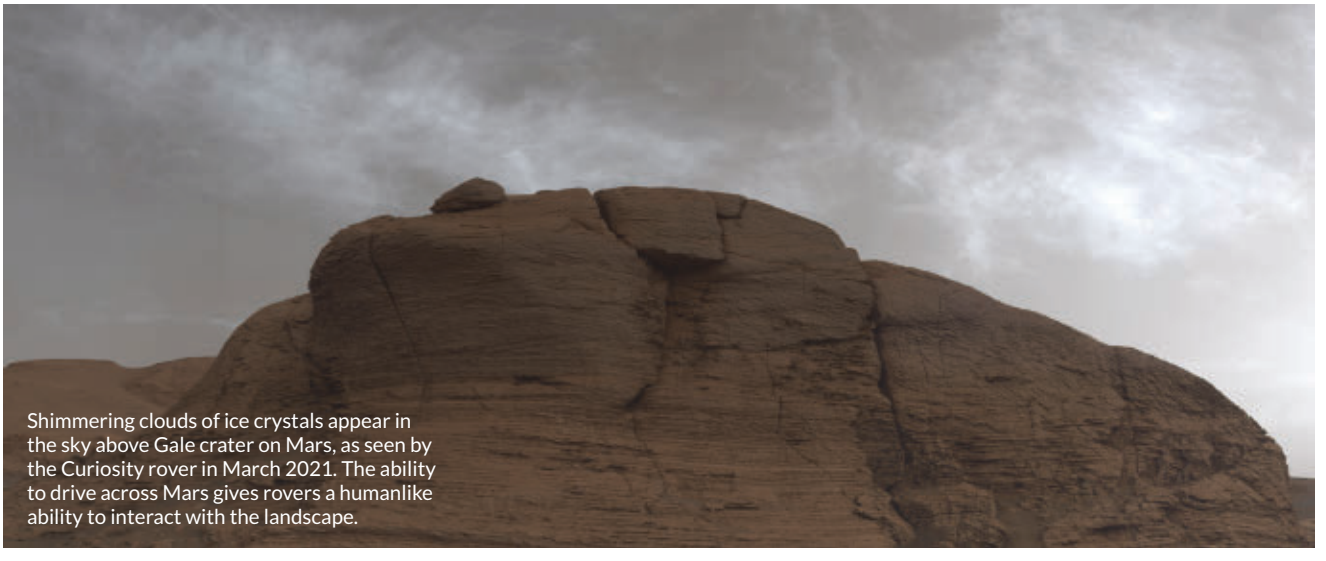


Curiosity

SIZE: SUV

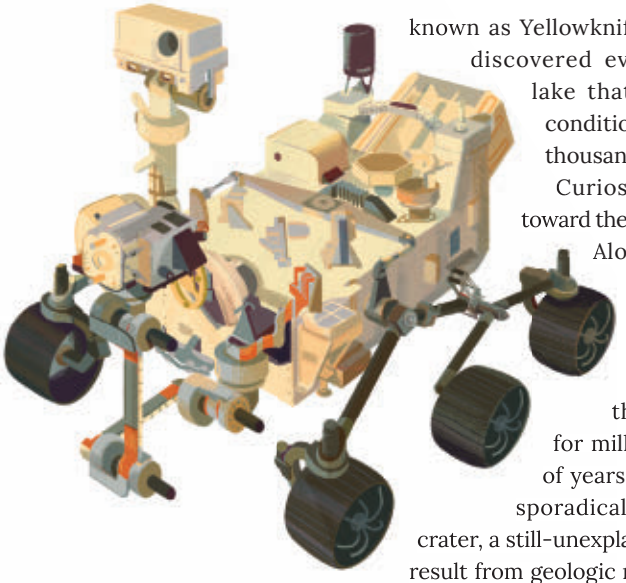
FUN FACTS: Needed a sky crane with rockets to hover above ground and slowly lower the behemoth to the surface

Found evidence of an ancient lake, sniffed methane gas, measured radiation levels



Shimmering clouds of ice crystals appear in the sky above Gale crater on Mars, as seen by the Curiosity rover in March 2021. The ability to drive across Mars gives rovers a humanlike ability to interact with the landscape.

MSSS, JPL-CALTECH/NASA



Perseverance

SIZE: SUV

FUN FACTS: Collecting rocks for later recovery mission

Traveled almost five kilometers in 30 Martian days

Helicopter Ingenuity was expected to fly five times, but it has made 29 trips so far

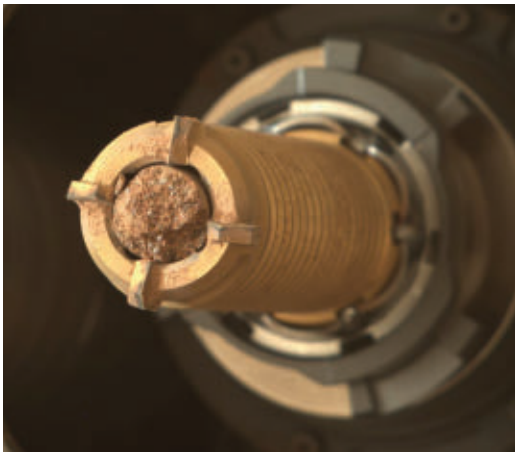
known as Yellowknife Bay. There Curiosity discovered evidence of an ancient lake that created life-friendly conditions for potentially many thousands of years.

Curiosity then headed back toward the foothills of Mount Sharp. Along the way, the rover discovered a range of organic molecules in many different rocks, hinting at environments that had been habitable for millions to tens of millions of years. It sniffed methane gas sporadically wafting within Gale crater, a still-unexplained mystery that could result from geologic reactions, though methane on Earth can be formed by living organisms (SN: 7/7/18, p. 8). The rover measured radiation levels across the surface—helpful for future astronauts who'll need to gauge their exposure—and observed dust devils, clouds and eclipses in the Martian atmosphere and night sky.

"We've encountered so many unexpectedly rich things," says Ashwin Vasavada of JPL, the mission's project scientist. "I'm just glad a place like this existed."

Ten years into its mission, Curiosity still trundles on, making new discoveries as it climbs the foothills of Mount Sharp. It recently departed a clay-rich environment and is now entering one that is heavier in sulfates, a transition that may reflect a major shift in the Martian climate billions of years ago.

In the course of driving more than 28 kilometers, Curiosity has weathered major glitches, including one that shuttered its drilling system for over a year. And its wheels have been banged up more than earthbound tests had predicted. The rover will continue to roll until some unknown failure kills it or its plutonium power wanes, perhaps five years from now.

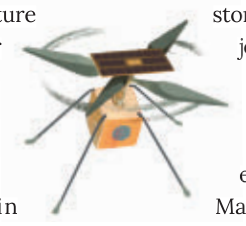


Perseverance collected its 9th rock core, barely the size of a pinky finger, on July 7. Future missions will return the stored samples to Earth for study.

A rover and its sidekick

NASA's first four rovers set the stage for the most capable and agile rover ever to visit Mars: Perseverance. Trosper likens the evolution of the machines to the growth of children. "We have a preschooler in Sojourner, and then ... your happy-go-lucky teenagers in Spirit and Opportunity," she says. "Curiosity is certainly a young adult that's able to do a lot of things on her own, and Perseverance is kind of that high-powered mid-career [person] able to do pretty much anything you ask with really no questions."

Perseverance is basically a copy of Curiosity built from its spare parts, but with one major modification: a system for drilling, collecting and storing slender cores of rock. Perseverance's job is to collect samples of Martian rock for future missions to bring to Earth, in what would be the first robotic sample return from Mars. That would allow scientists to do sophisticated analyses of Martian rocks in their earthbound labs. "It feels, even more than previous missions, that we are doing this for the next generation," Siebach says.



The rover is working fast. Compared with Curiosity's leisurely exploration of Gale crater, Perseverance has been zooming around its landing site, the 45-kilometer-wide Jezero crater, since its February 2021 arrival. It has collected 10 rock cores and is already eyeing where to put them down on the surface for future missions to pick up. "We're going to bring samples back from a diversity of locations," says mission project scientist Kenneth Farley of Caltech. "And so we keep to a schedule."

Perseverance went to Jezero to study an ancient river delta, which contains layers of sediment that may harbor evidence of ancient Martian life. But the rover slightly missed its target, landing on the other side of a set of impassable sand dunes. So it spent most of its first year exploring the crater floor, which turned out to be made of igneous rocks (SN: 9/11/21, p. 32). The rocks had cooled from molten magma and were not the sedimentary rocks that many had expected.

Scientists back on Earth will be able to precisely date the age of the igneous rocks, based on the radioactive decay of chemical elements within them, providing the first direct evidence for the age of rocks from a particular place on Mars.

JPL-CALTECH/NASA, ARIZONA STATE UNIV.

Once it finished exploring the crater floor in March, the rover drove quickly toward the delta. Each successive NASA rover has had greater skills in autonomous driving, able to identify hazards, steer around them and keep going without needing constant instructions from mission control.

Perseverance has a separate computer processor to run calculations for autonomous navigation, allowing it to move faster than Curiosity. (It took Curiosity two and a half years to travel 10 kilometers; Perseverance traveled that far in a little over a year.) "The rover drives pretty much every minute that we can give it," Farley says.

In April, Perseverance set a Martian driving record, traveling nearly five kilometers in just 30 Martian days. If all goes well, it will make some trips up and down the delta, then travel to Jezero crater's rim and out onto the ancient plains beyond.

Perseverance has a sidekick, Ingenuity, the first helicopter to visit another world. The nimble flier, only half a meter tall, succeeded beyond its designers' wildest dreams. The helicopter made 29 flights in its first 16 months when it was only supposed to make five in one month. It has scouted paths ahead and scientific targets for the rover (SN *Online*: 4/19/22). Future rovers are almost certain to carry a little buddy like this.

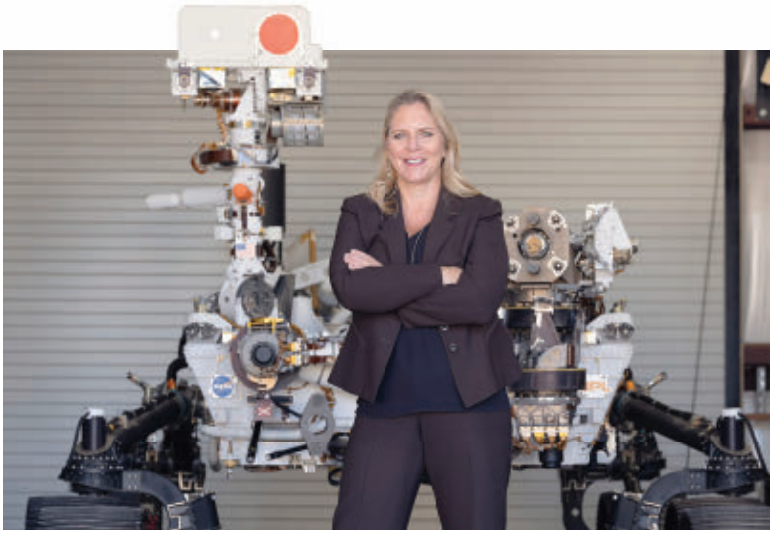
China's debut

While the United States has led in Mars rover exploration, it is not the only player on the scene. In May 2021, China became the second nation to successfully place a rover on Mars. Its Zhurong rover, named after a mythological fire god, has been exploring part of a large basin in the planet's northern hemisphere known as Utopia Planitia.

The landing site lies near a geologic boundary that may be an ancient Martian shoreline. Compared with the other Mars rover locations, Zhurong's landing site is billions of years younger, "so we are investigating a different world on Mars," says Lu Pan, a planetary scientist at the University of Copenhagen who has collaborated with Zhurong scientists.

In many ways, Zhurong resembles Spirit and Opportunity, in size as well as mobility. It carries cameras, a laser spectrometer for studying rocks and ground-penetrating radar to probe underground soil structures (SN *Online*: 5/19/21).

After landing, Zhurong snapped pictures of its rock-strewn surroundings and headed south to explore a variety of geologic terrains, including mysterious cones that could be mud volcanoes and ridges that look like windblown dunes. The rover's initial findings include that the Martian soil at Utopia Planitia is similar to some desert sands on Earth and that water had been present there perhaps as recently as 700 million years ago.

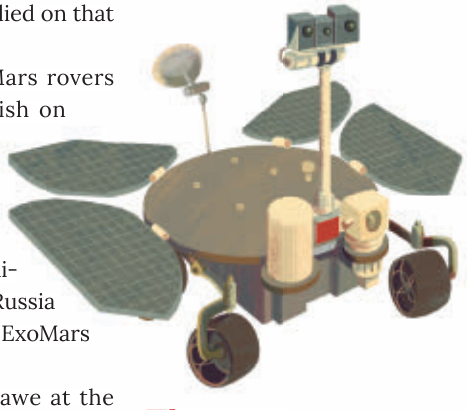


Jennifer Trosper, an engineer at the Jet Propulsion Laboratory, is part of a small group of people who have worked on all five NASA Mars rovers. Here she is in 2021 with a model of Perseverance.

In May, mission controllers switched Zhurong into dormant mode for the Martian winter and hope it wakes up at the end of the season, in December. It has already traveled nearly two kilometers across the surface, farther than the meager 100 meters that Sojourner managed. (To be fair, Sojourner had to keep circling its lander because it relied on that lander to communicate with Earth.)

From Sojourner to Zhurong, the Mars rovers show what humankind can accomplish on another planet. Future rovers might include the European Space Agency's ExoMars, although its 2022 launch was postponed after Russia attacked Ukraine (SN: 3/26/22, p. 6). Europe terminated all research collaborations with Russia after the invasion, including launching ExoMars on a Russian rocket.

Vasavada remembers his sense of awe at the Curiosity launch in 2011: "Standing there in Florida, watching this rocket blasting off and feeling it in your chest and knowing that there's this incredibly fragile complex machine hurtling on the end of this rocket.... It just gave me this full impression that here we are, humans, blasting these things off into space," he says. "We're little tiny human beings sending these things to another planet." ■



Zhurong

SIZE: Golf cart

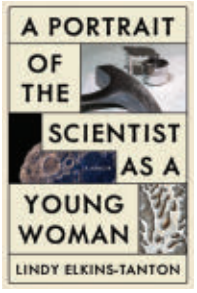
FUN FACTS: Dormant now during Martian winter, but is set to reawaken in December

Found signs of recent water activity in a geologically young setting

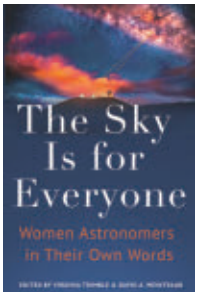
Found Martian soil similar to some of Earth's desert sands

Explore more

- Emily Lakdawalla. *The Design and Engineering of Curiosity*. Springer, 2018.
- Janet Vertesi. *Seeing Like a Rover*. University of Chicago Press, 2015.



A Portrait of the Scientist as a Young Woman
Lindy Elkins-Tanton
WILLIAM MORROW, $29.99



The Sky Is for Everyone
Virginia Trimble and David A. Weintraub (eds.)
PRINCETON UNIV., $29.95

BOOKSHELF

Female astronomers face a precarious path

Becoming an astronomer might seem straightforward. An awe of the night sky sparks a child to someday study astronomy in school, eventually leading to a graduate degree and a job in the field. But as two new books make clear, few women find the road so simple.

In *A Portrait of the Scientist as a Young Woman*, Lindy Elkins-Tanton, a geologist turned planetary scientist, recounts her struggles with depression and anxiety as a child and with the sexism she faced early in her career. In one example, she and colleagues (all men but one) were collecting rock samples in Siberia, searching for evidence of a connection between volcanic eruptions and past extinction events. Taking her time to set her chisel at just the right spot to break the rock, Elkins-Tanton could "practically smell the silent impatience from the men nearby," she writes. "Yes, they could have done it faster, and with fewer blows. But why should that be the important metric? Why is it not more important to let each person do the tasks they want and need to do, at their own pace?"

Her male colleagues' implicit and explicit bias against women in science, she writes, fanned her own self-doubt. To demand the same respect as male scientists, she learned she had to insist, gently, to carry her own baggage and take her own samples, her way and on her time. The lessons she learned in Siberia and in the lab, she writes, helped her develop a compassionate and just leadership style as the director of Arizona State University's School of Earth and Space Exploration and as the head of NASA's upcoming Psyche mission. That mission will send a spacecraft to probe a metal-rich asteroid to better understand Earth's iron-rich core.

> "When confronted with bias in our profession … many of us continue to deny the existence of the issue."
>
> **DARA NORMAN**

Every scientist's experience is unique, but elements of Elkins-Tanton's story, particularly the sexism in science, find voice throughout *The Sky Is for Everyone: Women Astronomers in Their Own Words*. Edited by astronomer Virginia Trimble and author David Weintraub, this anthology of 37 short autobiographies covers more than six decades of astronomy and shows the varied paths of female astronomers and the roadblocks that can slow or sideline their success.

Astrophysicist France Córdova, for instance, opens her story with an evocative description of the time she spent in the summer of 1968 in a pueblo near Oaxaca City, Mexico, working on a cultural anthropology project. She had planned to study anthropology in graduate school, but after watching a TV show on dead stars, she realized she "had a deeper wanderlust inside," she writes, "to connect with something wider, deeper than I could imagine—the stars and the Universe that held them."

As a child, Córdova hadn't known anyone who believed women could be scientists. Her parents thought finding a husband should be her college goal. Instead, she chose to pursue a graduate degree in astrophysics. She launched a career in X-ray astronomy and then pivoted again to policy and leadership, assuming the role of NASA's chief scientist and later head of the National Science Foundation—positions where, she writes, she could advocate more effectively for women in science.

Dara Norman, in contrast, never questioned that she'd become an astronomer; by age 10 she was certain. She earned a Ph.D. in 1999 after studying bias in the measurements of distant galaxies that can distort our understanding of the universe. To her, the similarities between biases in scientific data and biases in the culture of science were blatant. "I am amazed that as scientists we understand the idea of bias in our data and methods.... We work tirelessly to identify such biases … and eliminate that bias," she writes. "However, when confronted with bias in our profession … many of us continue to deny the existence of the issue."

Norman realized the traditional path of an astronomer wasn't for her. The joy of doing research was overshadowed by the negative experiences she endured "as a Black American woman just trying to *be* a scientist." Like Córdova, she now works to improve the culture of science, at the National Optical-Infrared Astronomy Research Lab in Tucson.

That culture is changing, slowly. Before 1990, fewer than 40 women held full-time positions in astronomy or astrophysics at North American universities. Now, the number is high enough that it's not as easy to track how many women successfully pursue a career in the field, Trimble and Weintraub note. Although those numbers point to progress, both books remind readers that blatant and subtle acts of sexism are still present and that careers in science can still be precarious for women. And yet women persist, perhaps, as Elkins-Tanton writes, driven by the "realization that we are only a tiny part of a vast unexplored universe." If true, it's a pillar of resilience to aspire to. —*Ashley Yeager*

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Peggy Scripps Award at Regeneron ISEF
CELEBRATING SCIENCE COMMUNICATION

Anika Puri, 17, of Chappaqua, N.Y., received the $10,000 Peggy Scripps Award for Science Communication at the 2022 Regeneron International Science and Engineering Fair (ISEF). She developed a new low-cost machine learning software that analyzes nighttime infrared drone videos from the African wilderness to spot elephant poachers in real time. In tests using data from real-life videos, her $300 system worked with 91 percent accuracy, a fourfold improvement over current systems employing high-resolution thermal cameras that can cost up to $10,000.

The Peggy Scripps Award for Science Communication recognizes the ISEF finalist who is best able to communicate their project to the lay public, explaining both the science and its potential impact on society. This is a vital skill, given that members of the public who understand science are more likely to support it. The award is named after Peggy Scripps, a science journalist who served as a writer and editor at *Science News* from 1952 to 1968.

Anika was selected from 1,750 high school students from 63 countries, regions and territories who participated at Regeneron ISEF held in Atlanta in May. These future STEM leaders competed for nearly $8 million in awards, prizes and scholarships honoring the creativity, innovation and scientific sophistication of their projects.

Anika's project also won first place in ISEF's Earth and Environmental Sciences category, sponsored by the National Geographic Society.

Review Anika Puri's research and that of other finalists at projectboard.world/isef

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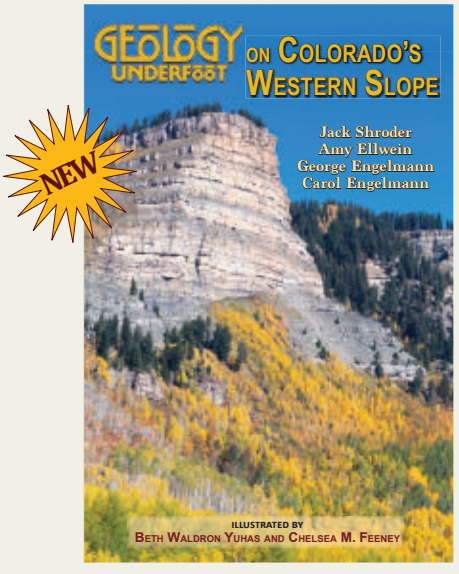

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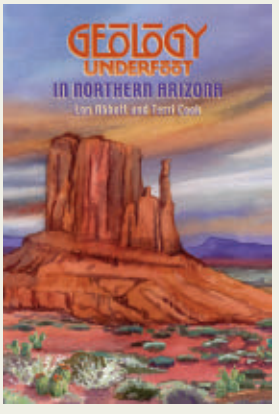

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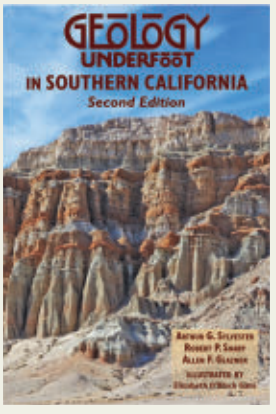

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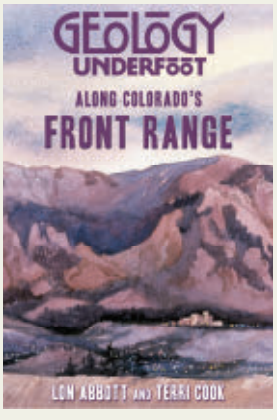

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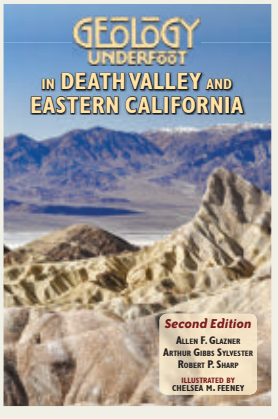

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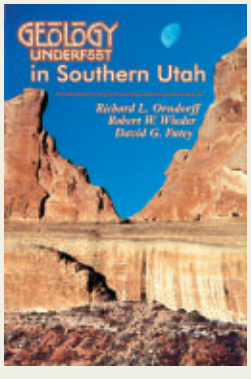

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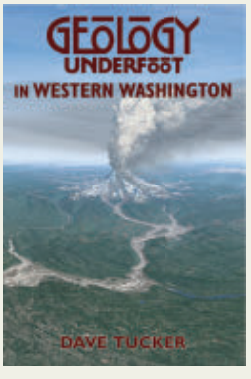

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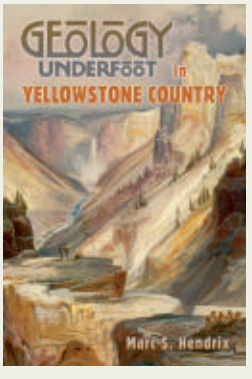

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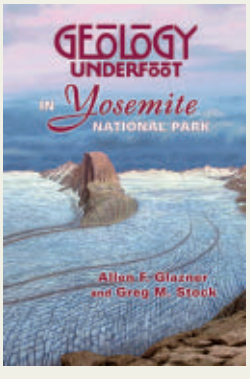

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ALL: NASA, ESA, CSA, STScI

Postcards from a new space telescope

We've now seen farther and more clearly into space than ever before.

A stellar birthplace, a cosmic vista that captures more than 13 billion years of history, a galactic quintet, a dying star. These are the first images from the James Webb Space Telescope, released July 11 and 12. "There's a sharpness and a clarity we've never had," astrophysicist Jane Rigby of NASA's Goddard Space Flight Center in Greenbelt, Md., said at a July 12 news briefing.

These images have been a long time coming. First dreamed up in the 1980s, the telescope suffered years of budget issues and delays before launching on December 25 (SN: 10/9/21 & 10/23/21, p. 26).

"We are so thrilled that it works," senior project scientist John Mather of Goddard told *Science News*. "The world has trusted us to put our billions [of dollars] into this and make it go…so it's an immense relief." Now, the first round of science operations begins. "The mysteries of the universe will not come to an end anytime soon," Mather says. —*Lisa Grossman and Asa Stahl*

❶ **Stellar birthplace** Ultraviolet light and stellar winds from baby stars sculpt gas and dust that span the Cosmic Cliffs, a site where massive stars are born.

❷ **Cosmic vista** Thousands of galaxies lie behind a galactic cluster, whose mass distorts spacetime and magnifies objects behind it. This lets astronomers peer more than 13 billion years into the past.

❸ **Galactic quintet** In Stephan's Quintet, four galaxies (lined up vertically in the middle) are bound by each other's gravity, caught in an endless looping dance. A fifth galaxy to the left sits in the foreground.

❹ **Dying star** In the Southern Ring nebula, a cloud of gas and dust escapes a dying star. Near-infrared light (left) highlights molecular hydrogen; mid-infrared light (right) reveals hydrocarbons forming on dust grains, plus a second star in the nebula's center.

JUNE 18, 2022

SOCIAL MEDIA

Face the fungi

Replacing 20 percent of the red meat in our diets with proteins derived from fungi and algae could cut annual deforestation by more than half by 2050, **Carolyn Gramling** reported in "Swapping meat for microbial protein may take a bite out of climate change" (*SN: 6/18/22, p. 5*). Twitter user **@CelStPierre** quipped: "This 'food for thought' is certainly worth researching."

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Navigating neutrinos

*Tidal disruption events, in which supermassive black holes rip apart stars, could supercharge ghostly subatomic particles called neutrinos, **Emily Conover** reported in "Zippy neutrino linked to a source"* (SN: 6/18/22, p. 8).

Conover reported that scientists tracked a high-energy neutrino to an area of the sky where a bright flare, thought to be a tidal disruption event, had been discovered roughly a year before. Reader **Doug McElroy** wanted to know if the delay in the observation of the neutrino reveals the distance of the tidal disruption event from Earth.

It doesn't, **Conover** says. "High-energy neutrinos and light travel at nearly the same speed (neutrinos are just slightly slower due to their mass), so that difference in travel time shouldn't make a big difference in when we see the particles," she says.

Instead, the timing suggests that the process of a black hole tearing apart a star, creating an environment that accelerates particles, can last for a while, **Conover** says. In this case, at least a year. Scientists think this particular neutrino would have been emitted about a year after the flare from the tidal disruption event.

Dust it off

*Biological soil crusts — thin layers of soil glued together by dirt-dwelling organisms — reduce global dust emissions by roughly 60 percent, **Nikk Ogasa** reported in "Biocrusts keep the dust settled"* (SN: 6/18/22, p. 12).

Extra dust could impact river flows, **Ogasa** wrote. For instance, fallen dust in the Upper Colorado River Basin reduced flows of meltwater into the Colorado River by an average of about 5 percent every year. Reader **Greg Skala** asked how dust can have such an effect on runoff.

Dust that fell on the basin's snowy surfaces decreased the amount of sunlight they reflected, causing the snow to melt several weeks earlier in the year than anticipated, **Ogasa** says. That left the vegetation and soils that were buried underneath exposed for a longer period, increasing the amount of water lost to the air through a process called evapotranspiration. As more water was lost to the air, less eventually made its way to the river.

Rogue one

*Scientists observed two black holes merge into one. Then, gravitational waves kicked the newly formed black hole away from its home, **Emily Conover** reported in "Space ripples gave black hole the boot"* (SN: 6/18/22, p. 8).

Reader **Bradley Ruben** wondered if the discovery implies that there are lone, rogue black holes zipping through space, potentially destroying solar systems or other celestial objects in the way.

Isolated black holes that travel through space do exist, **Conover** says. In fact, scientists may have spotted one a few thousand light-years from Earth (SN: 7/16/22 & 7/30/22, p. 11). But the implications are not quite as dramatic as one might imagine.

Space is really big, and the number of solo black holes is relatively small, making any direct hits by a black hole very rare, **Conover** says.

"And contrary to popular belief, black holes don't 'suck in' everything around them," she says. If the black hole doesn't get too close and simply passes by, it would just exert a gravitational pull on the planetary system it encounters. In that way, it would act similar to any other massive object traveling through space, such as a star, she says.

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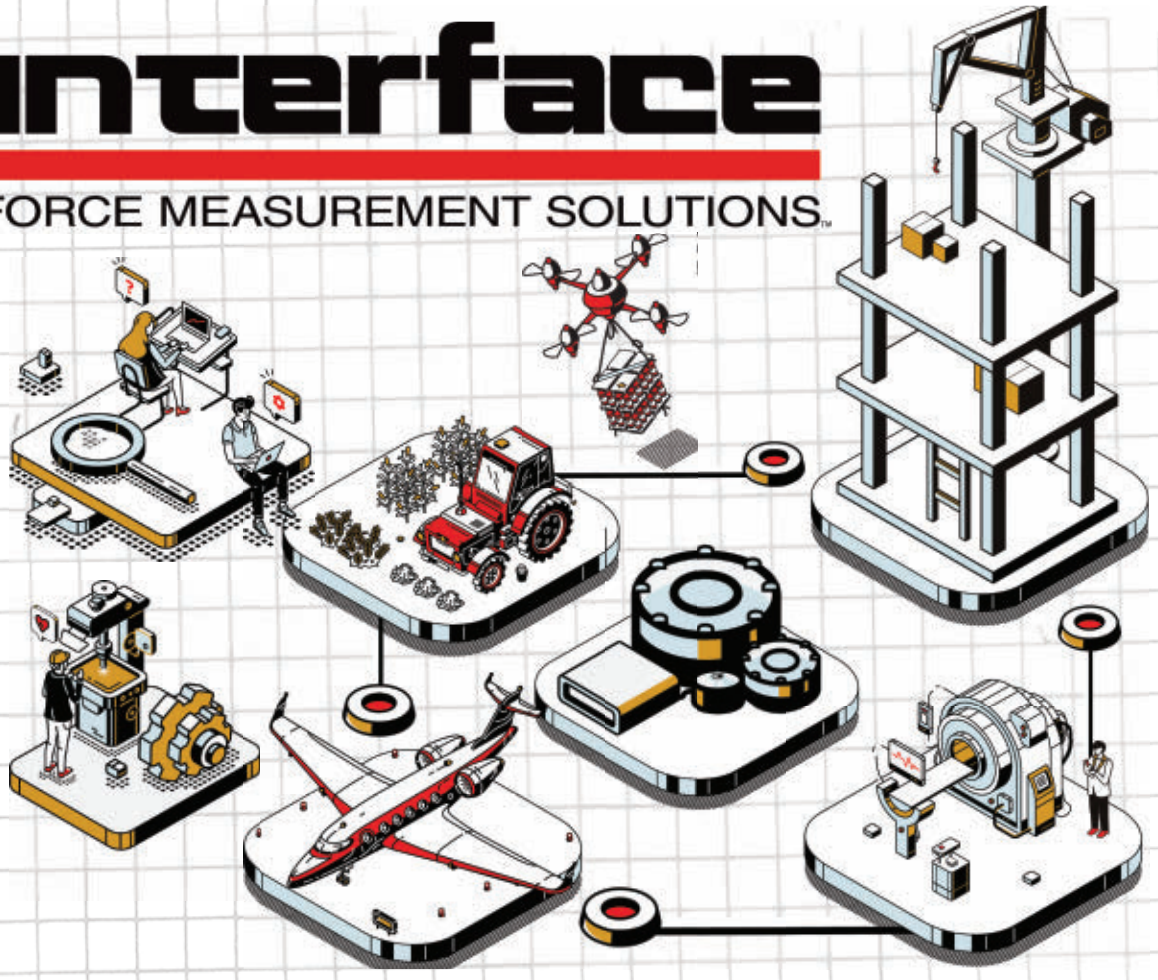

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