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ScienceNews

EXPANDING HORIZONS

The Vera C. Rubin Observatory will transform our view of the cosmos


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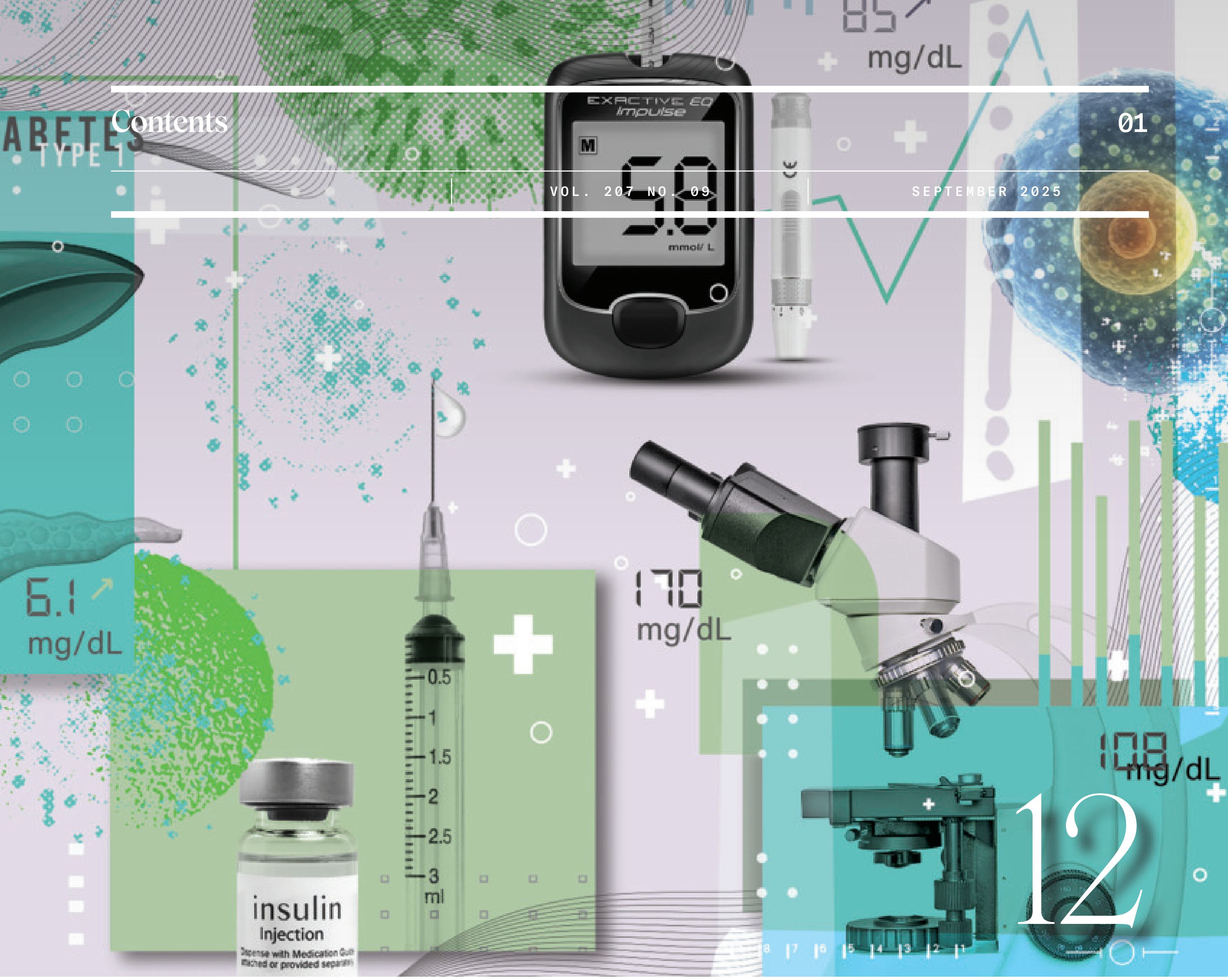

News

On the Cover

RubinObs/NOIRLab/SLAC/DOE/NSF/AURA, Paulo Assunção Lago

NADIA RADIC

SIEMENS energy

Make your next career step the first of many

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Features

Curiosities

Seeing the world in new ways

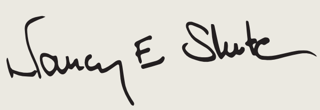
Seeing is believing, as the saying goes, so it's no surprise people would be eager for any technology that would help them see even more of the world around them. Using principles from a landmark series of books on optics by Arab astronomer Ibn al-Haytham, glassmakers in Italy created the first magnifying lenses in the 13th century, supposedly for older monks who strained to read manuscripts.

Next came innovations that allowed people to see farther into the distance, such as handheld telescopes for surveying and navigation. In the early 17th century, Galileo and other Renaissance astronomers pointed telescopes toward the stars and saw things no human had yet witnessed, such as moons orbiting Jupiter.

Ever since, astronomers have been striving to develop technologies that will let telescopes see farther, better. Their latest invention, the Vera C. Rubin Observatory, is a technological wonder that includes the world's largest digital camera, supported by a huge three-mirror system that lets the instrument clearly see very faint, far-off objects. Rubin will give us all the chance to repeat Galileo's experience: marveling at parts of the cosmos no human has seen before. In this issue, *Science News* astronomy writer Lisa Grossman reports on her adventure to a windswept mountaintop in Chile to visit the observatory and see for herself what Rubin is made of (Page 34).

Other visual treats to explore in this issue include the mesmerizing world of fractals, irregular shapes that defy the conventions of standard geometry and were first named 50 years ago by mathematician Benoit B. Mandelbrot (Page 44). They are everywhere: in clouds, in mountains, even in our bodies. Freelance journalist Stephen Ornes explains how fractals connect to number theory and might help crack the biggest unsolved problem in mathematics, the Riemann hypothesis.

Bringing our theme of visuals even further down to earth, let's talk magazine design. Many of you wrote in to share your thoughts about the new look of *Science News*, and we are thrilled that they are largely positive. A repeated critique was that the type size for news briefs, captions and the contributors page was difficult to read. I'm happy to report that we've increased it in this issue. We've also retired the Feedback page to make room for more science coverage. We will feature reader comments and questions in this editor's note going forward, so keep writing! You can email us at feedback@sciencenews.org.



Nancy Shute
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Science News

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LISA GROSSMAN

ASTRONOMY WRITER

● **THIS YEAR**, space fans gained a new tool for peering into the universe: the Vera C. Rubin Observatory, whose 8.4-meter-diameter telescope will survey the sky every night for 10 years. For our cover story, Lisa Grossman flew for almost 20 hours to the telescope's home in the mountains of northern Chile (Page 34). One of the most memorable parts of the trip, she says, was the people. "The scientists at the observatory were so open and generous with their time, answering all my questions, pointing out cool things that I might have otherwise missed," she says. And it wasn't just the scientists who cared deeply. The driver who brought Grossman to her dorm room at midnight navigated windy, dusty roads without headlights, so the lights wouldn't interfere with observations. "The driver turned the headlights on when we got below the telescopes' sight lines," she says.

Stephen Ornes
Freelance journalist Stephen Ornes cherishes his signed copy of *The Fractal Geometry of Nature* by Benoit B. Mandelbrot. So it's only fitting that he wrote an essay commemorating the 50th anniversary of the mathematician's coinage of the term "fractal" (Page 44). "Fractals' beauty offers a visual way to access math," says Ornes, who has a master's degree in mathematics. "If I tell people I write about math, they may retreat. If I say I'm writing about fractals, their eyes light up."

Carolyn Gramling
The seafloor is the latest battleground in the fight between the need to find new sources of critical metals for batteries and the desire to protect the environment, reports earth and climate writer Carolyn Gramling (Page 50). She details threats to deep-sea ecosystems, but there's more to the story. "The conversation is also about how Pacific nations are navigating partnerships, regulations and the legacy of colonialism," she says. "There's more to unpack."

Skyler Ware
Plastic waste is a global problem. One way scientists are tackling it is to turn plastic waste into painkillers (Page 21). Freelance journalist and former chemist Skyler Ware wanted to write about the research because "it seemed like a hopeful, solutions-oriented story," she says. "No one strategy is going to get rid of all the plastic waste. But I think it's important to highlight the many ways people are trying to address the issue."

Sofia Caetano Avritzer
Guinea fowl remind Sofia Caetano Avritzer, *Science News*' AAAS Mass Media Fellow, of her home in Brazil. But to some scientists, the birds offer a window into dinosaur behavior. These scientists used guinea fowl to challenge ideas about how to measure dinosaur speed (Page 26). When Caetano Avritzer first saw the research paper, "I was curious about what the cute birds had to say about how fast dinosaurs were."

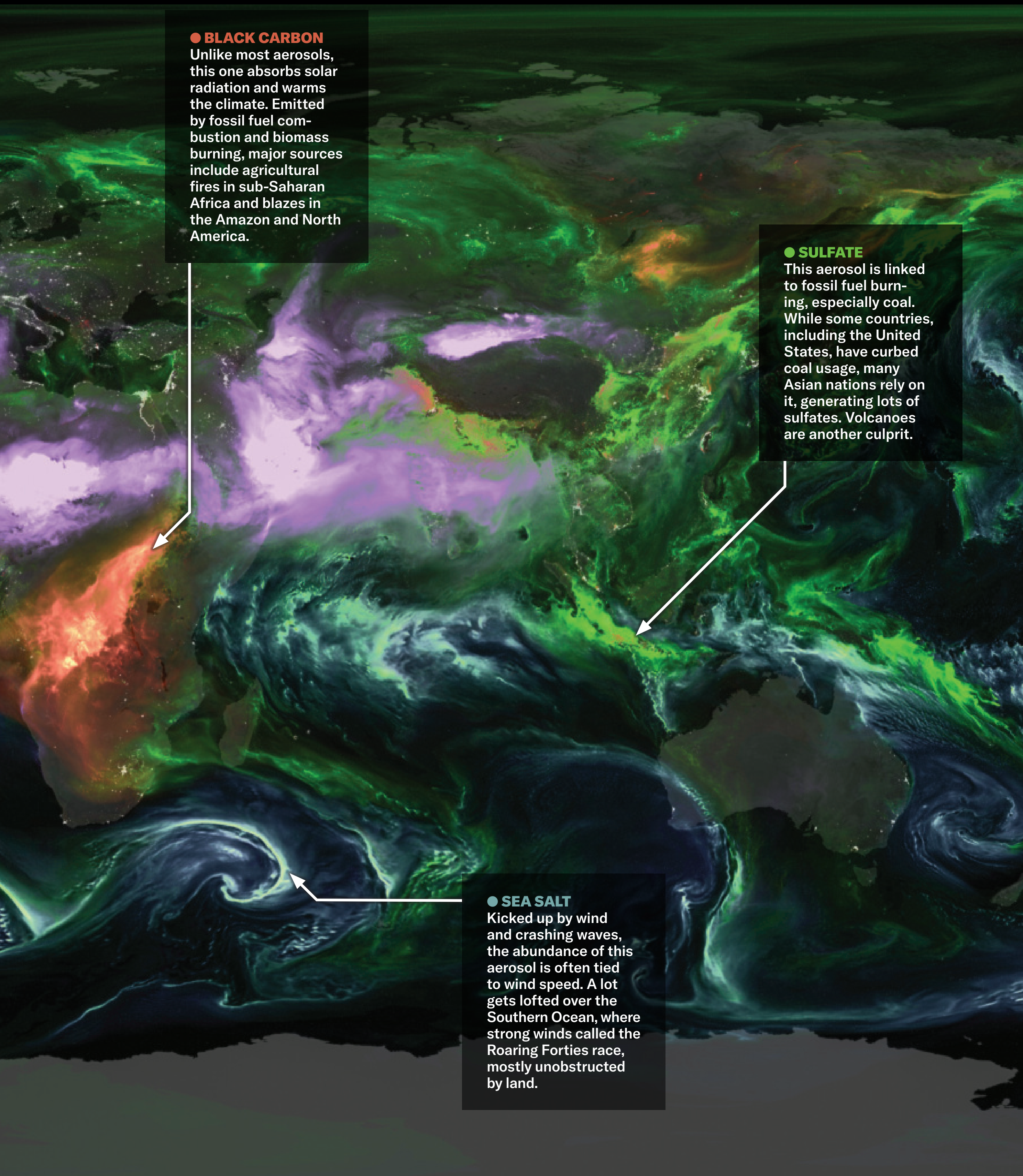
CLOCKWISE FROM TOP LEFT: LEISE JONES PHOTOGRAPHY; COURTESY OF S. ORNES; SOCIETY FOR SCIENCE; LEVI PALMER; FRANK VERONSKY/THE ROCKEFELLER UNIV.

EARTH

THE SKY ABOUNDS WITH AEROSOLS

By Nikk Ogasa

● This NASA visualization shows how aerosols — tiny particles such as dust (purple), sea salt (teal), black carbon (red) and sulfates (green) — move through the atmosphere and impact air quality far from their sources. Unlike greenhouse gases, aerosols last only days but can cool the planet by reflecting sunlight and brightening clouds. As pollution declines, this cooling effect weakens, possibly accelerating warming, says atmospheric scientist Sarah Doherty of the University of Washington in Seattle. The visualization, based on satellite and ground-based data and simulations, captures aerosol activity from late summer 2024. MAP BY NASA'S GLOBAL MODELING AND ASSIMILATION OFFICE AND NASA'S SCIENTIFIC VISUALIZATION STUDIO



● BLACK CARBON
Unlike most aerosols, this one absorbs solar radiation and warms the climate. Emitted by fossil fuel combustion and biomass burning, major sources include agricultural fires in sub-Saharan Africa and blazes in the Amazon and North America.

● SULFATE
This aerosol is linked to fossil fuel burning, especially coal. While some countries, including the United States, have curbed coal usage, many Asian nations rely on it, generating lots of sulfates. Volcanoes are another culprit.

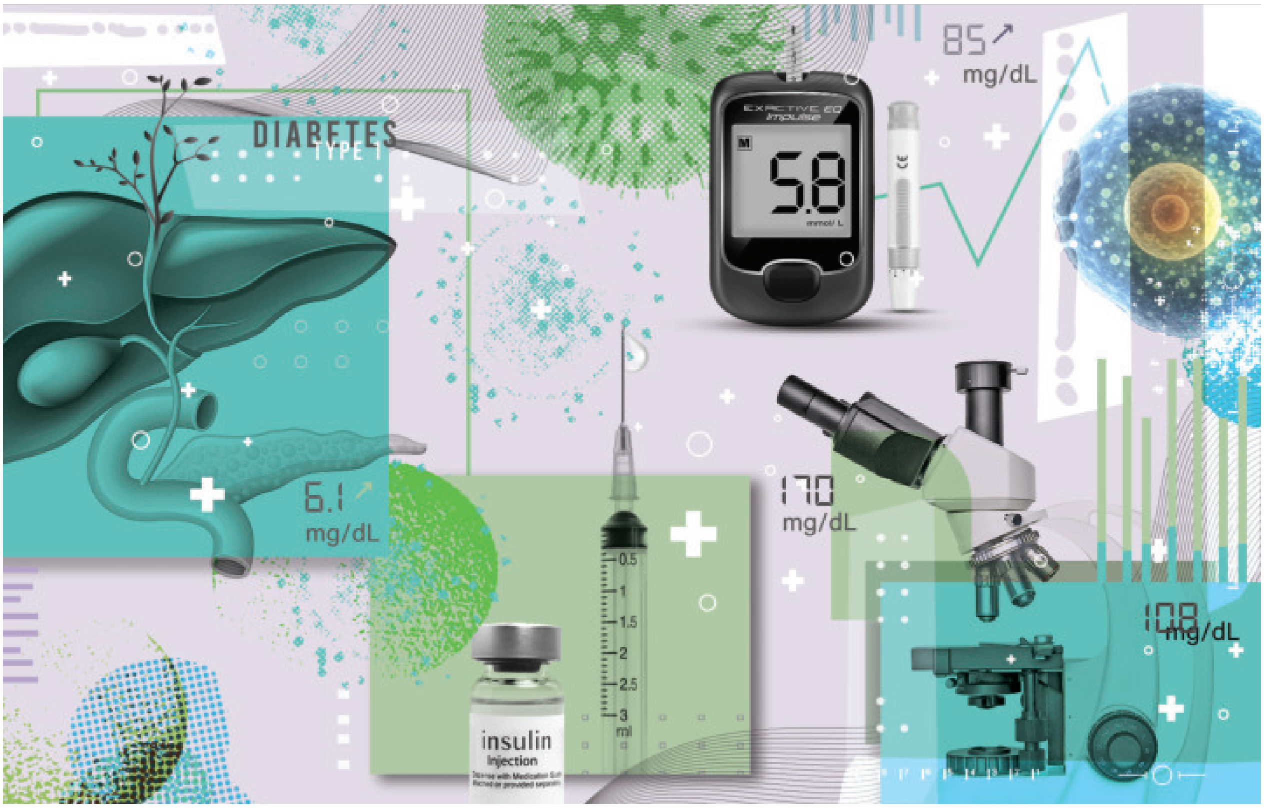
● SEA SALT
Kicked up by wind and crashing waves, the abundance of this aerosol is often tied to wind speed. A lot gets lofted over the Southern Ocean, where strong winds called the Roaring Forties race, mostly unobstructed by land.

News

ANTHROPOLOGY

PUTTING AN ANCIENT FACE TO A NAME

● The first fossil from the mysterious hominids known as Denisovans was discovered in 2008, but scientists had never been able to look one in the face — until now. Researchers working in China unearthed the skull of an adult Denisovan man, nicknamed Dragon Man, who lived about 146,000 years ago. The scientists compared proteins and DNA extracted from the skull with genetic material from known Denisovan fossils to make the match, the team reported in *Science* and *Cell*. *— Bruce Bower*



NADIA RADIC

HEALTH & MEDICINE

Hope for a diabetes treatment without insulin injections

By Meghan Rosen

● **A new therapy** for type 1 diabetes could someday nix the need for insulin injections. Just a single infusion of lab-grown pancreatic cells let patients' bodies make all the insulin they needed, scientists report in the *New England Journal of Medicine*. A year after treatment, 10 out of 12 participants no longer needed supplemental insulin.

"This is a landmark study — this cannot be overstated," says Giacomo Lanzoni, a diabetes researcher at the University of Miami Miller School of Medicine who was not involved in the new work. These lab-grown cells can successfully treat diabetes, he says, and the technique to make them can be scaled up. That opens the door to restoring insulin production for many people with the disease.

Type 1 diabetes affects over 8 million people worldwide. It's an autoimmune disease that pits a person's immune system against the insulin-producing cells in their pancreas, destroying them. Insulin helps sugar pass from the blood to cells for energy; without it, sugar stays in the blood, starving cells. "People can't survive without insulin," says study coauthor Felicia Pagliuca, a cell biologist and senior vice president at Vertex Pharmaceuticals, the company behind the new therapy.

That's where injected insulin comes in. The drug has been around for more than 100 years, and tools such as continuous glucose monitors and insulin pumps help patients track blood sugar and adjust insulin levels. But these tools aren't perfect. The body tolerates a narrow Goldilocks zone of safe blood sugar levels. Too high and

↑ An infusion of lab-grown cells could someday help replace needles and monitors for diabetics.

people can get kidney, nerve and eye damage. Too low and people can pass out, or worse. "There's really an urgent need for new therapies," Pagliuca says.

In 2023, the U.S. Food and Drug Administration approved a therapy using pancreatic cells from deceased donors intended to replace insulin-producing cells lost in people with type 1 diabetes. But the approach is limited by the number of available organ donors and the quality of their cells. Patients often need infusions from multiple donated pancreases, Pagliuca says.

To address these challenges, Vertex developed a method to grow pancreatic islet cells in the lab using human stem cells and a medley of nutrients and chemicals. These lab-grown islets, cell clusters that contain insulin-producing beta cells, don't wind up in people's pancreases. Instead, they settle in the liver, a location that seems to work well for them—and patients.

In a small clinical trial of 14 people with type 1 diabetes, doctors infused hundreds of millions of lab-made islet cells into participants' veins. These cells "start working right from the get-go," Pagliuca says, sensing blood sugar levels and producing insulin in response. After a full dose of the therapy, called zimislecel, 10 out of 12 participants once dependent on supplemental insulin no longer needed it—even a year after treatment. Two others reduced their insulin doses by up to 70 percent.

"Coming off insulin therapy is a remarkable achievement," says Tom Donner, director of the Johns Hopkins Diabetes Center. Managing diabetes can be a huge psychological burden, he says. Alleviating the need for supplemental insulin could ease that load.

While patients in the new study generally tolerated the therapy well, Vertex scientists reported two unrelated deaths and a slew of side effects. One death stemmed from a surgical complication, Pagliuca says. The other was from a preexisting brain injury.

Side effects, which included diarrhea, headache, nausea and COVID-19 infection, were largely due to immunosuppressive drugs that prevent the body from attacking and rejecting the new islet cells. Patients will have to stay on these medications to protect the cells.

"Immunosuppression is not a walk in the park," Lanzoni says. It brings along all sorts of risks, including infection. Ideally, he'd like to see a diabetes cell therapy that doesn't require long-term immunosuppression, something he and others in the field are working on.

Meanwhile, Vertex has expanded the study to include 50 total patients, almost all of whom have received their cell therapy dose. The researchers are hoping to have data from those patients and apply for regulatory approval for the therapy in 2026. ✖

ASTRONOMY

SPACECRAFT PRODUCE ECLIPSE ON DEMAND

By McKenzie Prillaman

● It takes two to imitate a total solar eclipse from space.

Two spacecraft have begun to make artificial eclipses, produced when one satellite blocks the other's view of the sun. The European Space Agency's Proba-3 mission involves the pair orbiting the Earth in an elliptical path. When the duo is closest to the sun, they create a total solar eclipse by lining up about 150 meters apart so that one craft casts a precise shadow on the other, which observes the corona, the sun's outer atmosphere (shown below).

At 1 million degrees Celsius, the corona is almost 200 times as hot as the sun's surface. The answers to why that temperature difference occurs and other burning questions may lie in the corona's middle layer, which can be observed only during a total solar eclipse.

The sun's light is completely blocked by the moon somewhere on Earth just once every 18 months, with an event lasting for a few minutes at most. The spacecraft duo, however, will replicate the phenomenon on demand. Every 20 hours, it can create an eclipse that may last up to six hours—though they can't be seen from Earth.

Proba-3 launched in December and should generate more than 1,000 hours of artificial eclipses over the next two years. ✖

EARTH

THE OLDEST ROCKS ON EARTH MAY BE 4.16 BILLION YEARS OLD

BY CAROLYN GRAMLING

A remote outcrop in Canada harbors rocks that are at least 4.16 billion years old, researchers report in *Science*. If true, these rocks would be the oldest known on Earth and the first to date to the planet's earliest and most mysterious eon.

Earth formed around 4.57 billion years ago, but no surface rocks date back that far. That's because too much has happened in the interim: During Earth's first 540 million years, known as the Hadean Eon, the planet was repeatedly pummeled by asteroids. The onset of plate tectonics, possibly as early as 3 billion years ago, has repeatedly remade Earth's surface through subduction, mountain-building and chemical alteration from extreme heat or pressure. Consequently, most of the planet's surface is fairly young, geologically speaking.

But some continents, such as North America, have extremely old hearts. These ancient continental centers, known as cratons, are far enough from tectonic plate boundaries to have survived for billions of years.

One such swath spans much of the Canadian provinces of Quebec and Ontario. "Most of that neck of the woods is known to be 2.7 [billion] to 3 billion years old," says Jonathan O'Neil, a geochemist at the University of Ottawa. But there's an even older part of that craton: a group of rocks in northern Quebec known as the Nuvvuagittuq Greenstone Belt, or NGB. It's at least 3.75 billion years old, among the oldest outcrops in the world.

But for the last 17 years, O'Neil and his colleagues have contended that the NGB is even older, kicking off a fierce debate.

The outcrop is "difficult to date because of the composition of the rocks," O'Neil says. The rocks are basaltic, formed through volcanism on the seafloor. Basaltic rocks typically don't form zircons — the hardy little minerals that offer geologists multiple windows into Earth's deep past. Zircons contain two isotopes, or forms, of uranium that decay into two types of lead — a twofer that provides dates difficult to disprove.

The zircon-poor NGB needed a different approach. In 2008, O'Neil and colleagues tried an unconventional isotopic dating method using the elements samarium and neodymium. The isotope samarium-146 decays into neodymium-142; this radioactive decay has been used to date moon rocks and Martian meteorites but had never been used on Earth rocks, O'Neil says. Using that isotopic decay, the 2008 study concluded that the NGB was about 4.3 billion years old.

Controversy ensued. One major issue was that the team had gotten a much younger age using another samarium-neodymium dating

An ancient intrusion of magma (striated rocks at center) in Canada helped geologists pin down the age of the planet's oldest rocks. ↙

J. O'NEIL

method, the radioactive decay of samarium-147 to neodymium-143. That method dated the outcrop to about 3.8 billion years ago.

That discrepancy, O'Neil says, can be attributed to differences in the isotopes' decay rates.

Another issue hinged on how to interpret the ages. The date discrepancy, some critics said, could indicate past chemical interactions between these rocks and ancient Hadean magma, creating an isotopic mishmash that muddles any age interpretation.

So in the new study, O'Neil and his colleagues intentionally looked for intrusions, places where ancient magma seeped into older rock so the geologic relationship between the rocks would be crystal clear. Then, the team performed the same two types of radioactive dating on the intrusions. This time, both methods came up with the same date: 4.16 billion years.

With that additional evidence, "I have to say that I was for the first time convinced that at least sections of the rocks exposed at Nuvvuagittuq may be of Hadean age," says Jörg Elis Hoffmann, a geochemist at the Free University of Berlin.

The original study's results were "provocative, but not wholly convincing," says Richard Walker, a geochemist at the University of Maryland in College Park. He has come around to the idea that this outcrop really does contain Hadean-age rocks — the first time that anything other than zircons have been shown to be so old.

That's exciting, he says, because having actual rocks from that time "provides an important window into the chemical and structural state of the Earth during its earliest period." ✖

MARIE LAFAUCI/GETTY IMAGES

↗ **Someday, consumers may be able to buy a cooling paint that reflects sunlight and mimics a body sweating.**

CLIMATE

A paint 'sweats' to keep buildings cool

By Larissa G. Capella

● **A cool house** without air conditioning may soon be possible. Scientists have developed paint that reflects sunlight and cools surfaces by slowly evaporating water. The paint works even in hot, humid places, offering a low-energy way to stay cool, researchers report in *Science*.

"The key is passive cooling," which requires no energy input, says materials scientist Li Hong of Nanyang Technological University in Singapore. Usually, passively cooling paints reflect sunlight and radiate heat from walls and roofs. But in humid places like Singapore, water vapor in the air traps heat.

Hong and colleagues developed a cement-based paint that combines three cooling strategies: radiative cooling, evaporative cooling (which our skin uses) and solar reflection.

The paint's porous structure holds water and slowly releases it, like the body does sweat. It reflects 88 to 92 percent of sunlight, even when wet, and emits up to 95 percent of the heat it absorbs. Nanoparticles boost reflectivity and strength, helping the paint maintain its reflective white color over time. In a test, the new paint remained white after two years of sun and rain in Singapore, while two other paints turned yellow.

A small amount of polymer and salt help retain moisture and prevent cracking. Tests showed a house covered in the paint used 30 to 40 percent less electricity for air conditioning than other houses.

Such highly reflective and water-retaining paint could help lower the urban heat island effect that makes cities hotter than surrounding areas. ✖

TECHNOLOGY

MARTIAN, HOW DOES YOUR ALGAE GROW?

By Erin Garcia de Jesús

● The future of plant life on Mars may be bioplastic. Green algae flourished under Mars-like conditions inside translucent, bioplastic habitats, researchers report in *Science Advances*. Algae or plants that produce bioplastics could be grown inside these habitats to provide more material to build livable structures. Such a self-sustaining loop could help space travelers make their own materials rather than relying on supplies hauled from Earth.

People would need a lot of supplies to live on another planet. "Extraterrestrial conditions are very hostile in general," says Robin Wordsworth, a Harvard planetary scientist. Among the biggest concerns is water.

Mars' atmospheric pressure is less than 1 percent that of Earth, too low for liquid water. "If you put a beaker of water on the surface, it would freeze and turn to steam in a very, very short time," Wordsworth says. He and colleagues wanted a way to both protect water and grow algae.

Beakers made of polylactic acid — a common bioplastic used in compostable utensils — can create a pressure gradient that stabilizes water. The 3-D printed chambers have a cloudy appearance that blocks harmful ultraviolet radiation but still allows enough light through so algae can photosynthesize and grow. The supplies needed to build the chambers include a 3-D printer and algal cells to jump-start growth, Wordsworth says. Other necessary raw materials such as ice and carbon dioxide are already found on Mars.

The habitats weren't designed to withstand Mars' cold climate. But the team has previously found that materials made from aerogels can be used to weather the cold, which suggests that a bioplastic-aerogel combo could better mimic Earth. Using such habitats to grow a diverse range of edible plants would also be important for survival. ✖

ARTIFICIAL INTELLIGENCE

HOW MUCH ENERGY DOES YOUR AI PROMPT USE? IT DEPENDS

BY CELINA ZHAO

A chatbot might not break a sweat every time you ask it to make your shopping list or come up with its best dad jokes. But over time, the planet might.

As generative AI such as large language models, or LLMs, becomes ubiquitous, crucial questions loom. For every interaction with AI, how much energy is used — and how much carbon dioxide is emitted?

In June, OpenAI CEO Sam Altman claimed that an average ChatGPT query uses as much energy as an oven does in a little over one second. AI research firm Epoch AI previously calculated a similar estimate. However, experts say the claim lacks key context, like what an "average" query even is.

"If you wanted to be rigorous about it, you would have to give a range," says Sasha Luccioni, an AI researcher at the AI firm Hugging Face. "You can't just throw a number out there."

Major players including OpenAI and Anthropic have the data, but they're not sharing. Instead, researchers can only piece together limited clues from open-source LLMs. One study in *Frontiers in Communication* examined 14 such models, including those from Meta and DeepSeek, and found that some models produce up to 70 times as much CO_2 emissions as others.

But even these numbers offer a narrow snapshot. Things get more dire after factoring in model training, manufacturing and maintaining hardware, and the scale at which generative AI is poised to permeate our daily lives.

LLMs are energy hogs, in part because of their large number of parameters — the internal knobs a model adjusts during training to improve performance. The more parameters, the more capacity the model has to learn patterns and relationships in data. GPT-4 is estimated to have over a trillion parameters.

These models are deployed in massive data centers across the world and loaded on servers containing powerful chips called graphics processing units. GPUs do the number crunching needed to generate helpful outputs. The more parameters, typically the more chips that are needed.

And that requires a lot of energy. Already, 4.4 percent of all energy in the United States goes toward data centers. By 2028, this number is projected to grow to up to 12 percent.

Training a model can take weeks and thousands of GPUs, but companies rarely disclose their training methods, so energy usage from training is largely a black box.

Over time, the latter part of a model's life cycle is expected to account for most emissions. That's because it uses a more energy-intensive process known as inference to make predictions. "You train a model once, then billions of users are using the model so many times," says computer scientist Mosharaf Chowdhury of the University of Michigan in Ann Arbor.

But inference, too, is difficult to quantify. The environmental impact of a single query can vary dramatically depending on which data center it's routed to, which energy grid powers the data center and even the time of day. Researchers can run open-source models locally and measure the energy consumed by their GPU as a proxy for how much energy inference would take.

In *Frontiers in Communication*, Maximilian Dauner and Gudrun Socher of Munich University of Applied Sciences reported testing 14 open-source AI models, ranging from 7 billion to 72 billion parameters, on the NVIDIA A100 GPU. Reasoning models, which explain their "thinking" step by step, consumed far more energy during inference than standard models, which directly output the answer.

That's due to tokens, or the bits of text a model processes to generate a response. More tokens means more computation and energy use. Even when responding to simple multiple-choice questions, reasoning models used an additional 543.5 tokens per question on top of the 37.7 tokens of standard models. At scale, the queries add up: Using the 70 billion-parameter reasoning model DeepSeek R1 to answer 500,000 questions would emit as much CO_2 as a round trip flight from London to New York.

In reality, the numbers are probably higher. Many companies have switched to NVIDIA's newer H100, a chip optimized for AI workloads that's even more power-hungry than the A100. To more accurately reflect the total energy used during inference, research suggests that reported GPU energy consumption needs to be doubled.

There are ways individuals can lower their AI carbon footprint. "Is it always needed to use the biggest model?" Dauner asks. "Or can a small model also answer easy questions, and we can reduce CO_2 emissions based on that?"

Similarly, not every question needs a reasoning model. Dauner and Socher found that the standard model Qwen 2.5 achieved comparable accuracy to the reasoning model Cogito 70B, but with less than a third of the carbon production.

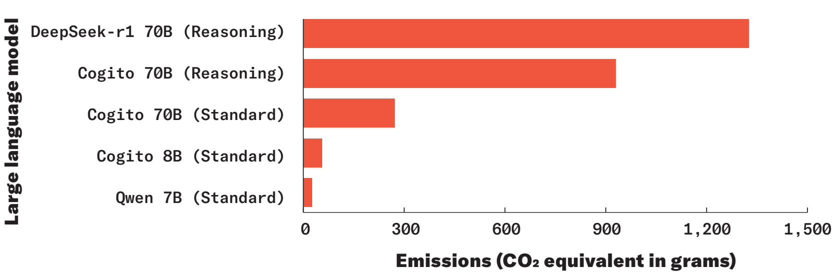
Public tools can help users measure and compare AI energy use. Hugging Face runs a leaderboard called AI Energy Score, which ranks models based on how much energy they use across 10 different tasks from text generation to image classification to voice transcription. It includes both open-source and proprietary models. The idea is to help people choose the most efficient model for a given job.

Even the way queries are phrased matters. Environmentally speaking, there's no need to be polite. "It costs millions of [extra] dollars because of 'thank you' and 'please,'" Dauner says.

Ultimately, policy must catch up. Luccioni, the researcher at Hugging Face, suggests a framework based on an energy rating system, like those used for household appliances. For example, "if your model is being used by, say, 10 million users a day or more, it has to have an energy score of B+ or higher," she says.

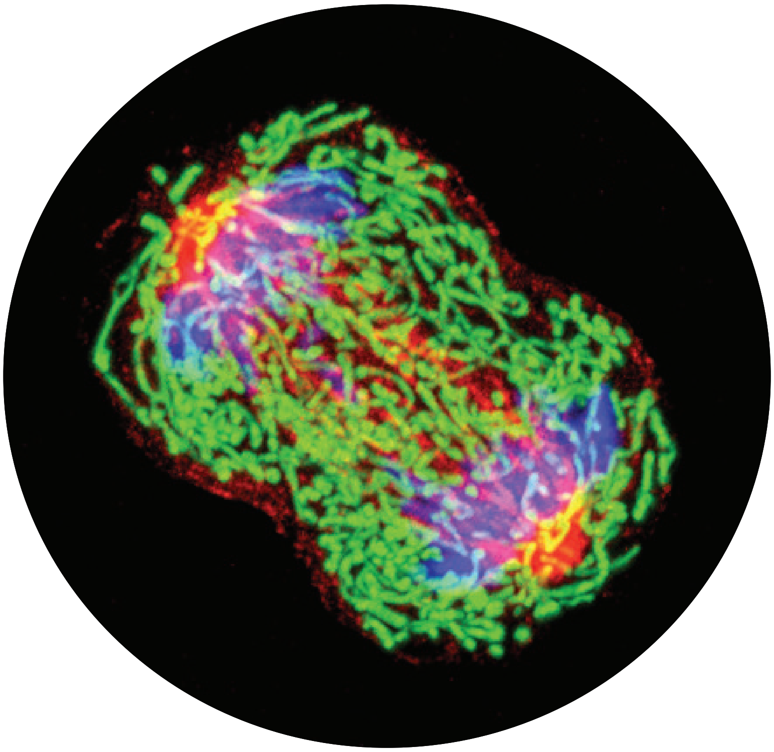
Otherwise, energy supply won't be able to sustain AI's growing demand. "I go to conferences where grid operators are freaking out," Luccioni says. "Tech companies can't just keep doing this. Things are going to start going south." ✖

THE CARBON COST OF RUNNING LARGE LANGUAGE MODELS



Researchers estimated the carbon emissions an LLM produced when answering 500 questions. Emissions varied widely. For example, the Cogito 70B reasoning model (which explains its "thinking" step by step) produced more than three times as much carbon as the standard Cogito 70B model. And the standard Cogito 70B model, with 70 billion parameters, produced five times as much carbon as the much smaller Cogito 8B, with 8 billion parameters.

M. DAUNER AND G. SOCHER/*FRONT. COMMUN.* 2025, ADAPTED BY T. TIBBITTS



HEALTH & MEDICINE

Cancer DNA is detectable in blood years before diagnosis

By Meghan Rosen

● **Cancer's genetic fingerprints** may lurk in people's blood long before they find out about the disease. It's possible to spot tumor DNA more than three years before a person is diagnosed with cancer, researchers report in *Cancer Discovery*. "We were shocked that we could find DNA," says Yuxuan Wang, an oncologist at Johns Hopkins University School of Medicine.

The findings suggest that hunting for these telltale traces using highly sensitive and accurate technology could be a powerful tool in cancer screening. It could one day help doctors detect cancers before any other signs or symptoms, Wang says. Even a diagnosis that's a few months earlier than usual might mean more treatment options. And a yearslong head start could be lifesaving. "It would dramatically change outcomes for our patients," Wang says.

Scientists have known for years that tumor cells shed DNA fragments into the bloodstream. Tests to pick up these fragments exist, but they're mostly for monitoring — not detecting — people's disease. Finding these fragments early in cancer progression is "like looking for a needle in a haystack," Wang says. Tiny, newly formed tumors shed infinitesimal amounts of DNA.

Her team wanted to find out just how early it could spy this DNA. The researchers studied blood collected during the 1980s and 1990s in a study that has been tracking participants' health for decades. They analyzed samples from 26 people who were diagnosed with cancer within the six months after the blood draw. Blood from eight of the 26 participants carried genetic signatures of cancer, lab tests revealed.

To see whether cancer could be detected even earlier, Wang's team tapped into samples collected from participants more than three years before their diagnosis.

Using whole genome sequencing, the team spelled out the individual letters that make up DNA and could pick out hallmarks of cancer DNA, alterations in the human genome that are cancer-specific. They were present at such low levels that other lab tests would have missed them.

Detecting cancer so early in the samples is "pretty provocative," says William Grady, a gastroenterologist at Fred Hutchinson Cancer Center in Seattle. He can imagine a future where patients with minute quantities of tumor DNA in their blood are given a "therapy that would basically eliminate those precancers." ✖

↖ Cancer cells, like this dividing breast cancer cell, can shed DNA fragments into the blood. Tests to spot these fragments could aid early cancer detection.

WEI QIAN/UNIV. OF PITTSBURGH CANCER INST., NCI

PSYCHOLOGY

AUTISM LOOKS SIMILAR IN YOUNG GIRLS AND BOYS

BY LAURA SANDERS

Autism in toddlerhood looks the same in boys and girls. A large study of autistic children between 1 and 4 years old turned up no overt differences in symptoms. Those results, published in *Nature Human Behaviour*, add clarity to how the disorder plays out in the first years of life. A deeper understanding of these symptoms could help clinicians identify kids who might benefit from specialized help early on.

Autism is more prevalent in boys than girls; roughly four boys are diagnosed for every girl. But studies have been inconclusive about whether boys' and girls' symptoms differ. Part of the uncertainty may have been due to studying older kids, whose life experiences may have shaped their symptoms. And part of the uncertainty may have come from small sample sizes, generally including less than 100 kids. By studying 2,618 kids with an average age of 27 months, the new study doesn't come with those concerns.

"This study, with its large sample size, provides stronger evidence for there being no differences in how autism is expressed in girls and boys," says Helen Tager-Flusberg, a developmental scientist and autism expert at Boston University who was not involved in the study.

Scientists tested these youngsters on 18 different measures, including their ability to dress independently, eye-tracking attention tests and language skills. On nearly all tests, scores for girls and boys with autism were indistinguishable. "We were actually incredibly surprised to find that there were no differences, no matter where, no matter how we looked," says neuroscientist Karen Pierce, codirector of the University of California, San Diego Autism Center of Excellence. The sole difference came from a parent-reported measure of daily living skills, such as feeding themselves, on which girls scored slightly higher than boys.

The study included boys and girls who did not have autism. Among those kids, girls were slightly more advanced on some social and developmental scores relative to boys, which was expected. But that's not what researchers saw for autistic youngsters. "At this very young age, they're just not presenting differently from a diagnostic perspective," Pierce says.

Differences in symptoms may show up later, as girls and boys grow up. But then again, they may not. Pierce hopes to follow these kids with autism over the years to explore what might change. If symptoms do diverge, as some studies suggest, that difference could be explained by biological differences, differences in social environments or a combination of the two.

The screening used to spot the girls with autism in the new study could have influenced the findings, Tager-Flusberg cautions. "Girls with milder symptoms may not have been identified," she says. If girls with less noticeable symptoms of autism were not included in the study, then the girls who remained would be more affected than other girls — a selection criteria that might have masked some differences between boys and girls, she says.

It's possible that the study missed autism in some young girls, Pierce says. But the screening method identified girls with autism at an expected rate, given national averages in the United States.

If the results are replicated, "then it opens up many questions about why girls with milder autism are often not identified until later in childhood, and why older autistic girls show somewhat different symptoms compared to boys," Tager-Flusberg says. "All these questions are important for understanding why autism is so much more common in males than females at all ages." ✖

3.2 percent

Prevalence of autism spectrum disorder in U.S. 8-year-olds

CHEMISTRY

Bacteria upcycle plastic trash into a pain reliever

By Skyler Ware

● **Dealing with plastic waste** is a real headache. But with a little help, bacteria can turn plastic into a painkiller.

Genetically engineered *Escherichia coli* bacteria converted a broken-down plastic bottle into paracetamol, the active ingredient in pain medicines like Tylenol and Panadol, scientists report in *Nature Chemistry*.

The approach could help reduce plastic pollution and curb reliance on the fossil fuels now used to make the ubiquitous medication. "I genuinely think this is quite an exciting sort of starting point for plastic waste upcycling," says engineering biologist Stephen Wallace of the University of Edinburgh.

Wallace and colleagues genetically engineered *E. coli* to transform polyethylene terephthalate, or PET, a polymer found in plastic bottles, into a molecule called para-aminobenzoic acid, or PABA. Next, the bacteria transformed PABA into paracetamol.

The tweaked *E. coli* converted 92 percent of the plastic waste to paracetamol within 48 hours.

There's a long way to go before this process could be scaled up, though. The method the researchers used to break down the plastic bottle into PET would be difficult to do in industrial proportions, says Dylan Domaille, a chemist at the Colorado School of Mines in Golden. But demonstrating that bacteria can turn plastic waste into something useful could motivate efforts to make breaking down plastics more scalable and sustainable, he says. ✖

FROM TOP: TADO STUDIO; PIEMAGS/NATURE/ALAMY STOCK PHOTO

ANIMALS

THIS SPIDER'S BARF IS WORSE THAN ITS BITE

By Susan Milius

● A drawing in a 94-year-old scientific paper has revived interest in one of the more roundabout recipes for a spider prepping dinner. First, swathe a fruit fly or other tidbit of prey in silk. Then throw up toxins all over it.

"I was like…what are you talking about?" says evolutionary biologist Giulia Zancolli of the University of Lausanne in Switzerland when she uncovered the revolting detail while reviewing another lab's paper for possible journal publication. Tracing back the references, she ended up with a 1931 paper.

Yet that turns out to be exactly how the feather-legged lace weaver (*Uloborus plumipes*) kills its meals. Zancolli and colleagues describe the novel food prep in *BMC Biology*.

Most spiders subdue their dinner by injecting venom from fangs. But cross sections of *U. plumipes* spider heads revealed rounded blobs of muscles where venom glands should be, perhaps to power their kill style. The researchers also confirmed that the spider fangs have no ducts for injecting anything. Instead, the team found signs in gut tissue of ample production of toxins.

The spiders take no chances when it comes to dosing: They don't just drool a bit on their meal, Zancolli says. They slather it liberally. ✖

ASTRONOMY

A record-breaking black hole smashup defies explanation

By Emily Conover

↑ Two black holes merged (illustrated) in the most massive collision of its type ever confirmed, physicists report.

● **Talk about epic.** A collision of two black holes was so extreme that it's challenging theories of how large black holes form and merge. The two black holes had masses bigger than any before confirmed in such a collision. One had about 140 times the mass of the sun, and the other about 100 solar masses. And both were spinning at nearly the top speed allowed by physics.

The merger produced a black hole with a mass about 225 times that of the sun, researchers report in a paper posted at arXiv.org. The biggest bang-up previously confirmed made a black hole of about 140 solar masses. Scientists deduced the black holes' properties from ripples in the fabric of spacetime called gravitational waves, which were detected in 2023 by the Laser Interferometer Gravitational-Wave Observatory, or LIGO.

Black holes with masses below about 60 times that of the sun form when a star collapses at the end of its life. But there's a window of masses — 60 to 130 solar masses — where this mechanism is thought not to work. The stars that would form such black holes are expected to fully explode when they die, leaving behind no black hole.

For the newly reported black holes, uncertainties on the mass estimates mean it's likely that at least one of them, and possibly both, fell in that forbidden mass gap. "This event doesn't have a clear and obvious match with any of the major formation mechanisms," says Cole Miller, an astronomer at the University of Maryland in College Park who wasn't involved with the study.

One explanation for the black holes' existence is that they were part of a family tree, with each one forming from an earlier collision of smaller black holes. Repeated mergers might happen in dense clusters of stars and black holes, and would lead to rapidly spinning black holes.

But there's an issue, Miller says. The black holes are so massive that if they came from a family tree, that tree might have required multiple generations of ancestors. That process would give rise to black holes that are spinning fast, but not quite as fast as the newly observed ones. That's because the black holes that merged in previous generations could have been oriented in different directions, partially canceling out their spins.

Another idea is that the black holes bulked up in the shadow of a much bigger black hole, a supermassive black hole feeding on a disk of gas. If the black holes were born in or fell into that disk, they could gobble up gas before merging.

But there's a hint that the two merging black holes were spinning in different directions. That conflicts with expectations for black holes all steeping in the same disk. ✖

ASTRONOMY

AN ALIEN COMET VISITS THE SOLAR SYSTEM

BY CELINA ZHAO

For only the third time in history, astronomers have detected a new interstellar visitor — an object from another star — blitzing into the solar system. Designated as 3I/ATLAS, the comet was spotted by a survey telescope in Chile on July 1 and confirmed by the International Astronomical Union's Minor Planet Center.

To piece together its trajectory, astronomers dug through older sky surveys and found its position as early as mid-June. Because 3I/ATLAS seems to be hurtling in nearly a straight line through the solar system and going so fast that the sun's gravity can't capture it, astronomers are certain the object, which could be as wide as 20 kilometers, has alien origins.

It may also have very ancient origins. Calculations suggest that 3I/ATLAS came from a part of the Milky Way called the thick disk. If so, there's a two-thirds chance that it's a comet over 7 billion years old. That would make it older than the solar system and the oldest comet known. Astrophysicist Chris Lintott of the University of Oxford and colleagues reported the age estimate at the Royal Astronomical Society's National Astronomy Meeting 2025 in Durham, England.

The first known interstellar visitor was a bizarre, asteroid-like object named ʻOumuamua. It was spotted in 2017 coming from the direction of the constellation Lyra. Because ʻOumuamua receded from view a mere 2.5 months after its discovery, astronomers caught only fleeting glimpses of the object. A second object, 2I/Borisov, was first glimpsed in 2019. It was later confirmed to be a rogue comet from the direction of the constellation Cassiopeia.

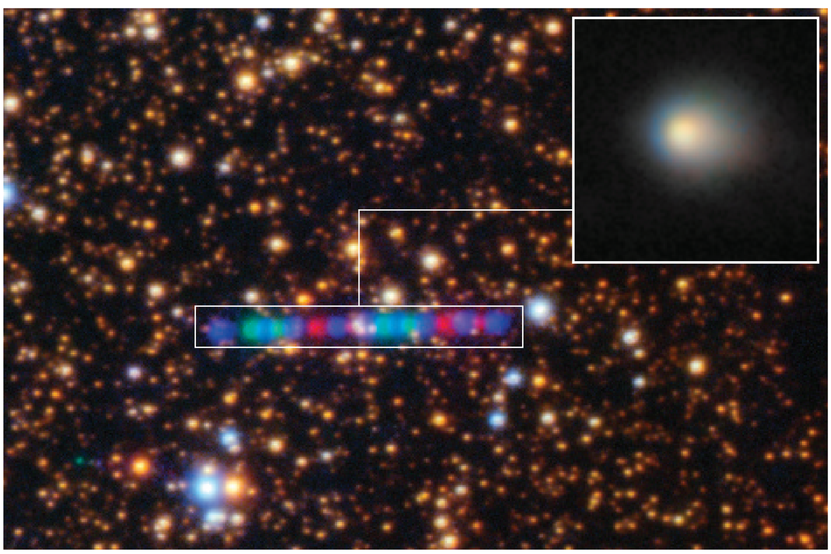
"What's amazing [about 3I/ATLAS] is we discovered this on its way into the solar system," says Pamela Gay, an Illinois-based astronomer with the Planetary Science Institute. That means scientists will have ample time to observe its path past the sun. 3I/ATLAS will likely be visible from Earth through early 2026.

Further observations will help determine 3I/ATLAS' composition, a "rare chance to get data about another solar system that we can get in no other way," Gay says. Comets are likely leftover planetary material, so such information could illuminate how planets form in general.

Composition data will also help confirm the prediction about the comet's age and origin. As the comet approaches the sun, sunlight will trigger outgassing, revealing vapor and dust signatures. Astronomers will be particularly eager to measure its water abundance and elemental makeup, which could help verify whether 3I/ATLAS came from the orbit of an old star.

Until then, 3I/ATLAS' origin remains a guessing game. "It's like *Wheel of Fortune*," Gay says. "We have four letters out of 20 right now, and someone might be able to guess the entire phrase, but they could also be very wrong." ✖

An Earth-based telescope captured comet 3I/ATLAS streaking across a dense star field. The comet (the inset shows a close-up) originated outside of the solar system. ↓



INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA, K. MEECH/IFA/U. HAWAII
IMAGE PROCESSING: JEN MILLER & MAHDI ZAMANI (NSF NOIRLAB)

CLIMATE

HARMFUL HEAT DOESN'T ALWAYS COME IN WAVES

BY NIKK OGASA

It's been another summer full of deadly heat waves. But scientists are warning of another hazardous form of heat: chronic heat. In places like Miami and Phoenix, temperatures can soar for months at a time without reaching heat wave levels, potentially contributing to health issues such as kidney dysfunction, sleep apnea and depression. But too little research has focused on how these impacts may compound over months of exposure, climate and health researcher Mayra Cruz of the University of Miami and colleagues report in *Environmental Research: Climate*.

"It's the family that lives with conditions that are just a little bit too hot all the time and no air conditioning," says V. Kelly Turner, an urban planner at UCLA who was not involved in the study. "The mother is pregnant in hot conditions, their children go to bed without air conditioning and go to schools without air conditioning, and then that's changing their developmental physiology."

There is an urgent need for research focused on the health impacts of prolonged heat exposure, experts say, especially as climate change increases the number of hot days worldwide.

Heat waves are typically defined as periods when daily temperatures exceed some threshold, often based on an area's average or baseline temperature. But in tropical and subtropical regions, the baseline may already be dangerously high. In Miami, the heat index — what the temperature feels like when relative humidity is combined with air temperature — can reach 32° Celsius (90° Fahrenheit) on roughly half the days of the year.

The strongest evidence linking chronic heat to health problems comes from research on agricultural workers in Central America, where persistently hot working conditions have been associated with chronic kidney disease. Some studies show that providing water, shade and rest can help halt the decline of kidney function.

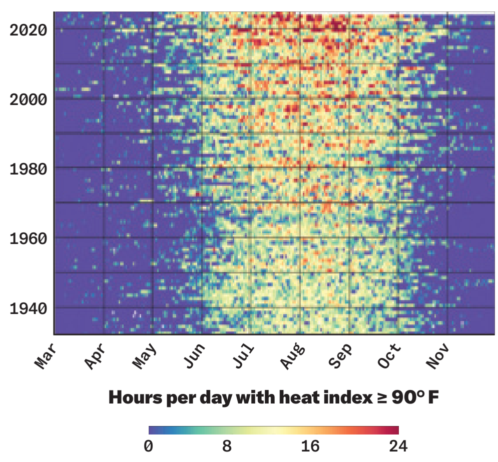
"It's one indication that if you're persistently exposed to heat and dehydrated, this could lead to you developing a disease," Cruz says.

However, there isn't much other research focused on chronic heat's health risks. Looking at data on heat-related deaths from places where it's hot for a season, "there's not a lot of evidence that they have higher mortality rates," says climate and health researcher Kristie Ebi of the University of Washington in Seattle.

But even baseline heat can exacerbate existing health conditions. "Heat is the great force multiplier of chronic medical conditions," says Pope Moseley, an intensive care physician and biomedical sciences researcher at Arizona State University in Phoenix. It's especially relevant for conditions related to blood flow or inflammation, as heat stress can cause more blood to flow to the skin and less to other parts of the body, he says. "We have 15 liters of tubing and five liters of blood, so we're shunting blood constantly."

Additionally, some medications can degrade and become less effective in the heat, Moseley says, and some can even exacerbate

THE RISE OF CHRONIC HEAT IN MIAMI



Chronic heat is a growing health concern. In Miami, the number of hours per day with a heat index of at least 90° Fahrenheit is increasing. Oranges and reds represent days with 16 to 24 hours of such high heat.

BRIAN MCNOLDY, NOAA

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heat stress by making it harder for people to regulate their body temperature. Diuretics can reduce the volume of body fluid, and some antipsychotics can impair sweating.

Sleep can be affected too, especially in cities where urban materials radiate heat at night. One study found that hot nights can increase the odds of experiencing obstructive sleep apnea. Another found that warming temperatures erode roughly 44 hours of sleep per person annually, with effects apparent when nighttime temperatures remained above 10° C (50° F) and little evidence of seasonal acclimatization.

Recurring sleep disturbances can lead to poorer cardiometabolic health and overall well-being, says Bastien Lechat, a sleep health researcher at Flinders University in Adelaide, Australia.

Chronic heat can also increase stress and anxiety, worsen mental health conditions and affect cognition. A 2020 study of U.S. high schoolers taking the PSAT found that when compared with 16° to 20° C school days (60° to 69° F), each additional school day that was 32° to 37° C (90° to 99° F) was associated with a drop in student achievement of about 0.17 percent of a year's worth of learning.

All these impacts may compound over months of heat, and vulnerable populations are most affected because they face the greatest challenges in affording or accessing cooling, Cruz says. "We're assuming that everyone has AC and has resources. But that's not true."

In fact, part of why relatively little research exists on chronic heat may be because of who it most affects, Cruz adds. "The populations that we tend to ignore are the exact ones that we're talking about when it comes to chronic heat." ✖

↗ Spikes of the spore-spreading form of *Cordyceps* fungus stick out of the cocoon of a dead caterpillar that had been turned into a food-gathering puppet.

C. WANG

LIFE

Why zombie caterpillars can't stop eating

By Susan Milius

● **Here's a new detail** of how a real-life fungus zombifies caterpillars: by crashing their blood sugar.

That's a recently discovered bit of science related to the zombie-apocalypse video game and TV series *The Last of Us*. The fiction chronicles an imaginary version of a *Cordyceps* fungus that has jumped from insects to humankind. The menace spreads via bites from crazed, ravenous bands of the infected stragglers of our species. Their voracious appetites turn out to be rooted — at least somewhat — in science.

Pathologist Chengshu Wang of the Shanghai Institute of Plant Physiology and Ecology and colleagues discovered that the species *Cordyceps militaris* carries a gene for making an enzyme called trehalase, a perfect tool for mind-controlling caterpillars. It breaks apart a form of sugar with 12 carbons that would normally circulate through the body of a caterpillar nibbling on a leaf. That enzyme messes with the signal of hunger being satisfied, so the caterpillar eats in a frenzy. And that will only make its plight worse.

The enzyme turns the caterpillar's normal sugar into a six-carbon glucose as a breakdown product. That's a fine feast to nourish a fungus. *C. militaris* flourishes while the caterpillar stays zombie-grade hungry, Wang's group reports in *Current Biology*. The caterpillar doesn't die until it has wrapped itself into a cocoon and no longer feeds the fungus. *C. militaris* then sprouts orange spore-bearing prongs out of the mummy-wrapped cocoon of the, finally dead, insect. ✖

GENETICS

DNA RECORDS ORIGIN OF A BELOVED ASIAN BEAN

By Celina Zhao

● Sweet red bean paste made from adzuki beans is a beloved staple in East Asia. But the origins of the bean have long been contested.

Scientists have now traced the plant's domestication to Japan between 3,000 and 5,000 years ago, with its spread and diversification in China occurring later, researchers report in *Science*.

Fossilized beans suggest early cultivation by Japan's Jomon people, hunter-gatherers who lived as early as 16,000 years ago. But genetic clues had pointed to China instead.

The new study found that Chinese cultivars show the most diversity in their nuclear genomes, DNA that's inherited from both parents. But their chloroplast genomes, DNA passed down maternally that evolves more slowly, closely match those of wild Japanese beans. That suggests the beans were first domesticated in Japan and later spread to China, where they hybridized with wild Chinese red beans.

During this process, adzuki beans also acquired mutations that gave them their signature red hue.

The trait's early spread may reflect human aesthetic preferences. Red, long considered lucky, also colored Jomon lacquer pottery. ✖

PALEONTOLOGY

How fast did dinosaurs really go?

By Sofia Caetano Avritzer

● **Over a video call** from a dig site near Oxford, England, Peter Falkingham points his phone down to show a fossilized footprint of what was probably a large sauropod.

Stepping inside the long-necked dinosaur's print, which could fit both of his feet multiple times, he explains that these marks are parts of trackways, sets of millions-of-years-old footprints left by dinosaurs walking on wet ground that fossilized. These trackways have long been considered key

FROM LEFT: YOYOCHOW23/GETTY IMAGES; RYAN SNOOK

to estimating dinosaur running speeds. “The faster you move, the longer the stride you take,” says Falkingham, a paleobiologist at Liverpool John Moores University in England.

In the 1970s, zoologist Robert McNeill Alexander used this principle to develop equations to calculate animals’ speeds based on the distance between their footprints. Suddenly, any scientist who found dinosaur trackways could calculate the potential speed of that animal in life — *Tyrannosaurus rex*, for example, might hit 20 kilometers per hour, about a five-minute-mile pace,

↖ **Scientists are rethinking calculations of how fast dinosaurs moved.**

while *Velociraptor* could go as fast as 40 kph, a 2.5-minute mile.

“It’s easy to plug numbers into the equation and get a number out, and you feel like you’ve done a calculation, so it must be correct,” Falkingham says.

But not so fast. The equations were originally developed using footprints of mammals walking on hard ground. Trackways form only on wet soil, and dinosaur skeletons are much more similar to those of modern birds, not mammals, says Jonathan Codd, a physiologist at the University of Manchester in England, who was not involved in the study.

Another variable is hip height. The calculations factor in that distance from the ground, but that’s often unknown when all that is left is the animal’s footprints.

The formula can’t give an animal’s exact speed like most studies report, Falkingham says. “I got grumpy at reading all these papers.”

Falkingham decided to put the math to the test using videos of helmeted guinea fowl (*Numida meleagris*) walking, recorded more than 10 years ago as part of a study to reconstruct the 3-D motion of the bird’s foot as it went in and out of mud. It was messy business and the birds had to have their feet cleaned after every experiment.

The guinea fowl’s actual speed didn’t match those calculated from the footprints they left, Falkingham and colleagues report in *Biology Letters*. The calculated speeds could be up to 2.5 times the speed that the animals actually moved, probably because walking over soft, sticky ground slowed the birds down.

The equations worked pretty well in previous studies of guinea fowl running on a treadmill because the birds were taking uniform steps on a hard surface. But the birds in this study had strides of different lengths even while maintaining a constant speed. “That’s just how animals move when they’re out in the wild. They speed up, they slow down, they take longer strides when they don’t need to,” Falkingham says.

These data are not the definitive answer to the challenge of dinosaur speed estimation, he says. They just show that the lab math isn’t adding up in the real world. There are limits on what can be said about a creature no one has ever seen, Codd says. ✖

THE HEALTH CHECKUP

MEASURE BLOOD SUGAR WITH A GRAIN OF SALT

BY SUJATA GUPTA

Nicole Spartano does not have diabetes. But the Boston University epidemiologist has occasionally worn a continuous glucose monitor, or CGM, a device once reserved for those with the condition. Her desire to understand how factors such as food, sleep and exercise influence her blood sugar levels stems from her own research into how CGMs might help individuals ward off diseases like diabetes and feel healthier overall.

People with diabetes use CGMs to monitor their blood sugar level and need for supplementary insulin, the hormone (produced naturally in most people) that enables cells to consume that sugar for much-needed energy. Less is known, though, about how to interpret CGM readings in people without the condition, Spartano and others say.

Nonetheless, the devices' popularity has exploded in recent years. That's in part thanks to endorsements from influencers like Casey Means, President Donald Trump's nominee for U.S. surgeon general. In her 2024 book, *Good Energy*, Means, who cofounded a company that sells the devices, touted CGMs as "the most powerful technology for generating the data and awareness to rectify our Bad Energy crisis in the Western world."

Last year, the U.S. Food and Drug Administration approved the sale of CGMs without a prescription. A single device, which typically lasts for two weeks and is then discarded, retails for roughly $50. CGMs attach to the arm or abdomen via a small, sensor-equipped needle that sits in interstitial fluid just below the skin. Glucose passes from the blood into that fluid. The sensors then transmit data every few minutes to a receiver or smartphone.

Based on conventional blood tests, blood sugar levels from 70 to 140 milligrams per deciliter while not fasting are widely considered optimal. Frequent spikes and prolonged time above that range have been linked to an increased risk of developing cardiovascular disease, as well as fatigue and anxiety.

Because people's responses to foods vary widely, CGMs can be used to develop personalized diet plans, says Ruchi Mathur, an endocrinologist at Cedars-Sinai Medical Center in Los Angeles. Mathur advises curious patients to treat the CGM as an experiment. If a patient wants to know how they respond to a tuna sandwich, they might go with white bread one day and wheat the next.

But interpreting CGM data is complex. The same meal could prompt different glucose responses from one week to the next, researchers reported in January in the *American Journal of Clinical Nutrition*. And Spartano and her team found that most individuals without diabetes spend roughly three hours per day with blood sugar levels above 140 mg/dL. If CGMs become standard health tools, the optimal glycemic range may need a rethink, the team notes.

CGM readings don't yet translate to broadly applicable medical guidance. When Spartano asked clinicians if certain patients' complex CGM readings indicated a need for further testing, they rarely agreed.

"We want to be able to tell [people], 'This looks normal. This looks abnormal,'" Spartano says. "We don't really know what is normal."

There's no standard way to interpret CGM data, concurs Vijaya Surampudi, an endocrinologist and nutrition expert at UCLA Health. But practitioners familiar with the devices can help patients interpret their data. When Surampudi advises patients without diabetes to try CGMs, she also recommends that they track foods, stressors, sleep and exercise.

Spartano says not to put too much stock in CGM data. Her results showed that scarfing rice kept her glucose levels flat, while chewing it slowly triggered a spike. She could have concluded that she should inhale her meal to block her body from processing the sugars. But health is much broader than a single metric. Scarfing food can encourage overeating or prevent nutrient absorption.

Blood sugar, she says, "shouldn't be all we focus on." ✖

EARTH

An ancient impact could help in the search for Martian life

By Douglas Fox

● **In a remote desert**, scientists have discovered one of Earth's oldest asteroid impacts. It most likely dates to a time when our planet was inhabited solely by single-celled life.

The impact happened at what's now called North Pole Dome in northwest Australia, its presence hidden within ragged, red rocks made of lava that erupted billions of years ago. Scattered here and there are sedimentary rocks that hold some of the planet's oldest microbial fossils, which grew in bubbling hydrothermal pools and shallow seafloors. Those fossils and the impact could be crucial for studying past life on Mars, geologist Alec Brenner and colleagues report in *Science Advances*.

These rocks are "the best analogs we have on Earth to what a lot of the surface of Mars look[ed] like" 3 billion to 4 billion years ago, says Brenner, of Yale University. During that era, the Red Planet was periodically wet and may have harbored life.

The finding could help scientists predict how Martian microbial fossils might appear if a rover encounters them. Many rocks on Mars' surface have been altered by things such as hot fluid flows or meteor impacts, which can obscure real fossils or create bubbly structures that resemble tiny fossils but aren't.

The impact structure "is a really cool place for people to learn what the effects of an impact happening on fossils and early life would look like" on Mars, Brenner says.

Scientists believe that early Earth was pummeled by asteroid impacts; the moon and Mars are littered with giant craters, some over 4 billion years old. In contrast, the oldest known impact structure on Earth is just 2.23 billion years old. Unlike Mars and the moon, Earth's oldest craters have been obliterated by erosion and plate tectonics, which melts and recycles the crust.

Brenner accidentally discovered the new site — now called the Miralga impact structure — while driving across North Pole Dome in 2023. When he stopped to show his field assistants some attractive lava rocks, he noticed that some of them appeared to have been chiseled into cone shapes, with their tips pointed skyward. These "shatter cones" formed as the shock wave from a massive impact penetrated kilometers into the planet's crust.

"The crater itself has been eroded away" along with three kilometers of rock, Brenner says. "All we're looking at is the deep, deep

↖ **Some ancient craters are marked by "shatter cones" (one shown), a few to tens of centimeters across, which formed as a shock wave penetrated the ground.**

A. BRENNER/HARVARD UNIV.

underneath of the crater that's been whacked really hard."

It's a surprising find, because scientists have studied this area for decades, says Aaron Cavosie, an impact geologist at Curtin University in Perth, Australia. "Sometimes these things are just hiding in plain sight."

Brenner, Cavosie and their colleagues mapped hundreds of small shatter cones across an area nearly 7 kilometers wide. The tips of the cones pointed like compass needles toward a central point overhead, where a 1- or 2-kilometer-wide meteorite had struck — sending shock waves into the ground and forming a crater estimated to be 16 kilometers across.

Most of the shattered rocks were 3.47 billion years old. But Brenner's team found that in one area, the shatter cones extended into an overlying rock layer only 2.77 billion years old — so the impact must be younger than that. Brenner estimates it happened between 1.2 billion and 1.8 billion years ago.

Cavosie is especially excited about the 3.47-billion-year age of the rocks that were hit. "There's no rocks on Earth older than these basalts that preserve evidence of shock deformation" from an impact, he says. The rocks contain rare "shocked" titanium minerals, denser than those normally found on Earth's surface, which recorded the high pressure of the strike.

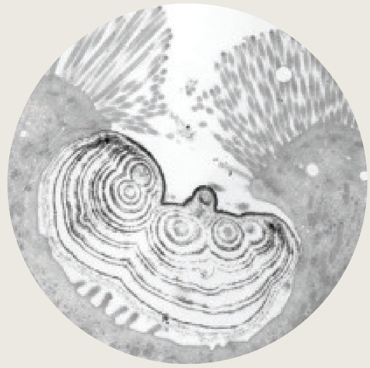
These earthly volcanic basalts are similar to those on Mars, particularly in places like Jezero crater, which may have intermittently held a lake 3 billion to 4 billion years ago. NASA's Perseverance rover has explored that crater and examined layers of sandstone and mudstone formed by flowing water. It drilled into those rocks and collected seven rock samples, one of which contains strange "leopard spot" structures that could have been created by ancient microbes.

Any potential biomarkers in those Martian rocks are likely to be ambiguous, altered by hydrothermal fluids, chemical weathering or meteor impacts, says Michaela Dobson, a Brisbane, Australia–based geologist with the New Zealand Astrobiology Network, who is not part of Brenner's team.

Ancient fossils in the North Pole Dome area were altered by similar processes, including — we now know — a large impact. "We can go back to these environments with fresh eyes," Dobson says, to understand how the fossils were altered and how they might appear in Martian rocks. ✖

"Sometimes these things are just hiding in plain sight."

— Aaron Cavosie



JEHAN-HERVÉ LIGNOT/UNIV. OF MONTPELLIER

ANIMALS

A NEWLY DISCOVERED CELL HELPS PYTHONS POOP BONES OF PREY

By Bethany Brookshire

● Burmese pythons and other snakes are well-known for swallowing their prey whole. But there's not a bone to be seen in their poop. The secret? A specialized cell in the snake's intestine that collects nuggets of calcium and phosphorus from the prey's bones, scientists reported in the *Journal of Experimental Biology*. These excess bits of ex-bone are then smoothly excreted.

Snakes like Burmese pythons (*Python molurus bivittatus*) have highly acidic stomachs that wear away at even the enamel of an animal's teeth. Without enough calcium in their diets, snakes' health can suffer. Too much, though, is poison.

Researchers examined the intestines and blood of 14 pythons with different diets. When the snakes were fed normal rats (bones and all), the scientists observed a different kind of cell — one that was not like the nutrient absorbing villi around it (shown above under a microscope).

These cells, shaped like small cups, contained iron-rich particles. These particles collected concentric layers of the excess calcium and phosphorus from the snake's meal much like rock candy collecting around a stick.

Similar cells may exist in other reptiles and even some birds. ✖

JUST RELEASED!

Cache of 832 Last Year 1921 Morgan Silver Dollars Still Pristine As The Day They Were Struck

Sold Nationally for as much as $141

Last Year of Issue

Actual Size 38.1 mm

90% Pure Silver

No coin embodies the spirit of America more than the Morgan Silver Dollar. From the Comstock Lode discovery that provided millions of ounces of silver to make them, to outlaws robbing stagecoaches in the Wild West to pay for their bar tabs and brothel visits, the hefty Morgan Silver Dollar holds a special place in American history.

It's no wonder collectors and history buffs alike clamor to get their hands on them. That is, if they can get their hands on them.

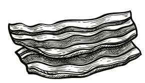
In 1921 This $1 Could Buy:

2.5lbs of flour

3 dozen eggs

8lbs of pot roast

22lbs of corn meal



8lbs of salted pork

Prized Last-Year Coins

Collectors love "lasts" as no collection is complete without the last coin struck. Last year coins are often hard to find and always in demand. Little did master engraver George T. Morgan know the legacy he was creating when he designed what has become known as "The King of Silver Dollars" but it came to an end 104 years ago with the last-year 1921 Morgan Silver Dollar, the most beloved coin in American history.

Public Release - Only 832 Coins Available

Rarcoa®, America's Oldest Coin Company, is announcing the public release of 832 of the very last year 1921 Morgan Silver Dollars, struck at the iconic Philadelphia Mint. Each coin today comes in Brilliant Uncirculated condition, pristine as the day they were struck!

Hold 104 Years of American History

Struck in 1921, each coin is one hundred and four years old. Could Charles Lindbergh carried your coin in his pocket during his flight across the Atlantic? Or maybe your great-grandfather carried it while storming the beaches of Normandy during World War II before ending up in a small coin shop in Tuscaloosa,Oklahoma. Each coin has its own unique history and you can hold 104 years of American history when you buy yours today!

A Miracle of Survival

Coin experts estimate that only 15%-20% of Morgans are still surviving today due to multiple mass-meltings over the years. The Pittman Act of 1918 melted over 270,000,000 coins, that's almost 50% of all coins produced at the time. Untold quantities were melted in the 1980s and 2000s when silver prices rose up to $50 per ounce.

Sold Nationally for as much as $141

This same 1921 Morgan Silver Dollar sells elsewhere for as much as $141. But thanks to Rarcoa's buying power and numismatic expertise, you can own one for as little as $49, in quantity while supplies last. **That's a difference of up to $91!**

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Act now and you can SAVE BIG when you buy more! But don't wait, our inventory won't last long.

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Features

ASTRONOMY

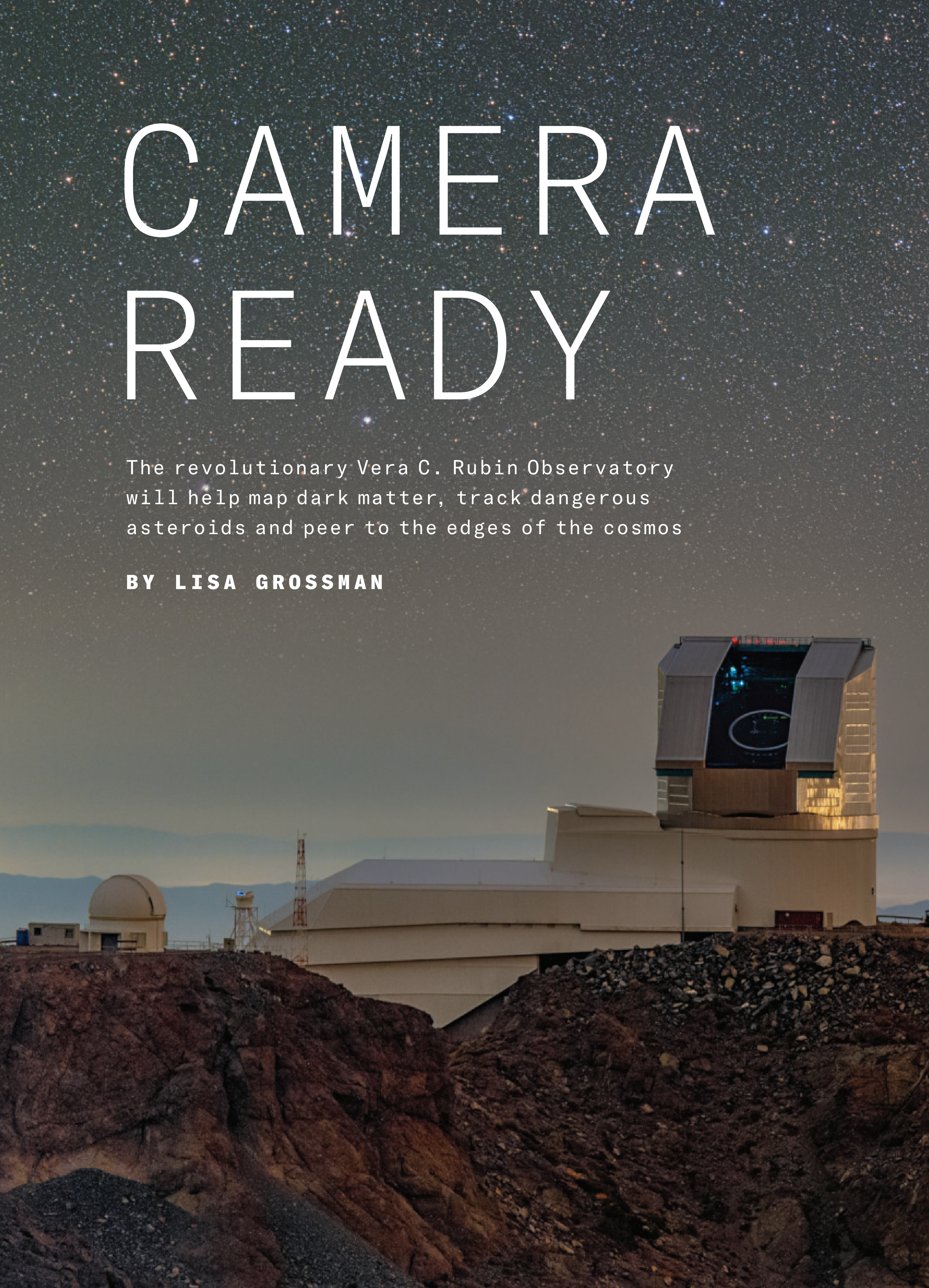
A GUIDING LIGHT FOR WOMEN IN SCIENCE

● In the 1960s, astronomy was a boys' club. Women were barred from doing research at some observatories, allegedly because they had no women's restrooms. Once, Vera C. Rubin staked her claim at an observatory by taping a triangle skirt to a stick figure on the men's room door. Now, Rubin, shown at Arizona's Lowell Observatory in 1965, has an observatory named after her (see Page 34). As a champion for women in astronomy until her death in 2016, she held open the door to science for future generations. —*Lisa Grossman*

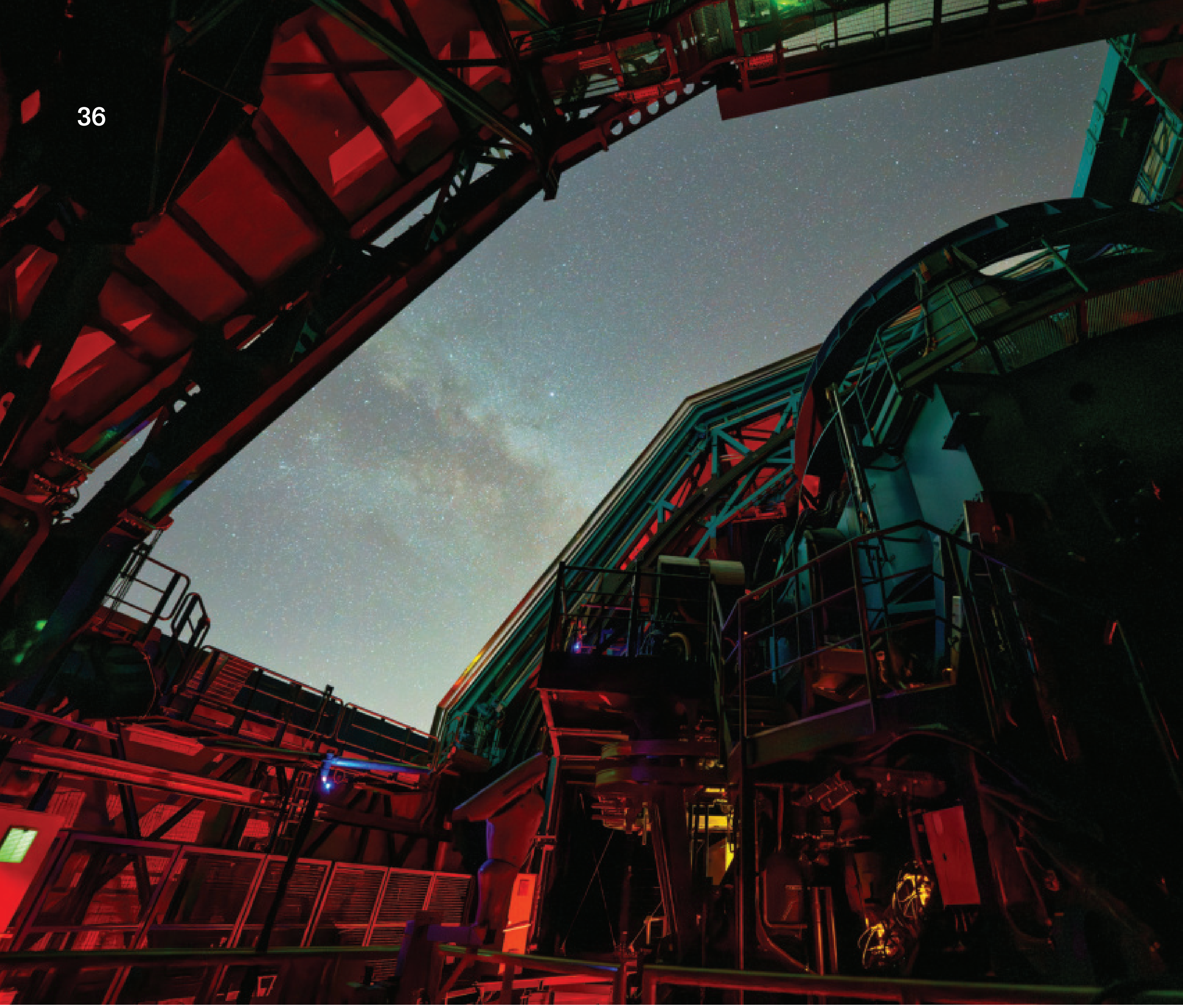
CAMERA READY

The revolutionary Vera C. Rubin Observatory will help map dark matter, track dangerous asteroids and peer to the edges of the cosmos

BY LISA GROSSMAN



Built on a flat mountaintop high in the Chilean Andes, the Vera C. Rubin Observatory was named to honor the work of a trailblazing U.S. astronomer.



PREVIOUS SPREAD: RUBINOBS/NOIRLAB/SLAC/NSF/DOE/AURA/P. HORÁLEK/ INSTITUTE OF PHYSICS IN OPAVA

AT 3 A.M. ON A CRISP MAY NIGHT IN CHILE, ALL SEEMED WELL WITH THE WORLD'S LARGEST DIGITAL CAMERA. UNTIL IT DIDN'T.

Inside the newly built Vera C. Rubin Observatory, site project scientist Sandrine Thomas was running tests when a flat line representing the camera's temperature started to spike. "That looks bad," she thought. She was right. Worried scientists quickly shut down the telescope.

I arrived a few hours later, jet-lagged but eager to get my first glimpse at a cutting-edge observatory that astronomers have been awaiting for more than 25 years.

Perched on a high, flat-topped mountain called Cerro Pachón, the Rubin Observatory was conceived back in the 1990s to give astronomers the unprecedented ability to probe the cosmos in every dimension. With a wide and deep view of the sky, Rubin can investigate some of the universe's slowest, most eternal processes, such as the assembly of galaxies and the expansion of the cosmos. And by mapping the entire southern sky every couple of nights, it can track some of the universe's fastest and most ephemeral events, including exploding stars and visits from interstellar comets.

At the end of its planned 10-year survey, Rubin will have taken 2 million images with 2,300 megapixels each, capturing more of the cosmos than any other existing telescope.

"For the first time in history, the number of cataloged celestial objects will exceed the number of living people!" Željko Ivezić, an astronomer at the University of Washington in Seattle, and colleagues wrote in a 2019 overview paper in the *Astrophysical Journal*.

As Rubin's director of construction, Ivezić might have worried that the project's scientific goals would be accomplished by other telescopes during the decades it took to build the facility. But, he says, the questions the team set out to answer when the project was dreamed up remain unresolved. "To answer them, you need something like Rubin," Ivezić says. "There is no competition."

In an unusual move, Rubin data will be made available online to anyone in the world, from professional astronomers to elementary school students. "That's a huge democratization of science," Ivezić says. The hope is that these data will help solve fundamental mysteries of the universe that can't be tackled any other way.

But first, Thomas and her team had to get the camera back online.

FROM DARK MATTER TO ASTEROIDS

The idea that led to Rubin's construction came during another 3 a.m. vigil almost 30 years ago, on the next mountaintop over from Cerro Pachón.

It was January 1996, and astronomer Tony Tyson, then with Bell Laboratories, and his colleagues had recently brought a new digital camera to a 4-meter telescope sitting on Chile's Cerro Tololo. The camera used what was then a relatively new technology called charge coupled devices, or CCDs. These silicon chips convert particles of light to electrons, which can then be turned into an image of the light source. CCDs started to be used in astronomy in the 1970s and quickly became the industry standard, replacing slow and bulky photographic plates. Several CCDs arranged in a mosaic act as one large camera, converting more electrons to more pixels and delivering higher-resolution images.

Tyson's camera, the most powerful in the world at the time, was made up of four CCDs. He and colleague Gary Bernstein built it to make a map of dark matter, the mysterious substance thought to make up 80 percent of all matter in the universe. Astronomers don't know what it is, but because of its gravitational effects on regular matter, they're pretty sure it's there.

One of those effects was discovered in the 1970s by astronomer Vera Rubin, the new observatory's namesake. Based on a galaxy's visible matter, you would expect stars to orbit slower the closer they are to the disk's edge, like planets in the solar system do. Instead, Rubin and her colleague Kent Ford noticed that stars at the edge were whipping around the galactic center so fast they should have been flung into space. The best explanation was that some other, unseen matter must be holding galaxies together.

There's another way dark matter can make its presence known. Matter warps the fabric of spacetime, and that changes the path of light as it speeds through the universe. Clumps of dark matter can therefore distort the images of visible objects in the background. This effect, called weak lensing, is the only way to "weigh" the distribution of dark matter in the universe, Tyson says.

That's what Tyson had come to Chile to do. But one night as he, Bernstein and some other astronomers sat in the telescope control room, Tyson had a revelation. He looked around and said, "Guys, we can do better than this." They could, in principle, build a bigger quilt of CCDs to create a much more powerful telescope. Computers were getting better and faster all the time, so they could keep up with the flood of data such a telescope would gather. All they needed were a few technical improvements.

Tyson decided to make this

↖ **Rubin's dome opens to let the camera survey the sky, then closes to protect it from the elements. → The crew works in shifts through the night from a control room in a separate part of the facility.**

THIS SPREAD, LEFT: RUBINOBS/NSF/DOE/NOIRLAB/SLAC/AURA, H. STOCKEBRAND; RIGHT: MARCOS ZEGERS/*THE NEW YORK TIMES*/REDUX new observatory his pet project. He rushed to submit a proposal to the 2000 Decadal Survey on Astronomy and Astrophysics, the major wish list of U.S.-led missions that astronomers think should get federal funding. His project would survey the whole sky in search of weakly lensed objects and map all the dark matter we can detect.

"I had called it the Dark Matter Telescope because that's what I wanted to do," he says. "But perhaps cleverly, on the last page, I had a picture of an Earth-threatening asteroid."

After all, such a telescope could do a lot more than map dark matter. A large enough digital camera, combined with a wide-eyed telescope, could also "make unique inroads in the ... universe of things that move and explode," Tyson says. That includes asteroids as well as pulsating stars, hungry black holes and any doomed stars that get too close to them. Such a telescope could map out millions of objects in our solar system, plus millions of supernovas and billions of galaxies. It could help answer questions that astronomers didn't even know to ask at the time (see Page 40).

That first proposal wasn't selected, but the astronomy community ranked it highly enough that Tyson and colleagues thought it was worth pursuing. Start-up funding from Bell Labs, along with a $20 million gift from former Microsoft developer Charles Simonyi, $10 million from Bill Gates and support from the U.S. National Science Foundation and Department of Energy, helped them start designing and building components.

In 2010, the project got top billing in the decadal survey, setting the stage for full funding led by NSF and DOE. The team initially dubbed the instrument that would anchor the observatory the Large Synoptic Survey Telescope: the telescope that will get the big picture.

FUN HOUSE MIRRORS

True to that project name, the observatory has what's now the largest digital camera ever built. It weighs about 3,000 kilograms and, at 1.65 meters wide, is bigger across than I am tall. It combines 189 individual CCDs, which deliver their data within seconds of taking an image. Its sensor has roughly the same number of pixels as 260 smartphone cameras.

In addition to demanding a record-setting camera, the observatory's science goals dictated its shape and structure. Want a survey that goes wide, fast and deep all at the same time? There are only so many ways to build an instrument to do that. For instance, to cover the whole sky every three or four nights, each snapshot must include an area equivalent to 45 full moons without blurring at the edges. Rubin therefore needs an enormous, unusual set of mirrors.

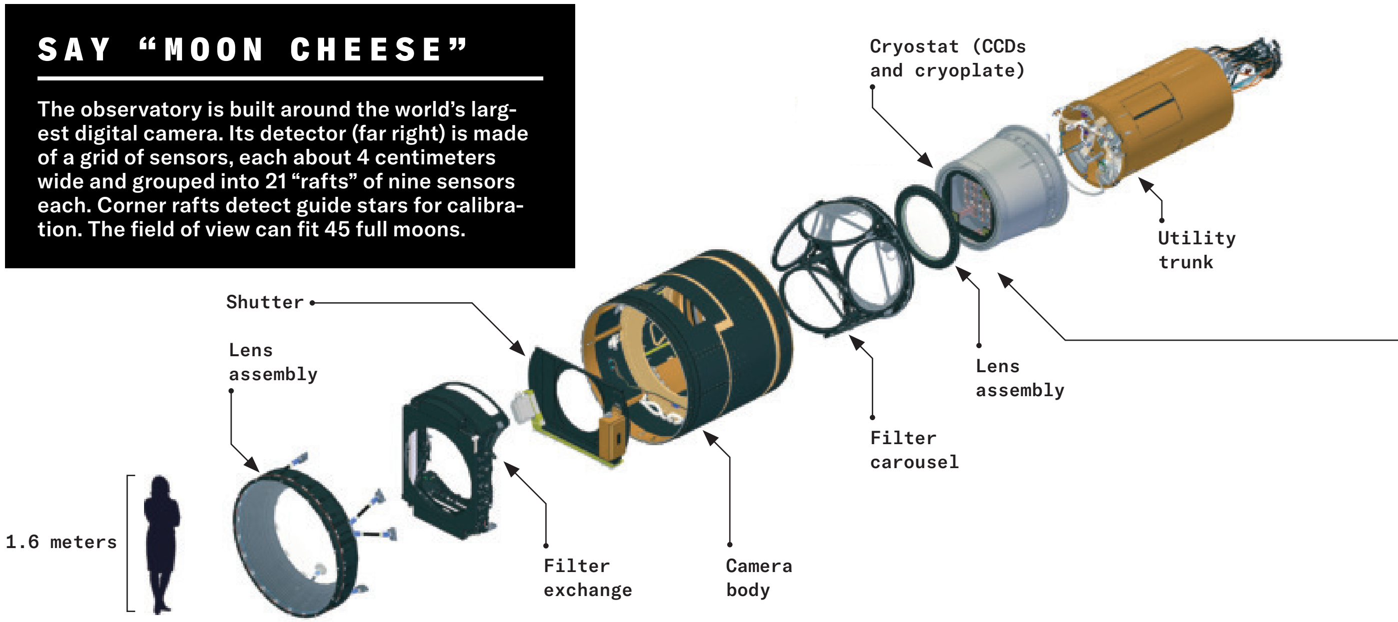
Rubin's telescope starts out the way most do: An 8.4-meter-wide primary mirror collects a tremendous amount of light in each exposure. That mirror reflects light onto a secondary mirror. At 3.5 meters wide, Rubin's is currently the largest secondary mirror ever built for astronomy.

Normally, that secondary mirror would focus the light onto a camera or detector. But even when the mirrors are perfectly constructed, the nature of optics means objects

SLAC, ADAPTED BY B. PRICE

SAY "MOON CHEESE"

The observatory is built around the world's largest digital camera. Its detector (far right) is made of a grid of sensors, each about 4 centimeters wide and grouped into 21 "rafts" of nine sensors each. Corner rafts detect guide stars for calibration. The field of view can fit 45 full moons.



that are not directly in the center of the telescope's view can appear blurred or distorted, creating properties called aberrations.

To correct those aberrations, Rubin uses a third mirror. In an unusual setup, the tertiary mirror is made from the same piece of glass as the first, as a 5-meter-wide dish with deeper curvature in the inner part of the primary mirror. This saves space and makes the telescope easier to align, Thomas says, because two of the mirrors can never go out of alignment.

By the time the light bounces into the car-sized digital camera, which is suspended in the middle of the secondary mirror, every point of light in the whole field of view looks needle-sharp.

To catch as many faint objects as possible, the telescope has only five seconds between shutter snaps to move on to a new place in the sky. On a normal night in the control room, you can hear the shutter clicking every 30 to 50 seconds, all night long. Thomas finds the sound soothing. "When you can't hear anything, you know something might be wrong."

"FOR THE FIRST TIME IN HISTORY, THE NUMBER OF CATALOGED CELESTIAL OBJECTS WILL EXCEED THE NUMBER OF LIVING PEOPLE!"

–Željko Ivezić and colleagues

Snapping images at these speeds kept the telescope on the ground — space telescopes can't move quickly enough. It also means that after the telescope slews to a new position, it has to stop on a dime, which is why the huge instrument is very compact.

"If you move, you will take a blurry image," Thomas says. "You can imagine, if you have a long telescope and you move it, it's going to vibrate a little bit."

Rubin's location on Earth is also key. Cerro Pachón is high and dry and far from the glare of city lights, which means it's an ideal place to build such a sensitive observatory.

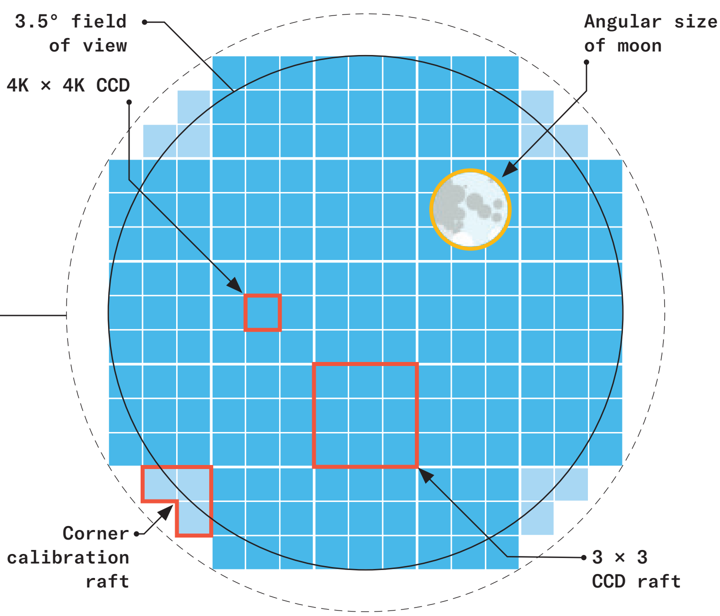
To get to Cerro Pachón back in May, I had to take an overnight flight from New York to Santiago, then a second flight to the seaside city of La Serena. From there, a local driver who was familiar with the sinuous, dusty, unpaved roads ferried me and three other journalists into the clay-colored mountains. As the ear-popping drive wound ever higher, I kept my eyes trained on the line of telescope domes glinting in the distance. I couldn't stop smiling.

Once on the ridge, the air was so dry I could feel it parching my nostrils and throat, and so clear I could see for miles in every direction. Aside from other telescopes and temporary buildings set up to support workers, all I could see were rocks and scrubby plants, with the occasional wild horse or viscacha, a local rodent that Thomas described as a bunny with a squirrel tail.

The observatory was still an active construction site, so we all had to wear reflective yellow vests and helmets to walk around. Some of the mountaintop crew bedecked their helmets with stickers, including custom-made ones of the facility's human namesake, Vera Rubin.

For almost a year while planning this visit, I had looked forward to seeing the massive telescope in action. The team had opened the camera shutter to the sky and let in its first photons about a month earlier, and it had dutifully taken data every night since then. The idea was for me and the other journalists to watch as the telescope took some of its earliest complete images.

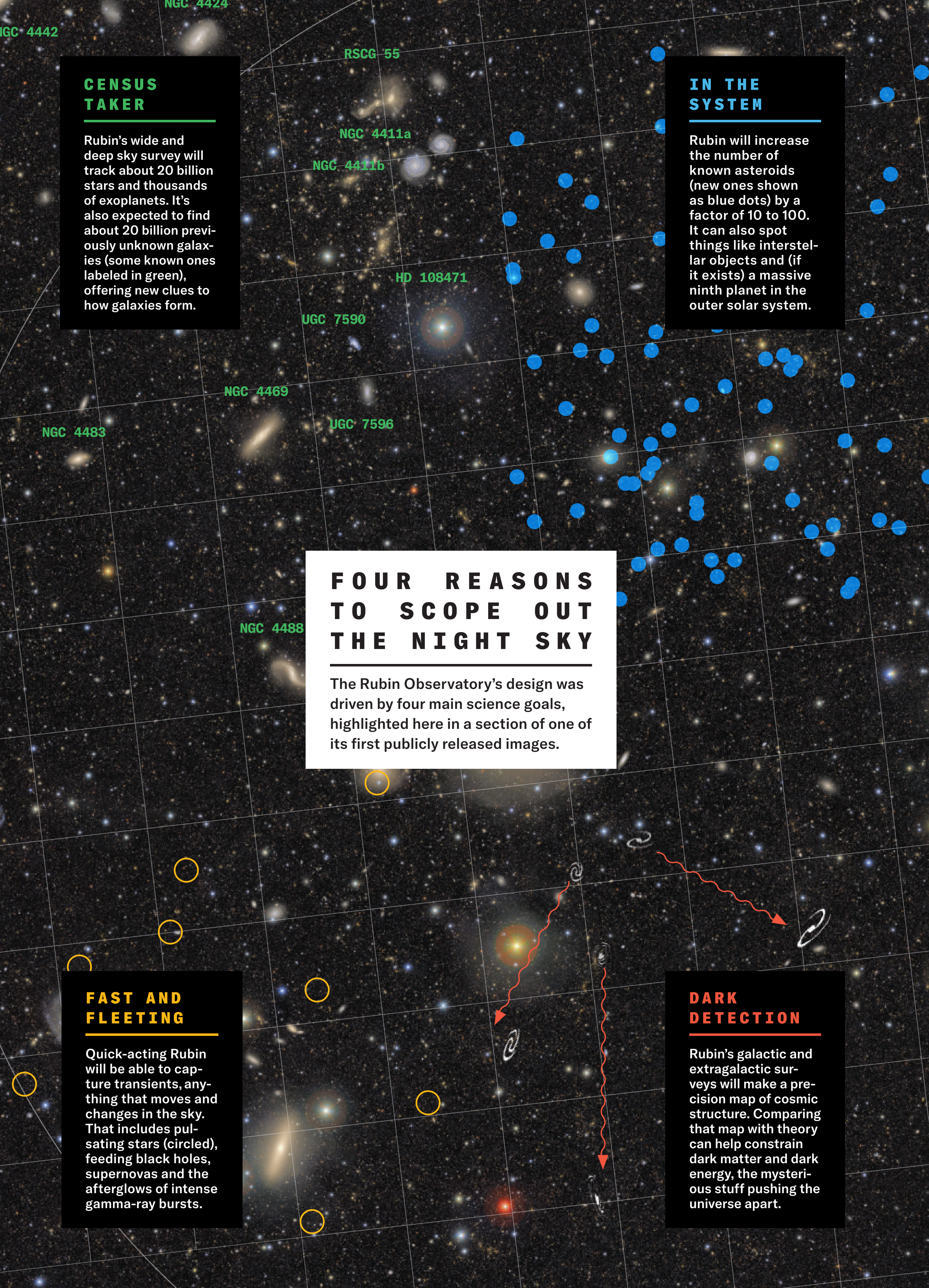
But when I arrived, it had been a mere eight hours since Thomas had exchanged frantic messages with the camera crew and



RUBINOBS/NOIRLAB/SLAC/DOE/NSF/AURA, ADAPTED BY B. PRICE

FOUR REASONS TO SCOPE OUT THE NIGHT SKY

The Rubin Observatory's design was driven by four main science goals, highlighted here in a section of one of its first publicly released images.



CENSUS TAKER

Rubin's wide and deep sky survey will track about 20 billion stars and thousands of exoplanets. It's also expected to find about 20 billion previously unknown galaxies (some known ones labeled in green), offering new clues to how galaxies form.

IN THE SYSTEM

Rubin will increase the number of known asteroids (new ones shown as blue dots) by a factor of 10 to 100. It can also spot things like interstellar objects and (if it exists) a massive ninth planet in the outer solar system.

FAST AND FLEETING

Quick-acting Rubin will be able to capture transients, anything that moves and changes in the sky. That includes pulsating stars (circled), feeding black holes, supernovas and the afterglows of intense gamma-ray bursts.

DARK DETECTION

Rubin's galactic and extragalactic surveys will make a precision map of cosmic structure. Comparing that map with theory can help constrain dark matter and dark energy, the mysterious stuff pushing the universe apart.

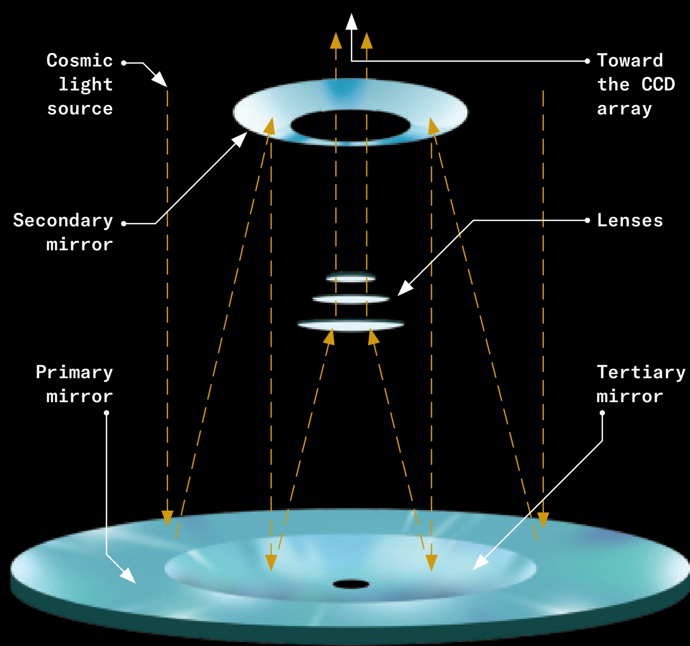
reluctantly shut down the telescope. When Thomas took me on a tour of the observatory, the whole structure was lying motionless, aimed at the horizon. We passed the camera team on a catwalk ledge on our way up to the dome.

"Is my camera moving yet?" Thomas asked the team cheerfully. "Make it work!" She turned to me. "We try to have a positive attitude, but we are all very bummed."

The silver lining was that I had an excellent view of the unusual primary mirror. Staring into it was like looking at a fun house reflection. Stripes of light and dark, reflected from the dome and other parts of the telescope, looked nearly straight in the outer part of the mirror but warped and wobbled in the inner part. I swayed back and forth, then crouched down and slowly stood up to see how the shapes changed. It was dizzying.

MIRROR, MIRROR (MIRROR)

Rubin's telescope uses a unique set of three mirrors, two of which are made from a single piece of glass. Light hits the 8.4-meter-wide primary mirror, reflects onto a 3.5-meter secondary mirror above it and bounces to the inner, 5-meter tertiary mirror below. Then it finally passes through a hole in the secondary mirror to enter the camera.



KEEPING IT COOL

The mystery of the malfunctioning camera led Thomas and her team to investigate another fundamental aspect of the telescope's design: temperature control.

It's crucial to keep the camera's detector cold. Thermal energy can trigger CCDs to release electrons, which could mimic signals from objects in space. Keeping the temperature as low as possible helps ensure that the detector reports only photons that actually come from the sky. And Rubin is going to collect an unprecedented number of photons. The plan is to observe the entire night sky visible in the Southern Hemisphere every three to four days. The camera shutter will open for 30 seconds per picture, for 1,000 pictures per night, every night for 10 years.

The instrument has a –123° Celsius metal cryoplate at the back of the detector, and another "cold" plate at –40° C behind that, all sealed in a vacuum. Refrigeration lines carry cooling liquids through the camera before snaking out the back of the telescope. Even the outside of the sparkling dome is specially designed to reflect sunlight away from the telescope.

Thomas and her colleagues were therefore anxious to figure out why the cryoplate had suddenly warmed up at 3 a.m. on that May night.

Crises are expected during the commissioning phase, when the crew puts a new telescope through its paces. "You test it all in the lab," says Rubin commissioning scientist Kevin Fanning, a researcher with the U.S. SLAC National Accelerator Laboratory. "And reality is always slightly different."

Still, Rubin had been working surprisingly well for the past month, Fanning says. This was its first crisis. But the effects could be worse than just detecting phony photons, commissioning scientist Sean MacBride of the University of Zurich told me during my visit. As the temperature goes up inside the frigid case that holds the CCDs, the pressure goes up too. Materials in the camera may then release gases that could get stuck on the sensors, which would be "really, really bad for the long-term health of the system," MacBride said.

"The probability is fairly low, but the consequence is pretty serious," he said. "This is on the top-five list of scariest things that could happen to the camera."

By midafternoon, the camera seemed to have gone back to normal all on its own. That was a clue,

BOTH IMAGES: RUBINOBS/NOIRLAB/SLAC/NSF/DOE/AURA, ADAPTED BY B. PRICE

Fanning said at the time.

Winter in Chile was just beginning, and on the night of the incident, the outside temperature had dropped to 5° C for the first time since the camera had been installed. "Today's warmer, and it seems to have recovered," he said. "So we have two data points now."

Maybe the issue was related to the outside temperature. But that was a paradox. Why would the cryoplate warm up as the outside air cooled off? And why was the critical temperature around 5° C, not zero? "There's not a lot of things that change state at that temperature," Fanning said. It was puzzling.

At a planning meeting at 4:45 p.m. on May 9, Fanning proposed an experiment: Deliberately cool the telescope dome down to 5° C and see if the cryoplate glitched in the same way. "Then we'd have three data points." The team decided to wait for the temperature outside the dome to drop below the temperature inside, then open the dome a little to let some cold air in and see how the cryoplate reacted.

At 6:30 p.m., the inside temperature was 9.74° C and the outside was 11.69° C. So the team took out a pack of Uno cards and settled in to wait.

OPEN DATA, CLOSING DOORS

By 10 p.m., the temperature outside the observatory hadn't dropped. It had gone up 2 degrees.

"I'm feeling personally disrespected by the weather right now," Fanning quipped. The next morning, though, he was in a good mood. The cryoplate had kept its cool, which reassured the camera crew that the failure had been triggered by the cold outside.

A few theories emerged: Maybe the oil in the refrigerant circuit started to congeal and couldn't cool the cryoplate as efficiently as it normally does. Maybe some water accidentally trapped in a thin pipe froze solid, causing a clog. If they could figure out where the cold spot is, they could wrap it in more insulation, like water pipes in a home.

The crew ended up turning the camera back on that night, and by the next night they were back to normal observations. They're still investigating the issue, Fanning told me, but they plan to add some insulation to the piping between the camera and the cryocompressors. The team is also adding heaters on the affected refrigerant lines and pumping extra heat into the dome.

"It was a difficult weekend, but I am very pleased by the progress we made and how the team got together to pivot back to an on-sky program so quickly," Fanning said by email. "This is what I love about commissioning new systems!"

In June, the telescope hit another big milestone: releasing Rubin's first images to the public. In an event in Washington, D.C., the Rubin team shared videos made up of hundreds of individual images from about 10 hours of observations.

The preview swooped through a field of 10 million galaxies and tracked over 2,000 previously unknown asteroids creeping across the sky. Rubin will eventually stitch together a patchwork quilt of images, with a new patch added every minute. Stacking images of the same spot over time will help faint objects

STACKED CAST

This picture of the Trifid and Lagoon nebulas combines 678 images taken in just over seven hours. During Rubin's 10-year survey, scientists will combine thousands of images of the same patches of sky. Those stacked images will make bright spots brighter and dark spots darker, allowing fainter and more distant objects to pop.

RUBINOBS/NOIRLAB/SLAC/NSF/DOE/AURA

pop out from the dark background.

About 90 percent of its time will be devoted to the wide and deep survey. But some of the time will be reserved for pointing at things quickly, like responding to alerts for supernovas or the faint ripples in spacetime known as gravitational waves. That's too complicated to do by hand, Ivezić says.

"One astronomer can't do it in their head." So a software named Scheduler will respond to alerts and run the observations autonomously. "It makes our telescope a … robot astronomer, who knows what we care about," Ivezić says.

Rubin will then put out alerts about cosmic events almost in real time, process and store the data on its own servers and let scientists bring in their analysis software. Indeed, anyone will be able to go to the telescope website and play with Rubin data, including students and amateur astronomers. "It's really your ideas and your knowledge and your persistence that determine the science you can do," Ivezić says.

But this open-door research philosophy is coming at a time of contraction for U.S. science. The White House's proposed budget for fiscal year 2026 would cut more than $5 billion from NSF's and more than $1 billion from DOE's science budget. At press time, Congress looked set to reject that proposal but had not yet passed a budget bill.

It was too late for funding cuts to prevent the telescope's completion. But scientists worry about continuity of funding over the next decade, and for the careers of the young scientists who will continue that work.

"Why would you ever build a world-class, unique facility and not … reap the scientific gains from it?" Tyson asks.

The Trump administration has also cut funding for and removed programs focused on diversity, which has included initiatives to encourage women in astronomy. The observatory was named after Vera Rubin in 2019, during the first Trump administration. Trump himself signed a congressional act declaring the moniker, which makes Rubin the first major U.S. observatory named after a woman. The project has had outreach and diversity initiatives baked into the mission since the beginning.

"WHY WOULD YOU EVER BUILD A WORLD-CLASS, UNIQUE FACILITY AND NOT … REAP THE SCIENTIFIC GAINS FROM IT?"

—Tony Tyson

But shortly after Trump's second inauguration, Rubin's biography on the observatory website was altered to remove references to present-day bias in astronomy. The website's Diversity, Equity and Inclusion page was taken down.

Even before concerns about funding set in, experts were worrying about an emerging threat to all ground-based astronomy: satellite megaconstellations.

Rubin is beginning its survey of things that move in the cosmos during an explosion in the number of satellites in the sky. SpaceX began launching its Starlink megaconstellation in 2019, and other companies are getting in on the action. To date, more than 9,000 new satellites have launched as part of megaconstellation projects, and some experts expect we'll have between 50,000 and 500,000 satellites in low Earth orbit in the coming decade. When those satellites cross Rubin's field of view, they leave a long white streak on the detectors, blocking or otherwise marring the telescope's images.

Scientists are finding clever work-arounds, such as data processing software that can tell the difference between cosmic objects and satellite streaks. A 2022 paper also suggested a way to change the Scheduler algorithm to avoid streaks as much as possible, though it would sacrifice about 10 percent of the instrument's observing time. Whether that trade-off is worth it depends on how much science the survey would lose, which isn't clear.

WAKING THE DRAGON

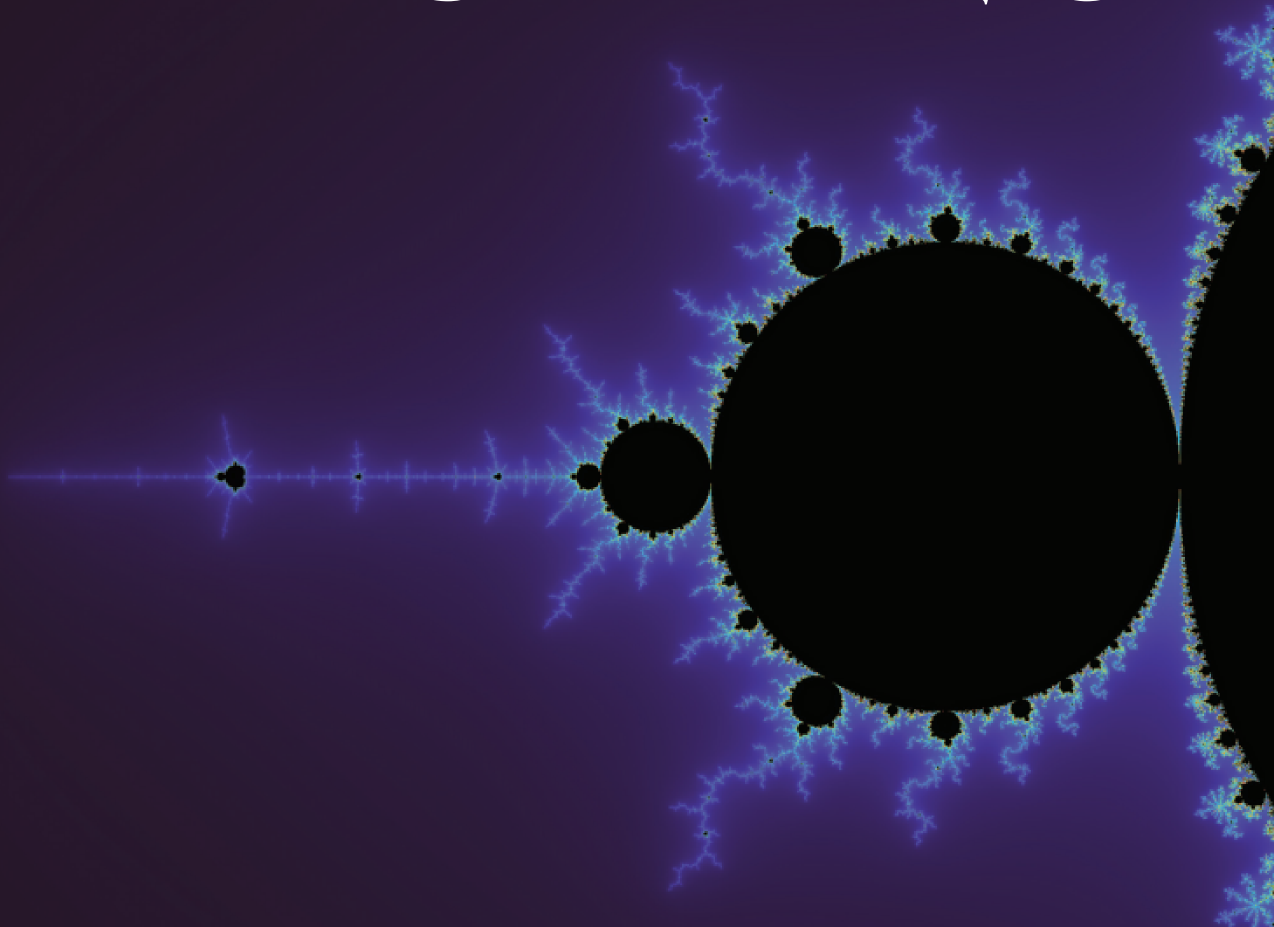
About an hour before I headed down from the mountain back in May, the crew decided everything was healthy enough to activate the telescope. Everyone working onsite that morning, about 15 people, hustled upstairs into the dome to watch. When we entered, the dome was rotating, and it felt like the floor beneath us was moving instead.

The dome was like a cathedral, cavernous and round. But nothing echoed: The telescope filled most of the space, and the dome walls were covered with black corrugated baffling to absorb stray light that also soaked up much of the sound.

Seated in a rolling desk chair with a laptop, Fanning commanded the telescope to do a series of prechoreographed moves designed to test its range of motion: Look up, slew from low to high on an angle, spin around 180 degrees.

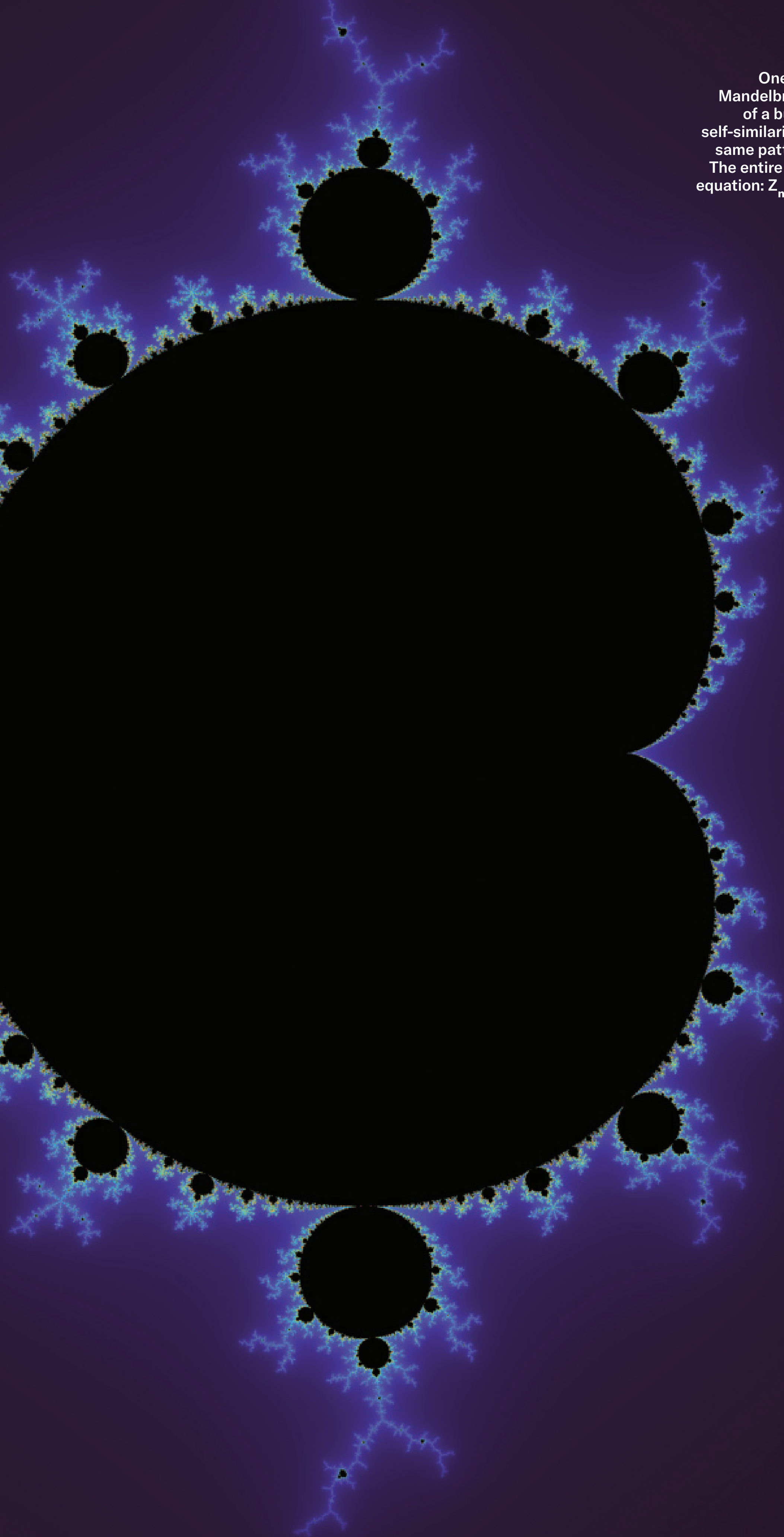
Rubin in motion was like a dragon waking up. It moved smoothly, purposefully, with surprising elegance and speed. It leaned its head back, shook out its shoulders and turned its face to the sky, ready to open its eyes. ✖

Fifty years of FRACTALS



Over the last half century, these beautiful, complicated shapes have challenged conventional ideas about geometry and inspired researchers in many fields of science

BY STEPHEN ORNES



One of the most famous fractals is the Mandelbrot Set, which resembles the shape of a bug. It demonstrates the property of self-similarity: If you zoom in on the edges, the same patterns repeat at ever-smaller scales. The entire thing arises from a simple iterative equation: $Z_{n+1} = Z_n + C$. In the equation, Z and C represent complex numbers.

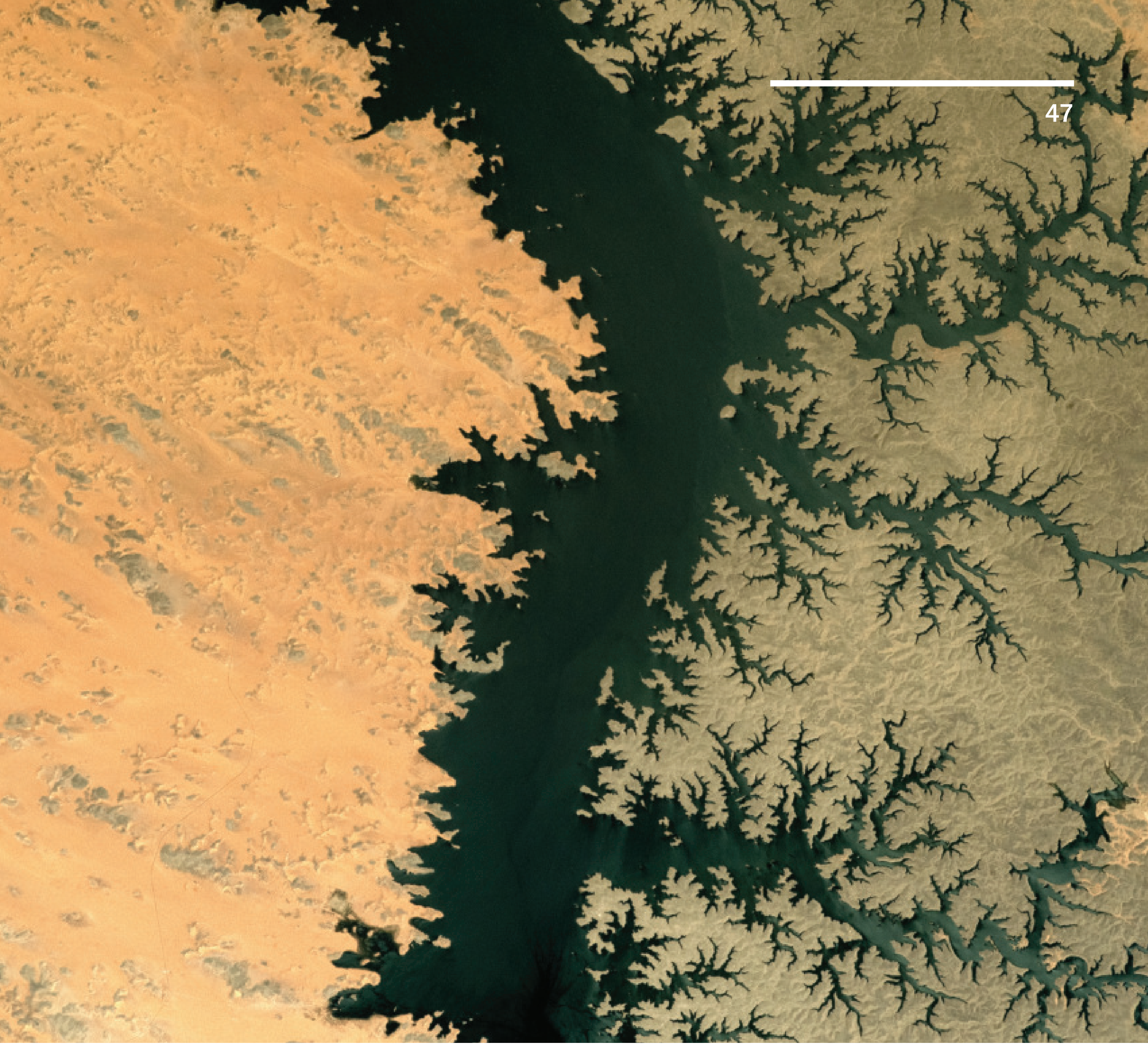
Fifty years ago, "fractal" was born.

In a 1975 book, the Polish-French-American mathematician Benoit B. Mandelbrot coined the term to describe a family of rough, fragmented shapes that fall outside the boundaries of conventional geometry. Mathematicians had been describing these types of shapes since the late 19th century. But by giving them a name — derived from *fractus*, Latin for "broken" — Mandelbrot gave fractals value. He introduced a way to measure and analyze them. With a name, he recognized order in complexity.

↖ **The florets of Romanesco broccoli follow the rules of fractals to a degree. At the teeniest level, molecules and atoms don't resemble the shape of the vegetable.**

If you know anything about fractals, it's probably this: Their hallmark trait is self-similarity. No matter how much you zoom in or out, you find similar patterns. Take a snowflake. The overall shape of the crystal is repeated at smaller and smaller scales as the snowflake branches out. (A snowflake and other natural forms are considered only "fractal like," though, because the pattern breaks down at the level of molecules and atoms.) In a nod to this self-similarity, Mandelbrot often told people that his middle initial, B., stood for "Benoit B. Mandelbrot." So his full name becomes "Benoit Benoit B. Mandelbrot Mandelbrot." And spelling out the middle initial again results in "Benoit Benoit Benoit B. Mandelbrot Mandelbrot Mandelbrot." No matter how many times you iterate, you find him behind his middle initial.

Fractals can take multiple forms — rough lines, jagged shapes or porous solids. They stand out for defying our usual idea of dimension, defined casually as the minimum number of coordinates needed to specify any point within it. A line is one-dimensional, the area inside a circle is two-dimensional, the space inside a sphere is three-dimensional. Fractals don't fit neatly in these categories, and Mandelbrot introduced a mathematical definition for fractal dimension, which characterizes the



roughness of a curve area or other shape. A shape known as the Koch Snowflake, for instance, has a fractal dimension of about 1.2619.

Fractal-like patterns are ubiquitous, basking on the edges of clouds or the craggy ridges on mountains. "Clouds are not spheres, mountains are not cones, coastlines are not circles," Mandelbrot once wrote. Fractal-like structures even appear in the body. "If you don't have a fractal network of blood vessels, we would probably die every second, every time our heart beats, because it's a very powerful pump," says Michel Lapidus, a mathematician at the University of California, Riverside and editor in chief of the *Journal of Fractal Geometry*. A branching structure, he says, both slows the flow and gets the blood where it needs to go. Fractal-like forms also appear in cancer cells and the lungs.

↑ Benoit B. Mandelbrot noted that traditional geometric shapes like circles and straight lines don't describe everything we see in nature. The edges of lakes and rivers, for example, are irregular.

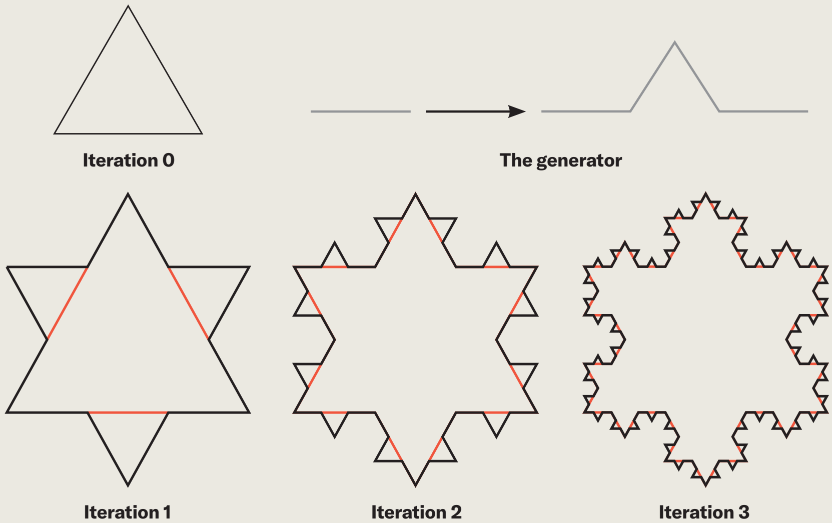
NASA

In the last half century, fractals have led mathematicians into unknown terrain, like fractal calculus and fractal algebra. But fractals are more than just a subfield of math. Their characteristic roughness helps scientists visualize chaos and model the evolution of changing systems. They help engineers find new designs for practical gizmos. They even inspire artists and musicians.

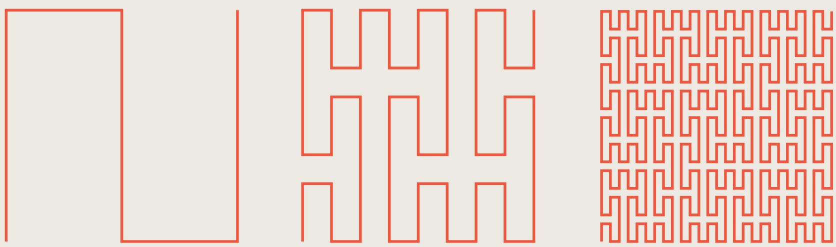
In the world of mathematics, Lapidus, who counts Mandelbrot as a friend and was the last person to talk to him before his death in 2010, has unearthed deep connections between fractals and the mathematical field of number theory. He and others have used fractals to analyze the Riemann zeta function, which is connected to the distribution

JAGGED GEOMETRY Traditional geometry focuses on smooth, regular shapes, based on principles put forth 2,300 years ago by the mathematician Euclid. Fractal geometry, in contrast, deals with self-similarity and intricate, irregular patterns.

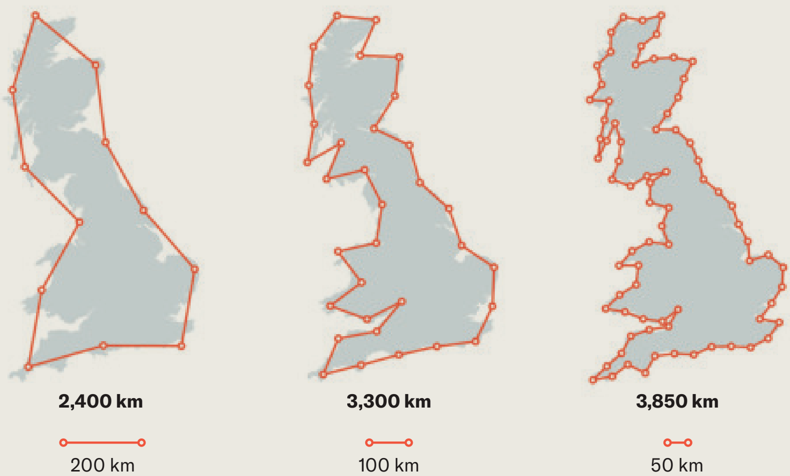
'Pathological' curve
Before Benoit B. Mandelbrot, mathematicians regarded the Koch Snowflake, named for mathematician Niels Fabian Helge von Koch, as a "pathological" curve. If you start with an equilateral triangle and add a triangle-like bump (called the generator) to each of the shape's sides infinitely many times, the resulting shape occupies a finite area, but has an infinite length. It is neither a 1-D line nor a 2-D area. Instead, it has a fractal dimension that falls between the two, at about 1.2619.



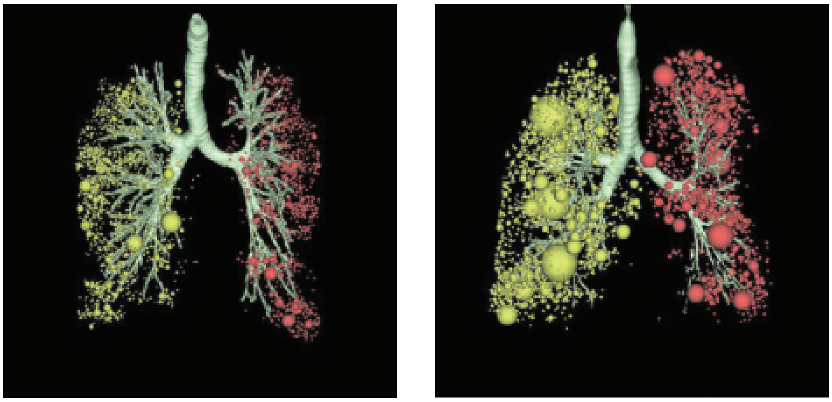
2-D line
The Peano space-filling curve, identified by mathematician Giuseppe Peano, starts as a line but, through infinitely many iterations, can touch every single point in a square without crossing itself. A line is 1-D, and a square is 2-D. So the curve, which has a fractal dimension of 2, is a two-dimensional line. And it follows the concept of self-similarity, with the same irregular pattern found at every scale within the square.



Craggy coast
In 1967, Mandelbrot famously asked, How long is the coast of Great Britain? The answer, mathematically, depends on the size of your ruler. With a larger ruler, you miss the finer details and get a smaller answer. As you shrink the ruler, you capture more of the nooks and crannies along the shore. Mandelbrot used the seacoast as a natural example of a shape that is statistically self-similar.



MAPS: PETER HERMES FURIAN/ALAMY STOCK PHOTO



↑ Scientists have used fractals to study lung disease, such as emphysema, which damages the walls of the lungs' air sacs. Using CT scans, doctors can use fractal analyses to characterize the size and distribution of clusters of damaged areas and monitor emphysema progression. Shown in 3-D reconstructions, the airway on the left, with many small clusters, is healthier than the right airway, with many small clusters and several large ones.

N. TANABE *ET AL* / *FRONTIERS IN PHYSIOLOGY* 2020

Fractals may prove vital to today's most transformative technology: AI.

of prime numbers along the number line. The Riemann hypothesis, which makes a claim about this function, is widely regarded as the most important unsolved problem in all of mathematics, and an underlying fractal structure may one day figure into its proof.

Fractals also permeate society. Mandelbrot and others long suspected that financial markets could be modeled with chaotic fractal processes, though it's yet to be proved. Researchers have measured the fractal dimension of the drip patterns in Jackson Pollock paintings. Some Johann Sebastian Bach compositions contain fractal-like self-similarity, as the combinations of long and short individual notes repeat at larger scales, in longer and shorter phrases.

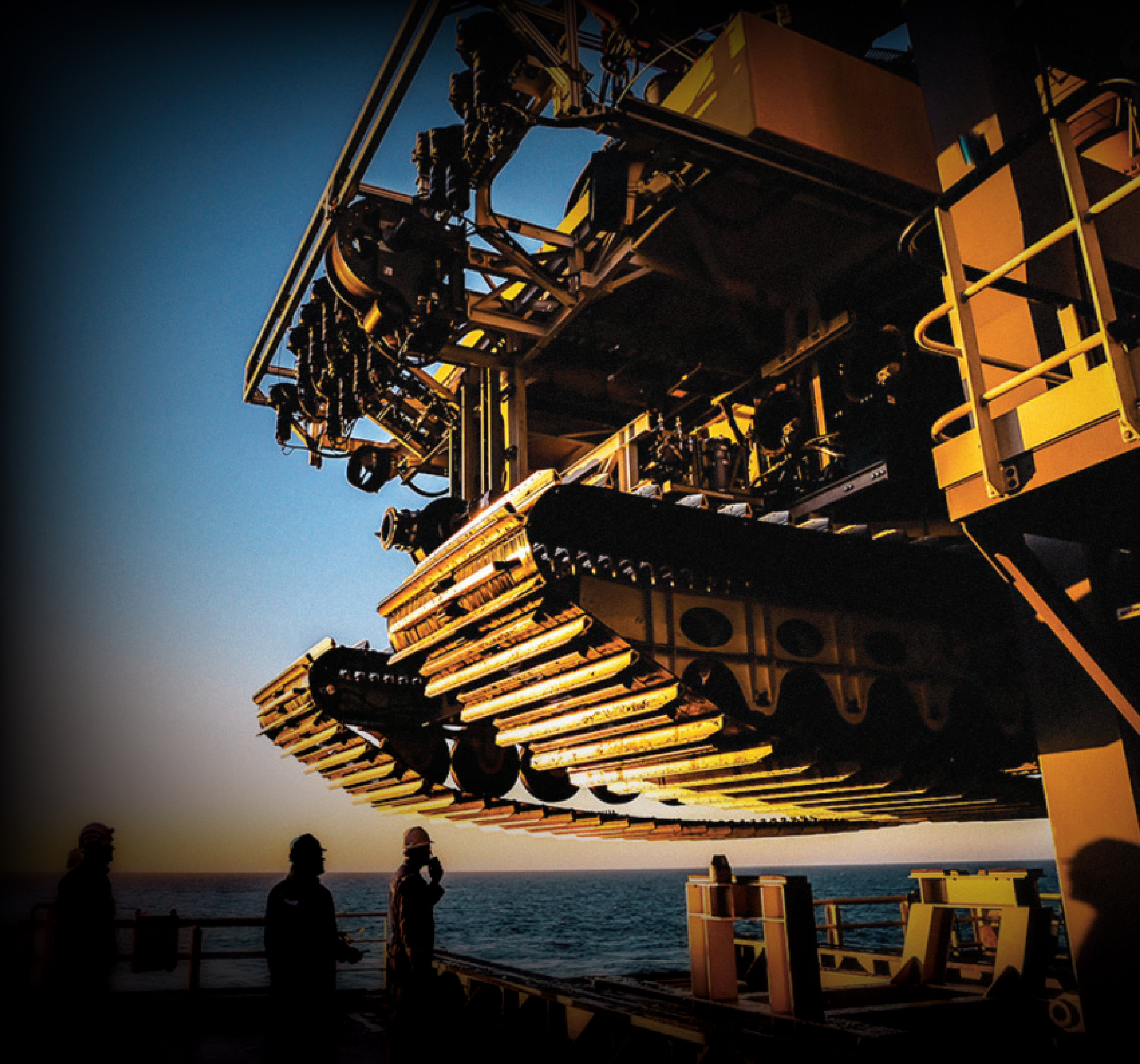
While some mesmerizing fractal patterns might be considered art in their own right, they can also be a gateway to practical innovations. "It begins with, 'Oh, that's really interesting that you could make these complicated pictures,' but mathematicians get drawn in, far beyond the pictures," says Michael Barnsley, a mathematician at the Australian National University in Canberra who was inspired by fractals to design an image-compression strategy.

Barnsley began scrutinizing fractals in the 1980s because he was interested in chaos theory, the study of how random processes evolve from simple, deterministic starting points. He recognized that images often include self-similar details — the way a line crosses a pixel in one part of an image might look the same as in another pixel.

From that observation came an image-compression method that could reduce or enlarge parts of an image. By the early 1990s, Microsoft began using the method. Fractal-inspired designs have also been explored for signal processing and data analysis. Fractal-like antennas with tortuous curves enable communication over multiple frequencies and occupy a tiny area in some wireless devices.

Fractals may even prove vital to today's most transformative technology: AI. Barnsley suspects that as AI companies race to improve algorithms and architectures, they will recognize benefits in exploiting self-similarity. "Our brain is pretty much a fractal-like object," he says. Connections between neurons are like a self-similar branching system. "And if you're going to arrive at consciousness, an artificial consciousness," he says, "it's got to have a self-referential template inside it." ✖

Stephen Ornes is a freelance science writer based in Nashville and author of the forthcoming book *Breakdown: A Brief History of the End of the World and Everything in It*, due out in 2026.



DEEP-SEA MINING: THE NEW FRONTIER?

THE PUSH TO TAKE METALS FROM INTERNATIONAL WATERS COULD UPEND THE OCEAN'S EQUILIBRIUM

BY CAROLYN GRAMLING

← The Metals Company tested this collector vehicle in 2022 as part of its deep-sea mining efforts. If the company wins a permit, hundreds of collectors could scour the seafloor for polymetallic nodules (shown below), which are rich in valuable metals.

An underwater gold rush may be on the horizon — or rather, a rush to mine the seafloor for manganese, nickel, cobalt and other minerals used in electric vehicles, solar panels and more. Meanwhile, scientists and conservationists hope to pump the brakes on the prospect of deep-sea mining. They warn that it may scar the seafloor for decades, cause lingering harm to the deep ocean's fragile ecosystems — and even reduce the ocean's ability to mitigate climate change.

OPPOSITE: THE METALS COMPANY; THIS PAGE: COURTESY OF NOAA OCEAN EXPLORATION, 2021 NORTH ATLANTIC STEPPING STONES: NEW ENGLAND AND CORNER RISE SEAMOUNTS

"The deep sea cannot become the Wild West," said United Nations Secretary-General António Guterres at a U.N. oceans meeting in June.

That prospect is closer than ever. In July, delegates to the U.N. body charged with stewardship over mining resources in international waters met to discuss whether to issue its first deep-sea mining permits. To date, the International Seabed Authority has issued 31 exploration permits to companies scanning the seafloor for likely prospects, but none yet for actual removal of ore.

But this year, the ISA faced an unprecedented situation, says Emma Wilson, a policy officer at the Deep Sea Conservation Coalition, a nonprofit based in Amsterdam. "It's the first time ever that an application for exploitation in international waters is actually on the table."

That application is tied to recent actions by the United States. In April, President Donald Trump issued an executive order that would expedite deep-sea mining licenses in international waters to U.S.-based companies — by issuing them through the National Oceanic and Atmospheric Administration, rather than through the ISA.

Shortly afterward, The Metals Company, which is headquartered in Canada and has a U.S. subsidiary, applied to NOAA for the world's first deep-sea mining permit in international waters.

Gerard Barron, CEO and chairman of The Metals Company, had expressed frustration in March in an open letter on the company's website that, after years of wrangling, the ISA's member states have still not agreed upon regulations for seabed mining, necessary to issue permits. "We are increasingly concerned that the ISA may not adopt the [mining regulations] in a timely manner, and that the regulations may be written in a way so as to not allow commercial enterprises to operate," Barron wrote.

If the United States circumvents the ISA's authority, that would "violate international law and undermine the principle of the seabed as the common heritage of humankind," ISA Secretary-General Leticia Reis de Carvalho said in response to Trump's executive order.

After years of dispute and negotiations, there's concern that the ISA might feel pressured into fast-tracking its own mining permits, Wilson says. That's especially worrisome, she says, because the ISA is also charged with protecting these deep-sea environments, and there is not yet a regulatory framework in place to do so.

↑ Deep-sea mining could harm rare wildlife, including a crustacean called *Macrostylis metallicola* (a model is shown, top) and the snail *Chrysomallon squamiferum* (bottom).

FROM TOP: © SENCKENBERG TRÄNKNER; © CHONG CHEN

IN THE DARK

Determining how best to protect deep-sea ecosystems is challenging because there are so many unknowns — not just about the possible impacts of mining, but also about what sorts of creatures live in the deep.

Two-thirds of the planet is covered by deep ocean waters, mysterious ecosystems and murky stretches of seafloor hidden at least 200 meters below the surface. The deep ocean is Earth's lifeline in myriad ways: It sequesters carbon dioxide from the surface, helping to regulate climate. Upwelling of deep ocean waters brings nutrients to the surface, nurturing the phytoplankton that generate up to 80 percent of Earth's oxygen. Seafood feeds a fifth of the world's population each year. Discoveries of chemical compounds from marine sponges and other organisms have been the source of treatments for HIV, breast cancer and COVID-19, among other diseases.

But only a minuscule fraction of the deep ocean — less than 0.001 percent — has ever been visually observed over decades of deep-sea exploration, researchers reported in May in *Science Advances*. That dearth of knowledge is problematic as human activities, including mining, threaten to cause irreparable damage to the region, says oceanographer Katy Croff Bell, founder and president of the nonprofit Ocean Discovery League, which is based in Narragansett Pier, R.I.

"We have made amazing strides, especially in the last decade, to better understand the deep ocean," says marine biologist Julia Sigwart of Senckenberg Natural History Museum in Frankfurt. "But we also know how much there is left to discover ... unnamed and unprotected."

In 2001, a snail called the scaly-foot gastropod (*Chrysomallon squamiferum*) was found living near deep-sea hydrothermal vents, scavenging iron sulfide spewing from the vents to incorporate into its shell. In 2019, *C. squamiferum* was added to the International Union for Conservation of Nature's Red List of Threatened Species; it was the first deep-sea creature designated as endangered by the prospect of mining.

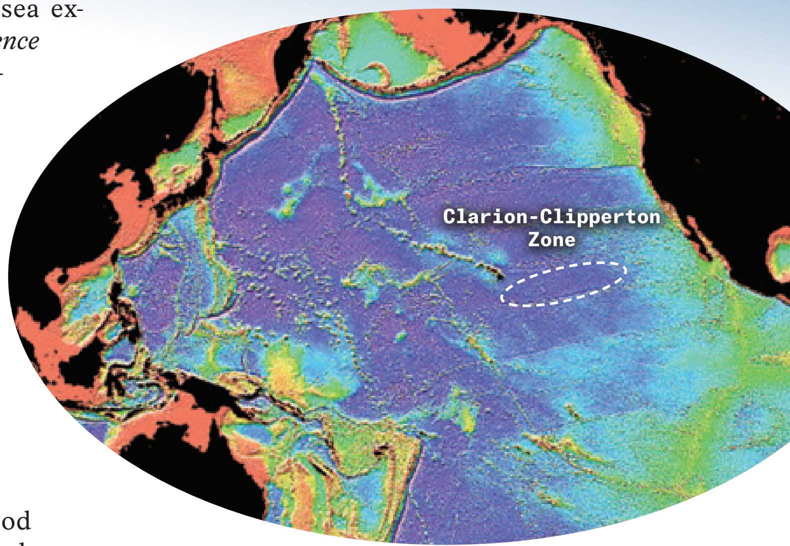
But there are likely many others. There's a tiny deep-sea crustacean that lives on polymetallic nodules, chunks of rock scattered in abyssal regions of the seafloor that are enriched in manganese, nickel, cobalt and copper. Researchers describing the creature in 2020 dubbed it *Macrostylis metallicola*, after the band Metallica. Scavenging the nodules for their metals would also remove the crustacean's home, Sigwart says. "Mining could cause potentially irreversible impacts" for these and many other still-unnamed species.

"There are a variety of different habitats within the abyssal landscape, and it is likely that they respond differently to disturbance and have different sensitivities," says Daniel Jones, an oceanographer at the National Oceanography Centre in Southampton, England. Deep-sea research is revealing abundant new forms of life and diverse new habitats. But, he says, "their resilience to impact [is a] big remaining question."

LONG-LASTING DAMAGE

Scientists have warned for years that the hunt for metals and minerals in the deep could hurt ecosystems, including microbes at the base of the ocean food web. Grooves cut in the seafloor by dragging equipment to scoop up polymetallic nodules could disturb the microbial populations in the sediment for decades, given the very slow sediment accumulation rates in the deep sea. A recent study of the impact of striations cut by years of ships anchoring in the seafloor below Antarctic waters showed crushed sponge colonies and little to no marine life.

In March, Jones and colleagues reported that four decades after a company tested a strategy for the collection of polymetallic nodules, the seafloor ecosystem has still not fully recovered. In 2023, the team visited the site of the 1979 mining operation, a four-day test of equipment in a region of the North Pacific Ocean called the Clarion-Clipperton Zone.



↑ **The Metals Company wants to mine the Clarion-Clipperton Zone, a deep-sea region in the Pacific Ocean that's home to nodules of precious metals.**

The operation had used a remotely operated mining vehicle to scoop up the nodules, and the tracks "looked very similar to when they were created 44 years ago," Jones says. The test mining also kicked up sediment across an area of about half a square kilometer. That's a relatively small plume compared with full-scale mining plumes that are expected to spread across tens of square kilometers of seafloor each year, Jones adds. Sediment plumes can clog seafloor organisms' filtration and breathing structures, create visual and mobility barriers for organisms, and introduce heavy metals into the food chain.

In the aftermath of the 1979 test, some creatures have started to reestablish themselves, Jones says. Generally, those are more mobile creatures and larger-bodied denizens of the deep. But the scars persist, suggesting that impacts in the abyss could linger for decades.

The Metals Company points to dozens of research studies it has contributed to public databases over the last decade, including data on the possible impact of mining collected during a 2022 deepwater

NOAA, ADAPTED BY C. CHANG

↑ In June, protesters called for a moratorium on deep-sea mining days before the start of the U.N. Ocean Conference in France.

test of equipment to sample polymetallic nodules. "We believe preliminary analysis is demonstrating that much of the conjecture around environmental impacts of nodule collection is not supported by the science," Michael Clarke, the company's environmental manager, said in a 2024 statement.

But what has been observed still just barely scratches the surface of what is down there, opponents say. "We can't know what the impacts of human activities are going to be until we have the baseline knowledge of what's there," Bell says. "And we don't have that. Every cruise, every dive, we find something new. And there's so much left to be explored and understood."

HITTING PAUSE

Researchers and environmental groups including the Deep Sea Conservation Coalition are calling for a moratorium on seabed mining, at least until the ISA finalizes a framework of environmental protections from that mining. The current draft of the mining code that is under discussion is "deeply flawed and incomplete," the coalition states.

Developing an effective set of protections could delay deep-sea mining activities, given how little is known. "We are hearing from a large group of independent scientists that ... at least another 10 to 15 years of research is required to be able to properly inform certain aspects of the regulatory network," Wilson said during a webinar in June held by the coalition. "This sort of frenzied rush just seems totally out of step with the reality of the situation, of our knowledge," she said. It's an "unreasonably accelerated pace of work."

July's ISA summit ended in a stalemate, with no new regulatory mining code adopted but also no immediate plans to issue mining permits. However, the authority did agree to open a legal investigation into mining contractors to assess whether they're complying with the U.N. Convention on the Law of the Sea. The United States has not signed on to that treaty, and its plan to issue mining permits for international waters circumvents this law. The U.S.-based subsidiary of The Metals Company might therefore apply for a permit, but the company has other international partners that have expressed concern.

Meanwhile, the demand for many metals that are key to current battery and renewable energy technologies could decline in the near future. Traditional lithium-ion batteries, which incorporate cobalt, helped drive the push to mine elements from the seafloor, but they are "in many respects yesterday's technology," venture capitalist Victor Vescovo, founder and CEO of Dallas-based Caladan Capital, said at the webinar.

China produces "more EV batteries than any country on Earth by far, and the majority of them ... are lithium-iron-phosphate," Vescovo said. "They use no nickel, cobalt, manganese or copper." They don't have quite the energy density of traditional lithium-ion batteries, but they have a longer life cycle and are cheaper to produce. Next-generation batteries based on sodium and iron that are in development would be even cheaper and may be available in the next few years.

Proponents of deep-sea mining say that it's needed because these metals are essential to fueling a transition away from fossil fuels. "The biggest threat to the oceans is climate change," The Metals Company's website states. "We believe the top priority for the entire planet — including the oceans — should be achieving net-zero emissions." Mining the ocean can also "alleviate some of the pressures on fragile terrestrial ecosystems" due to land-based mining, the company states.

Others argue that since these elements are more abundant and accessible on land, it doesn't make sense to mine the oceans. Deep-sea mining would do little to alleviate the social or environmental pressures of terrestrial mining, a group of political scientists noted in May in *npj Ocean Sustainability*. "To date, the record indicates that deep-sea mining is a risky and unprofitable investment. [It] is a multibillion-dollar solution to problems that do not exist." ✖

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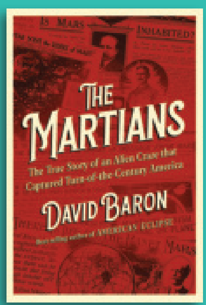
Curiosities

ANTHROPOLOGY

THE PHOENIX CROSSES AGES AND CULTURES

● The mythical phoenix, a majestic bird that dies in fire and is reborn from its own ashes (see Page 70), has been a symbol of renewal and hope across millennia and around the world. In ancient Rome, phoenixes were printed on coins, like this gold one from the rule of Emperor Hadrian dating roughly to A.D. 117. The bird was a symbol of the empire itself, which was revived with each new emperor. In more recent times, the phoenix became a symbol of rebuilding after the September 11, 2001 terrorist attacks. *— Lisa Grossman*



HOW WEIRD 'CANALS' SPARKED DEBATE OVER LIFE ON MARS

By Emily Conover

THE MARTIANS | *David Baron*
Liveright | $29.99

It's not aliens. It's never aliens.

Claims of extraterrestrial life are so common that experts now have this cheeky retort at the ready. In *The Martians*, journalist David Baron considers an early, influential example of the "it's not aliens" phenomenon: the turn-of-the-century Mars craze, during which many people were convinced that earthlings had neighbors on Mars.

From the late 1800s through the early 1900s, a Mars mania gripped the world, and the United States in particular. Newspapers blared with sensationalist headlines. (One example: "Scientists now know positively that there are thirsty people on Mars.") Astronomy lectures tantalized the public. Theater performances envisioned hypothetical interactions with Martians. Advertisers hitched themselves to the trend to sell their products. Even Alexander Graham Bell was convinced.

The frenzy was sparked by apparent linear features on Mars, observed by multiple astronomers through various telescopes. The lines, dubbed "canals," were claimed by one particularly vocal faction of astronomers to have been constructed by intelligent life for irrigation. The canals, we now know, were illusions. More detailed observations taken in 1909 suggested they were either irregular natural features or didn't exist at all.

Among the canals' most notable proponents was American astronomer Percival Lowell, an aristocrat who used his wealth to fund his observations of the planet. The book also follows other researchers, including inventor Nikola Tesla, who claimed to have detected Martian messages to Earth. Other Mars enthusiasts make cameos, such as science fiction writer H.G. Wells, who published his famous extraterrestrial-invasion story, *The War of the Worlds*, during this period.

Greedily encouraged by the yellow journalism of the era, canal believers engaged in wild speculation about Martians' appearance and culture. That clamor drowned out the sober voices of many scientists who argued there was no evidence for canals, much less for life that created them.

Baron doesn't shy away from calling out the racism in the public's fascination with Martians, which sometimes seemed an extension of the exoticization of people of color: During a trip to Algeria, Lowell compared the locals to Martians. And Martians were sometimes depicted with exaggerated features reminiscent of racist imagery of Black people.

Baron mostly confines his commentary to the era of the

Martians, apparently capable of irrigating their entire planet and sharing water with one another, were depicted as wise and good, living in harmony.

Mars craze, but in reading, one can't help but consider current events. Recently, prominent astronomers have claimed to have seen potential signs of life on an exoplanet and evidence of an alien spacecraft in the solar system in announcements that quickly drew criticism from other scientists. The warping of science to back unsubstantiated but sensational claims — that vaccines cause autism, for example — is a persistent problem.

The Martian craze took off, Baron argues, partly because people wanted to believe. The creatures, apparently capable of irrigating their entire planet and sharing water with one another, were depicted as wise and good, living in harmony — a vision of a civilization earthlings could only dream of. ✖

A WINDOW INTO THE LIVES OF SCIENTISTS

By Karen Kwon

THE SHAPE OF WONDER | *Alan Lightman and Martin Rees*
Pantheon | $28

One of my closest friends is a neuroscientist, investigating how brain cells develop and how they search for and choose other brain cells to connect with. When she's not decoding the mysteries of one of the body's least understood organs, she's like anyone else. She watches Netflix and goes for runs. When we meet, we talk about the books we're reading.

About 0.1 percent of the global population identifies as scientists, which means only a small fraction of people personally know a scientist. Maybe that unfamiliarity is one reason why almost a quarter of Americans say they're not confident that scientists have the public's best interest at heart. In their new book, *The Shape of Wonder*, physicists Alan Lightman and Martin Rees aim to win the public's trust by demystifying what scientists do, what drives them and what they're striving for.

Perhaps the most engaging parts of the book are the profiles of scientists, which offer glimpses into their daily lives, motivations and influences. Readers meet contemporary scientists such as Lace Riggs, a mid-30s American neuroscientist from a working-class background, and Magdalena Lenda, a Polish ecologist in her 40s who loves Argentine tango. Historical scientists also get spotlighted, including Barbara McClintock, an American biologist who won the 1983 Nobel Prize in physiology or medicine for her discovery of jumping genes, and Govind Swarup, remembered as India's "father of radio astronomy."

The authors argue that scientists must be resources for policy makers and the public as we navigate today's biggest ethical issues in fields such as AI and gene editing. By connecting with the humans behind science, they hope more people will see scientists not as elusive elites but as fellow members of society. ✖

Conversations with Maya

Maya Ajmera, President & CEO of Society for Science and Executive Publisher of Science News, chatted with Eric Sporkin. Sporkin is an alumnus of the 2007 International Science and Engineering Fair (ISEF), a program of Society for Science, and is a software engineer at Jane Street, a quantitative trading firm.

WHAT ARE YOUR FAVORITE MEMORIES FROM ISEF? The whole ISEF experience was outstanding. I've never been to anything so big and diverse. Being in Albuquerque, N.M., for ISEF was exciting, and I think I remember hearing there were more than 50 countries represented. What was even more incredible was the intellectual density. I felt like everyone I met was an expert in some obscure field, even though we were all high schoolers. My project, for example, focused on a math concept called full reptend primes, which are prime numbers (P) where 1/P repeats only after P-1 digits.

YOU'VE SPENT YOUR CAREER AT JANE STREET, A MARKET MAKER. WHAT IS A MARKET MAKER? A market maker helps connect buyers and sellers by simultaneously offering to buy or sell various assets to meet natural demand. My go-to example is a college bookstore. When most textbooks were still physical books, people would go to their school bookstore to buy and sell their used textbooks. Students could try to find each other directly – and sometimes they succeeded. But there were often significant gaps in both time and space between the sellers and the buyers, and it would be a lot of work for any one person. The bookstore provided this service by buying textbooks from students looking to sell and then holding onto that inventory for when students are looking to buy. A market maker provides a similar service but for tradable financial instruments, such as stocks, bonds, exchange traded funds (ETFs) and other securities.

WHAT IS YOUR ROLE AT JANE STREET? We don't have proper titles at Jane Street. There are no VPs or managing directors or head of this or that, which helps to encourage a flat culture. People feel more independence to pursue ideas or chime in on conversations. I feel like it helps instill a sense of entrepreneurship and autonomy. I enjoy the flexibility of my role. I'm a software engineer, and I focus on a variety of projects across areas. My role involves managing the international ETF desk developer team. I also help to coordinate a number of cross-desk initiatives. The technological design challenges I think about every day are fascinating.

To be honest, when I was in college, I never thought that a trading firm was a viable path for a theoretical math major. I thought that working in trading would mean shouting a lot and taking huge, risky bets based on gut intuition. In reality, places like Jane Street are very mathematical and rigorous in how we approach trading, and the culture is a great mix of welcoming and intellectual. The day-to-day is much more about collaboration and problem-solving.

MANY FIELDS ARE BEING TRANSFORMED BY EMERGENT TECHNOLOGIES SUCH AS AI. WHAT DO YOU FORESEE FOR THE FUTURE OF QUANTITATIVE TRADING? There's no question that AI has and will continue transforming finance. However, I think people underestimate the difficulty of applying AI successfully in financial markets. These technologies have been very successful at solving deeply complex problems, but the shifting rules and relationships in markets pose a unique challenge that has taken a lot of time to overcome.

That said, machine learning is pushing the boundaries of what's possible in quantitative trading. There is a new wave of technologies changing the business by developing a deeper understanding of the massive universe of relationships between tradable assets, for example. It's difficult to say what exactly this means for the future of trading. It's possible that AI and machine learning will lead to fundamental changes in how markets operate, but I'm hopeful that it helps us access increasingly efficient markets.

FOR A DECADE, YOU'VE BEEN HEAVILY INVOLVED WITH RESOLUTION PROJECT. TELL ME ABOUT THAT WORK AND WHY IT'S IMPORTANT TO YOU. Resolution Project is a youth leadership program that helps fund, accelerate and support social ventures founded by college students. Over the last 10-plus years, I've served as a mentor, a board member and a judge at the Social Venture Challenges, business plan–style competitions, where we select our fellows.

I feel like the similarities between Resolution Project and ISEF are numerous. Both programs center on bringing young leaders together and unleashing their potential for breakthrough thinking. Both take great pride in fostering a lifelong passion for innovation from an early age.

THROUGH RESOLUTION PROJECT AND YOUR INVOLVEMENT WITH OTHER SOCIAL IMPACT VENTURES, YOU'VE COLLABORATED WITH MANY RISING SOCIAL ENTREPRENEURS. WHAT ARE THE MOST IMPORTANT TRAITS FOR THOSE WORKING TO BUILD SOMETHING NEW? Most successful social entrepreneurs I know did not set out to start a venture. They became hyperfocused on a problem, searched for an existing solution and eventually realized that the only way to solve it would be to start a new venture. The commitment and dedication required to succeed as a social entrepreneur is huge and requires a lot of sweat equity to succeed. It can be all-consuming, it can feel impossible and it can be lonely. That is why I care so deeply about programs that provide support and mentorship to young innovators and entrepreneurs because having support at those moments is so critical.

WHO INSPIRED YOU WHEN YOU WERE YOUNGER AND WHO INSPIRES YOU TODAY? Growing up, I was lucky to have mentors who encouraged me to care deeply about my work and to push myself. My high school math teacher taught me that math could be fun and encouraged me to enter my local science fair, which led to ISEF.

My life was also greatly impacted by my grandfathers. My maternal grandfather was a strong, serious man with a "work to live" mentality. He was a successful small-business owner, but his job didn't define him. He taught me to focus on what matters most, to put family first and to approach things with a healthy dose of common sense. My paternal grandfather was a brilliant businessman and entrepreneur, who taught me the value of creativity, of hard work and of being willing to chart my own path.

WHAT BOOKS ARE YOU READING NOW, AND WHAT BOOKS IMPACTED YOU AS A YOUNG PERSON? Right now, I'm reading *Everything Is Tuberculosis* by John Green. It's a fascinating and fairly depressing book about the history and continued impact of one of the deadliest diseases of all time. It's a painful reminder that many treatable illnesses are still killing millions of people. A book that made a big impact on me early in my career is *Thinking, Fast and Slow* by Daniel Kahneman. If you want to understand how your own mind processes and responds to information, this is a must-read book. Finally, a book that I wish I had read much earlier in life is *Quiet: The Power of Introverts in a World That Can't Stop Talking* by Susan Cain. As someone who's always needed more alone time and can find certain environments overstimulating, the book gave me a better understanding of myself.

THERE ARE MANY CHALLENGES FACING THE WORLD TODAY. WHAT'S KEEPING YOU UP AT NIGHT AND WHAT GIVES YOU HOPE FOR THE FUTURE? We talked about AI and productivity, and I'm frightened about the consequences of enabling rapid development of technology by people who might not understand or even read the code that they produce. As these systems become increasingly complicated and tightly coupled with other pieces of infrastructure, we risk scary scenarios that will be difficult to prepare for or even predict. Progress is a double-edged sword. I'm excited about what these technologies will enable, but I also imagine that there are going to be challenges along the way that we'll have to overcome.

I think the thing that gives me hope is the ingenuity of young people. Students and young professionals are often the ones who have the most energy, the most idealism and the most enthusiasm to tackle the world's problems. I believe that they should be helping to lead right now, whether or not the rest of us think they're ready.

THE PHOENIX ISN'T THE ONLY CRITTER TO SURVIVE THE FLAMES

BY BETHANY BROOKSHIRE

At the end of its life, the phoenix goes out in style. With a loud cry, the crimson bird bursts into flames. Then from a pile of ash, a baby bird pokes out its tiny head. The phoenix has burned, but it is born anew. This story is common to ancient Greek and Egyptian mythology. And references to the phoenix span fiction today, from *Harry Potter* to the anime series *One Piece*. There are no real phoenixes hiding anywhere. But science has revealed that some living things can take quite a bit of heat. And like the phoenix, a few are even born from the ashes.

Some single-celled life-forms known as hyperthermophiles like it hot. These microbes live in places such as hot springs and deep-sea vents. Some are bacteria. But the toughest, hottest of all are members of the archaea, one of the three domains of life.

Not all archaea love the heat, but the ones studied by Robert Kelly, a microbiologist at North Carolina State University in Raleigh, do. The upper limit for these hardy cells is 120° Celsius (250° Fahrenheit) — well above the boiling point of water. If you step into the hot springs where they live, Kelly says, "your skin will basically just fall off your bones." At temperatures that high, he explains, meat — including human muscle — begins to cook. Proteins fall apart.

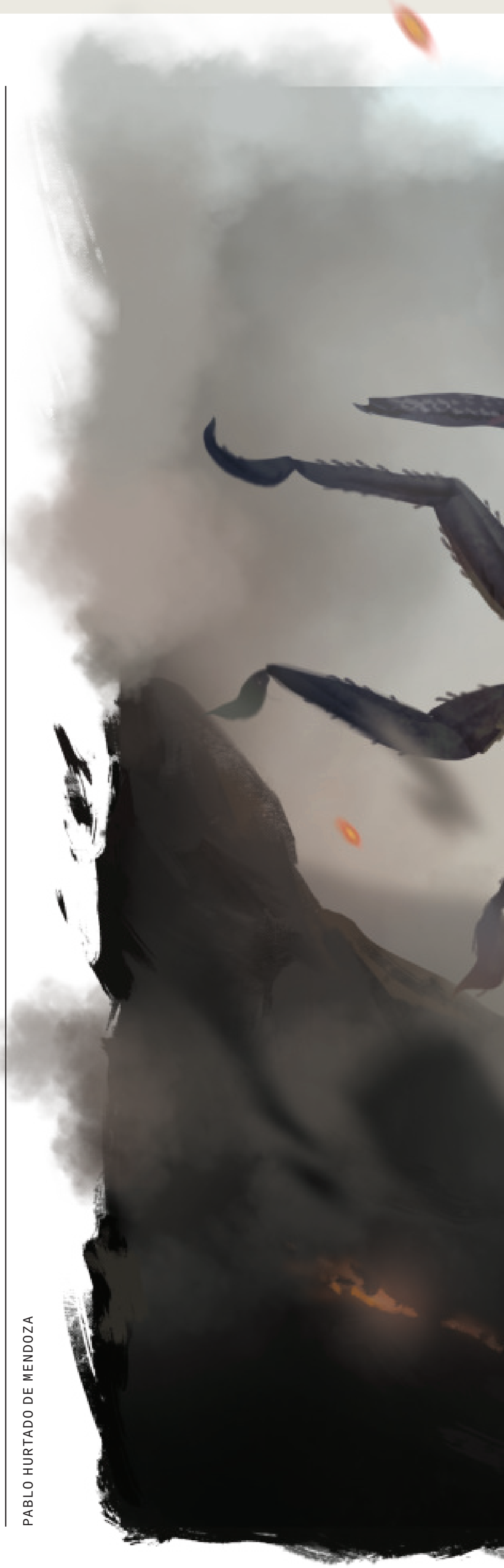
But archaea have evolved molecular tricks that keep proteins stable in these environments. Kelly and his colleagues have found thousands of tiny relationships between molecules that help hold archaea cells together as temperatures soar.

"Nature has a lot of very subtle things [it does] to stabilize a protein," he says.

Nature also offers heat protection to animals that are much larger than a single cell.

In South Africa, beetles called weevils live in the fynbos — a dry, shrub-filled area that's prone to wildfires. Entomologist Marion Javal was on a hike there with her friends several years ago. As they crossed an area that recently had burned, she got inspired.

"We saw a bunch of very tiny weevils walking on the floor. But, like, very, very small insects that



PABLO HURTADO DE MENDOZA

are not really able to fly," says Javal, of the Institute of Research for Development in Montpellier, France. "We started wondering how and why they were here."

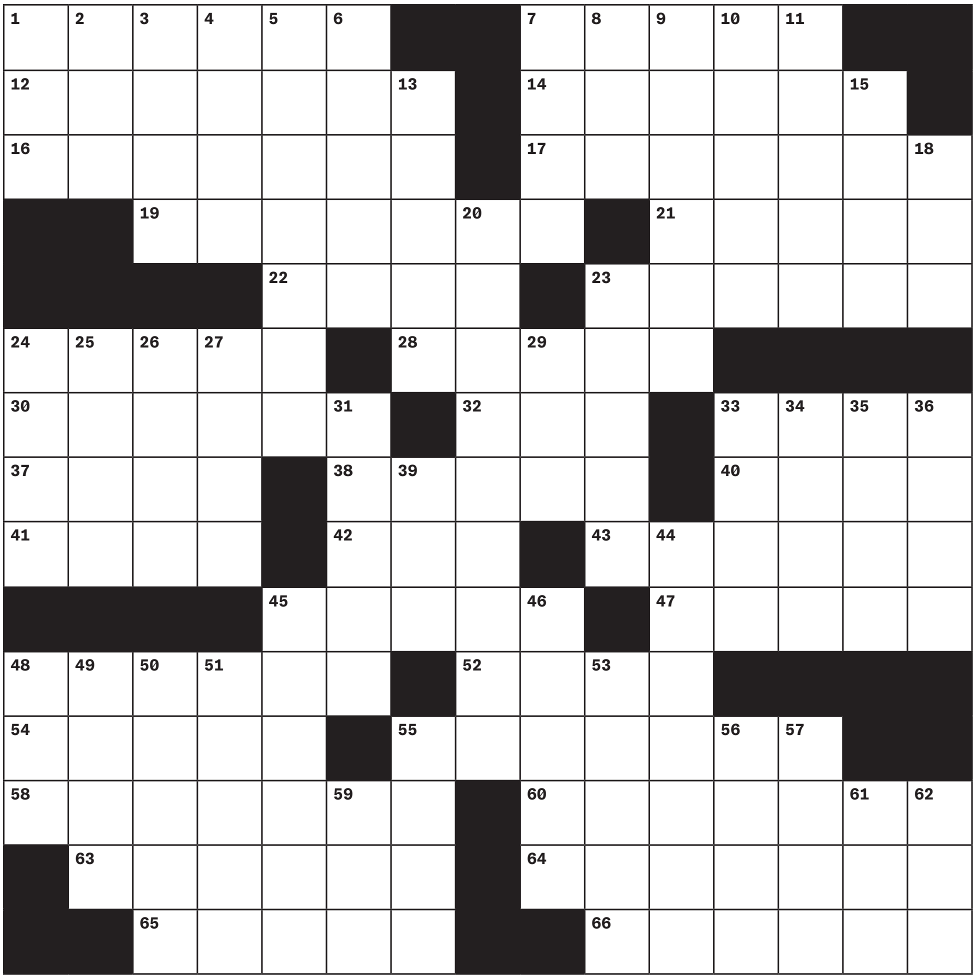
Weevils able to fly would be able to escape a burn. But those that can't fly are stuck, Javal says. Insects are ectothermic — their bodies are the same temperature as the air around them. As the air heats up during a wildfire, they do too. So how do flightless bugs survive the burn?

Javal and her colleagues collected weevils from the area and tested how much heat they could take. One species, *Ocladius costiger*, could survive at up to 52.6° C (126.7° F). Another, *Cryptolarynx variabilis*, lived at up to 53.4° C (128.1° F), the researchers reported in 2022 in *Ecological Entomology*.

"It was quite unexpected to try to find such high temperature for these very tiny weevils that we had in the study," Javal says.

Like the archaea, these beetles might have some molecular adaptations in their cells that help them survive, she notes. Or perhaps the bugs dig down into the soil to flee the flames.

Other weevil species find safety in another life-form that can withstand the burn, Javal notes. These beetles lay eggs inside plants with tough, woody exteriors that act as natural fire protection. When the wildfires peter out, the weevil eggs hatch — like a phoenix from the ashes. ✖



COLD CUTS

BY RACHEL FABI

ACROSS

1 "The Hill We Climb" poet Gorman
7 Uncanny
12 Egotist's guiding principle
14 *Natural structure that forms over water, enabling migration of animals or people
16 *Frozen worlds
17 Helpers often found near home plate
19 Sketches anew
21 Common aquarium fish
22 Al who said he "took the initiative in creating the internet"
23 "On your mark, ___, go!"
24 Chevy model that shares its name with a lake
28 Look of derision
30 Itinerary
32 Harmful by-product of some cigarettes
33 *Extremely cold high-latitude regions
37 Ripped
38 *Weather event that may involve sleet
40 Zone
41 *Time spans characterized by reduced global temperatures
42 Sound from a Samoyed
43 Unbroken record?
45 Gamma ___ (radiosurgery technique that doesn't actually involve incisions)
47 Takes a breather
48 Timon's companion, in "The Lion King"
52 Intro to science?
54 Poppy product
55 Dug for dirt
58 "You're better off not knowing"
60 Bioethics principle requiring a fair distribution of the benefits and burdens of scientific research … or the mere three letters that must be added to the starred clues' answers
63 *Particles around which freezing precipitation forms
64 Before birth
65 Singer Mendes with a self-titled 2024 album
66 Showed contempt for

DOWN

1 Psych (up)
2 First name of two Spice Girls
3 Way, way off
4 Number eaten by seven in a classic math joke
5 Coated in flour before frying, perhaps
6 Houston athlete
7 Flows back
8 Historical period
9 "Three's Company" actor John
10 "Seems likely …"
11 Quadruple prize winners in entertainment
13 Bygone Russian rulers
15 Jane who loved Mr. Rochester
18 Used a chair
20 Ranted and raved at
23 Bacteriologists' specimens, perhaps
24 "Toodle-oo!"
25 Amazed
26 Roll call response
27 About half the digits in a string of binary code
29 Part inspected by an otoscope
31 Yoga pose
33 Give a darn
34 Adversary of Wonder Woman
35 Biomass found in some wetlands
36 ___ Fifth Avenue (department store)
39 3-
44 Stumps
45 "We did it, Joe!" speaker
46 Contents of a symbolic text?
48 Friend of the ___ (loyal listener, maybe)
49 Atop
50 –
51 Identity held by some queer women
53 They may be abstract or concrete
55 Largest organ of the human body
56 "At Last" singer James
57 Descriptor for a sugar-free soda
59 Stitch
61 ___-Magnon
62 Loooooong time

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