SPECIAL ISSUE The SN 10: Scientists to Watch

ScienceNews

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Launching at Last

After years of delays, the James Webb Space Telescope will take flight to explore the earliest galaxies

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COVER Once unfolded, as in this illustration, the James Webb Space Telescope will observe exoplanets and distant galaxies. *NASA*

Good things come to astronomers who wait

Scientists and journalists share a deep fascination with what's new, but our patience can be tried when a promised big new thing is delayed. That's particularly true of the protracted wait for the James Webb Space Telescope, which has stretched from a promised 20 years or so to 32 years — enough to make the project the butt of many jokes.

Finally the massive telescope, designed to capture faint hints of infrared light from the distant reaches of the universe, is poised to launch in December. And astonishingly, it's not past its freshness date. In this issue, astronomy writer Lisa Grossman explains that the long delay may end up making the instrument actually more useful (Page 26). Advances in the last few decades, including the discovery of thousands of exoplanets, have raised exciting questions, including whether there's life on those planets, that the telescope is now poised to explore.

The telescope is also beautiful, with a golden sunflower-like mirror and horizontal "sails" that shield the spacecraft from the sun. I'm a word person, and one of the great pleasures of my job is to see how our design team uses images and graphics to explain complex science. In this case, it involved sifting through many images to find an illustration that reveals how the craft, which will be folded like an umbrella for launch, will look once it's unfolded and flying in space. It's a joyous expression of science in action that requires no words.

Also in this issue, you'll find an update on our SN 10: Scientists to Watch (Page 32). In years past, this project has introduced early- and mid-career scientists doing fascinating, significant work. This year, because of the tumult in science and the world, we chose to check back in with several of the scientists we profiled in years past to see how their research, and their perspectives, have changed. Theirs are inspiring stories of adaptability, creativity and perseverance, and speak to how essential science is in answering the challenges that humankind and our planet face. They give me hope for our shared future. — *Nancy Shute, Editor in Chief*

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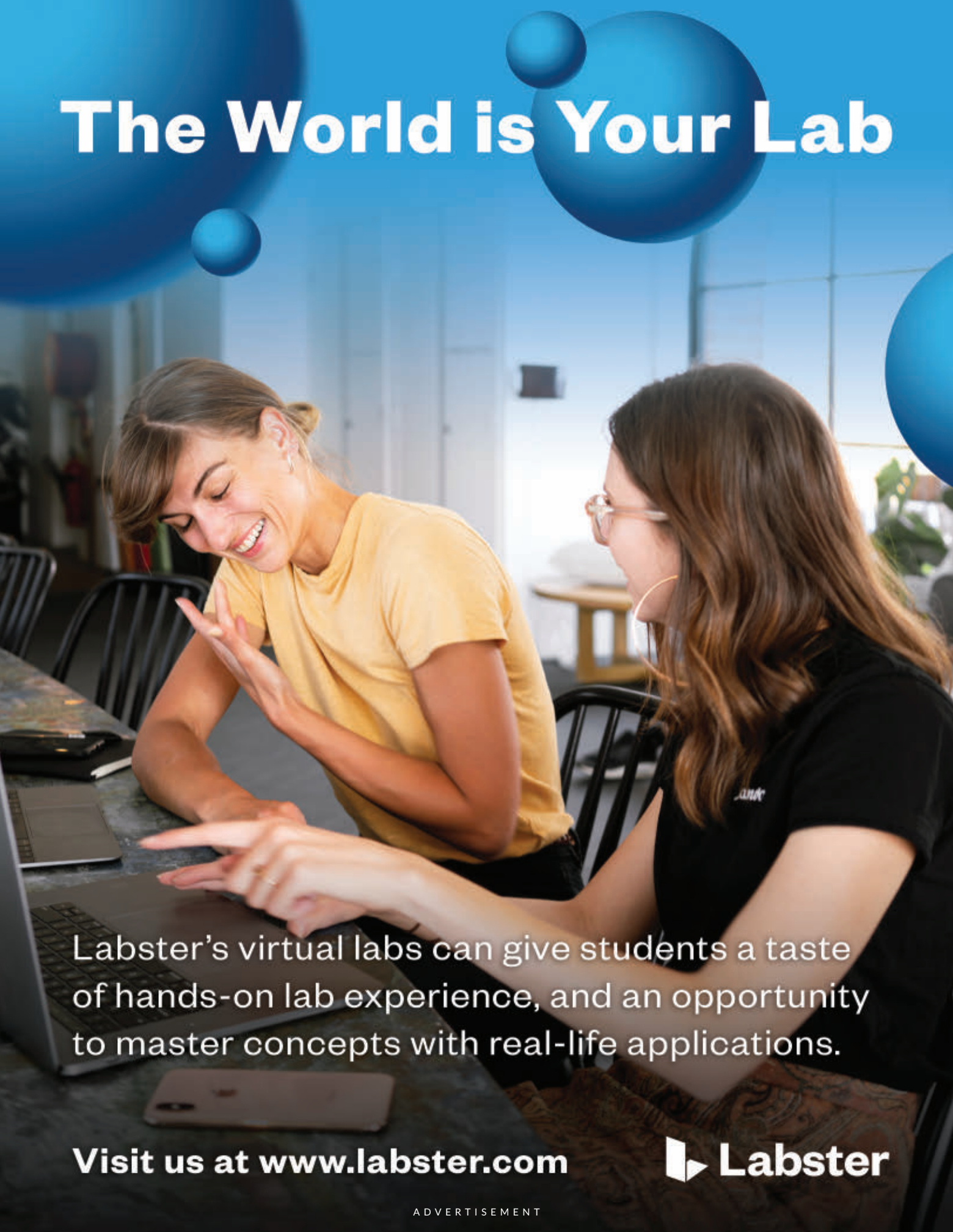


Excerpt from the October 9, 1971 issue of *Science News*

50 YEARS AGO

Probing pharaohs with X-rays

The 29 mummies of pharaohs and queens were examined without disturbing their present positions.... [Researchers using portable X-ray equipment] found evidence of rheumatoid inflammation of the vertebrae of Amenophis II, ruler of Egypt from 1436 to 1413 B.C.... [A queen] was buried with what was thought to be her mummified infant. But radiography of the object confirmed its identification as a mummified adolescent baboon.

UPDATE: Scientists now investigate Egyptian mummies with advanced imaging devices that were unavailable in 1971. Micro-CT scans and virtual reality models have provided detailed life history and embalming information about three animal mummies — a cat, a bird and a snake (*SN: 9/12/20, p. 17*). 3-D printing has enabled scientists to reconstruct the vocal tract and simulate the voice of a 3,000-year-old mummified priest (*SN: 2/15/20, p. 14*). And infrared scanners have revealed tattoos on seven mummies dating to about 3,000 years ago (*SN: 12/21/19 & 1/4/20, p. 8*).

The Hispaniolan vineboa's large eyes and zigzag coloring alerted researchers that they had stumbled upon a new species, one that may be among the world's smallest boas.

INTRODUCING

Eye-popping boas constitute a new species

A wide-eyed snake has made scientists do a double take. The Hispaniolan vineboa, with its large protruding eyes and square snout, is the first boa species to be discovered in the Dominican Republic in more than a century.

Naturalist Miguel Landestoy of the Universidad Autónoma de Santo Domingo in the Dominican Republic and colleagues discovered the snake, *Chilabothrus ampelophis*, slithering in a patch of mountainous dry forest near the country's southwestern border with Haiti on the island of Hispaniola. The last time researchers described a new boa species on the island was in 1888.

"The fact that an animal could have gone undetected for so long on this island that has a lot of people on it is pretty remarkable," says herpetologist R. Graham Reynolds of the University of North Carolina Asheville.

What's more, the Hispaniolan vineboa may be among the world's smallest boas, Reynolds, Landestoy and colleague Robert Henderson of the Milwaukee Public Museum report August 17 in *Breviora*. In general, adult boas typically reach 2 meters or more in length. The longest Hispaniolan vineboa that the team found, an adult female, measures less than 1 meter. The shortest, probably a juvenile male, is less than a half meter long.

Compared with the features of the three other boa species on the island, the Hispaniolan vineboa's small size, large eyes and dark, zigzag-patterned scales tipped off the researchers that they had spotted something new. Genetic analyses and close inspections of five snakes confirmed the team's hunch that the boas belong to a species new to science.

The species may already be in trouble. All serpents that the team found were within one kilometer of each other. That's "a little bit alarming in the sense that they might be restricted to a very small area," Reynolds says. Agricultural activities threaten the species's habitat. Next, the team plans to figure out the extent of the boa's range. — *Erin Garcia de Jesús*

SCIENCE STATS

COVID-19 vaccines are doing their job

As the coronavirus continues to surge across the United States, hospitals are filling up with people with COVID-19. And the vast majority of those patients are unvaccinated, as two recent charts (see Page 5) make clear.

The first of those charts shows that from the week ending January 30 to the week ending July 24, vaccinated individuals (red) were hospitalized with COVID-19 at a much lower cumulative rate than unvaccinated individuals (blue). And the difference in rates between the two groups grew over time. By late July, a total of about 26 adults per 100,000 vaccinated people had been hospitalized for COVID-19. That's compared with about 431 adults hospitalized per 100,000 unvaccinated people. The

TEASER

A pinch of fat could make tempering chocolate a breeze

Glossy, velvety chocolate that snaps in the fingers and melts in the mouth is the chocolatier's dream.

But crafting cocoa confections with this optimal texture is no easy feat. The endeavor, known as tempering (shown at right), demands carefully warming and cooling liquid chocolate until it crystallizes into its most delectable form. Now, scientists may have found a shortcut: adding a small pinch of fatty molecules called phospholipids, researchers report August 31 in *Nature Communications*.

With phospholipids, "you can simplify the whole tempering process, making sure you always have the right quality of the chocolate," says food chemist Alejandro Marangoni of the University of Guelph in Canada.

Curious about what occurs on a molecular level during tempering, Marangoni and colleagues focused on the ingredient that gives chocolate its texture — cocoa butter. While previous tempering research had targeted cocoa butter's main component, triglycerides, the team set its sights on a different sweet spot: the minor components, which include free fatty acids and phospholipids. Removing these minor components from the cocoa butter and adding them back in one by one allowed the researchers to figure out the role of each during tempering.

With just a pinch of phospholipids added to the cocoa butter — achieving a concentration of 0.1 percent of the chocolate's total weight — the mixture rapidly crystallized into the elusive, melt-in-the-mouth texture. The process required a single cooling to 20° Celsius rather than multiple heating and cooling cycles as tempering typically demands.

Next, the team increased the phospholipid concentration in melted dark chocolate by an extra 0.1 percent and easily produced high-quality textures. The result suggests that phospholipids could be used to simplify chocolate tempering.

The hack could help small-scale chocolatiers avoid some of the complications and expenses associated with tempering machines, Marangoni says. Large-scale manufacturers, on the other hand, would need to figure out how to evenly disperse phospholipids in a large vat of molten chocolate.
— Nikk Ogasa

FROM TOP: JUPITERIMAGES/THE IMAGE BANK/GETTY IMAGES; C. CHANG

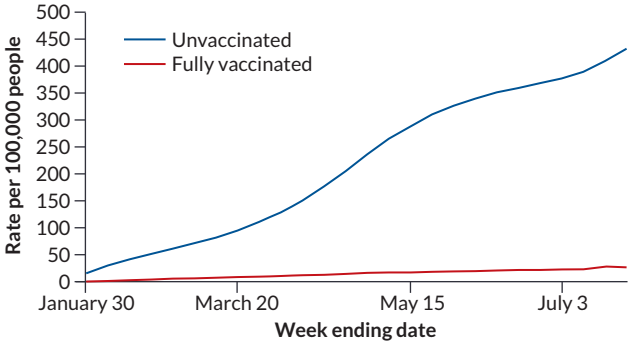
data come from 13 states, including California, Georgia and Utah.

That trend held when researchers charted hospitalization rates on a weekly basis too (below, right). From January to July, weekly hospitalization rates among unvaccinated people (blue) were six to 31 times as high as those among vaccinated people (red), the team reports August 29 at medRxiv.org.

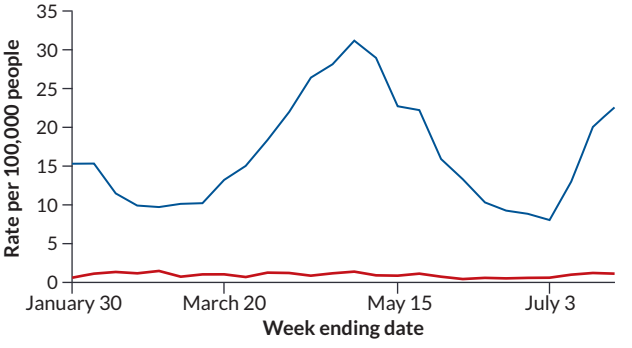
The cumulative rates and the weekly rates send two clear messages: If you're vaccinated, your overall risk of hospitalization is much lower than if you're not vaccinated. And, even as hospitalization risk among unvaccinated people fluctuates week by week, probably as a result of community transmission, risk remains low for vaccinated people.

The findings "remind us that if you are not yet vaccinated, you are among those highest at risk," Rochelle Walensky, director of the U.S. Centers for Disease Control and Prevention, said August 24 at a White House news briefing. "Please do not underestimate the risk of serious consequences of this virus."
— Erin Garcia de Jesús

Cumulative rates of U.S. COVID-19 hospitalizations of adults by vaccination status, January–July 2021



Weekly rates of U.S. COVID-19 hospitalizations of adults by vaccination status, January–July 2021



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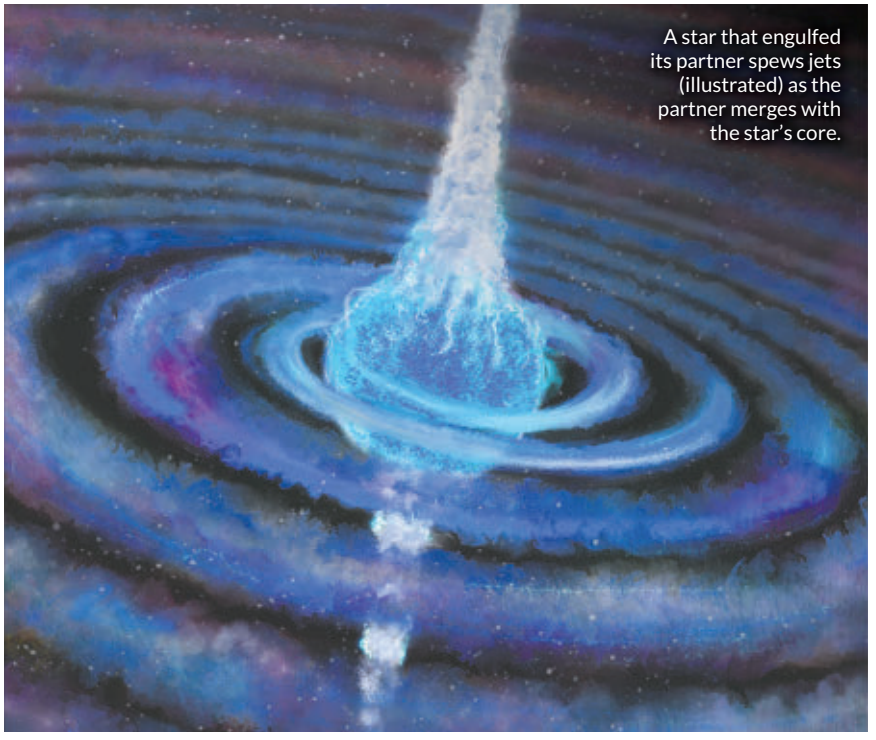
ATOM & COSMOS

Double cannibalism sparks explosion

It could be astronomers' first glimpse of this rare stellar event



A star that engulfed its partner spews jets (illustrated) as the partner merges with the star's core.

CHUCK CARTER

BY ADAM MANN

For the first time, astronomers have captured solid evidence of a rare double cosmic cannibalism: A star swallowed a compact object such as a black hole or neutron star. In turn, that object gobbled the star's core, causing it to explode and leave behind only a black hole.

The first hints of the gruesome event, described in the Sept. 3 *Science*, came from the Very Large Array, or VLA, a radio telescope consisting of 27 enormous dishes in the New Mexican desert near Socorro. During the telescope's scans of the night sky in 2017, a burst of radio energy as bright as the brightest exploding star — or supernova — as seen from Earth appeared in a dwarf galaxy.

"We thought, 'Whoa, this is interesting,'" says astronomer Dillon Dong of Caltech.

Dong and colleagues made follow-up observations of the galaxy, which is about 500 million light-years from Earth, using the VLA and one of the telescopes at the W.M. Keck Observatory in Hawaii. The Keck telescope, which sees optical light, like our eyes, caught a luminous outflow of material spewing in all directions at 3.2 million kilometers per hour from a central location. That finding suggests an energetic explosion had occurred there.

The team then found an extremely bright X-ray source in archival data from the Monitor of All Sky X-ray Image telescope on the International Space Station. This X-ray burst was in the same place as the radio burst but had been observed back in 2014.

Piecing the data together, Dong and colleagues think this is what happened: Long ago, a pair of stars were born orbiting each other; one died in a spectacular supernova and became either a neutron star or a black hole. As gravity brought the two objects closer together, the former star actually entered the outer layers of its larger stellar sibling.

The compact object spiraled inside the still-living star for hundreds of years, eventually making its way down to and then merging with its partner's core. Before the merger, the larger of the pair shed huge amounts of gas and dust, forming a shell of material around the duo.

In the living star's center, gravitational forces and complex magnetic interactions from the partner's munching launched enormous jets of energy — picked up as the X-ray flash in 2014 — as well as causing the larger partner to explode. Debris from the detonation smashed with colossal speed into the surrounding shell of material, generating the optical and radio light.

While theorists have previously envisioned such a scenario, dubbed a merger-triggered core collapse supernova, this event appears to be the first direct observation of this phenomenon, Dong says.

"They've done some pretty good detective work using these observations," says Adam Burrows, an astrophysicist at Princeton University who was not involved in the work. The findings should help constrain the timing of a process called common envelope evolution, in which one star becomes immersed inside another, he says. Such stages in stars' lives are relatively short-lived in cosmic time and difficult to both observe and simulate. Most of the time, the engulfing partner dies before its core is consumed, leading to two compact objects such as white dwarfs, neutron stars or black holes orbiting one another.

The final stages of common envelope evolution are exactly what observatories like the Advanced Laser Interferometer Gravitational-Wave Observatory, or LIGO, detect when capturing ripples in spacetime (*SN: 1/30/21, p. 30*), Dong says. Now that astronomers know to look for these multiple lines of evidence, he expects more examples of this strange phenomenon to pop up. ■

A lush Arabia enticed Stone Age groups

Migrating hominids trekked through the area during wet periods

BY BRUCE BOWER

Arabia, known today for its desert landscape, served as a "green turnstile" for migrating Stone Age members of the human genus starting around 400,000 years ago, a new study finds.

Monsoon rains periodically turned northern Arabia into an oasis, creating windows of opportunity for humans or their relatives to trek through that crossroads region from starting points in northern Africa and southwestern Asia.

That's the implication of five ancient lake beds of varying ages, each accompanied by distinctive stone tools, unearthed in northern Saudi Arabia at a site called Khall Amayshan 4, or KAM 4. Sediments from the lake beds, which were linked to periods when the climate was wetter than today, also yielded fossils of hippos, wild cattle and other animals. Like hominids, those creatures must have migrated into the region along rain-fed lakes, wetlands and rivers, an international team reports in the Sept. 16 *Nature*.

Until now, the oldest stone tools in Arabia dated to at least 300,000 years ago (*SN: 12/22/18 & 1/5/19, p. 6*). Aside from providing the earliest known evidence of hominids in Arabia, the new finds demonstrate that *Homo* groups traveled there when conditions turned wet, say archaeologist Huw Groucutt of the Max Planck Institute for the Science of Human History in Jena, Germany, and colleagues.

The number, completeness and time frames of KAM 4's lake deposits make this site "one of a kind ... that will continue to produce remarkable results," says archaeologist Donald Henry of the University of Tulsa in Oklahoma, who did not participate in the study.

Across five occupation phases covering hundreds of thousands of years, different *Homo* species or closely related *Homo* populations at KAM 4 "were doing broadly the same things," Groucutt says. Small groups camped by lakes where individuals made stone tools for food preparation, hunting and woodworking.

But each phase, dated mainly by a technique that estimates the amount of time since grains of lake sediment were last exposed to sunlight, had its own evolutionary character.

The identity of the KAM 4 crowd 400,000 years ago, who left behind hand axes, is unclear, but it couldn't have been *H. sapiens*. Our species didn't originate until roughly 300,000 years ago in Africa. One possibility is that those ancient Arabians represented a now-extinct *Homo* population from southwestern Asia that later migrated into Africa, possibly contributing to *H. sapiens* evolution, Groucutt speculates.

Similar but slightly smaller, more finely worked hand axes turned up at a roughly 300,000-year-old KAM 4 lake bed, indicating a second occupation phase. The researchers doubt that early *H. sapiens* from Africa scurried over there in time to make the tools. Whichever *Homo* group did could have come either from northern Africa or southwestern Asia.

A third round of KAM 4 occupants, probably *H. sapiens*, fashioned artifacts found at a roughly 200,000-year-old lake bed, Groucutt says. These finds consist of rock chunks shaped so that sharp flakes, also unearthed there, could be pounded off. Humans based in northeastern Africa around that time made similar tools. Some of those people may have reached Arabia before journeying to southwestern Asia, Groucutt suggests.

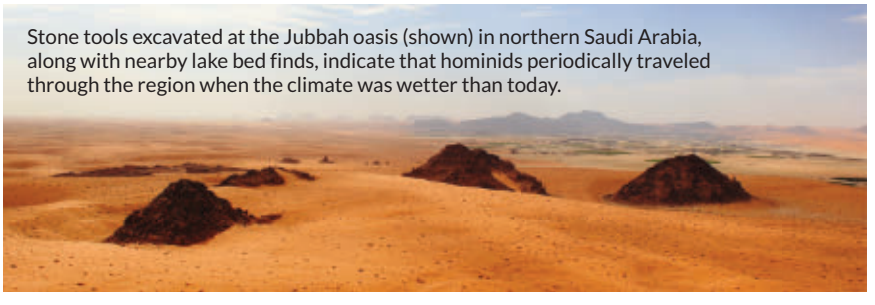
Roughly 400,000 years ago, members of an unidentified *Homo* group left behind stone hand axes such as this one near a lake in northern Arabia.

Groucutt's group excavated comparable tools at a site called Jubbah, about 150 kilometers east of KAM 4. Those tools date to about 210,000 years ago and are another sign of migrations into Arabia at a time when the corresponding KAM 4 lake bed shows that wet conditions reigned. Additional stone tools unearthed at Jubbah date to about 75,000 years ago.

Stone implements resembling the Jubbah finds were also excavated at the youngest two KAM 4 sites, one dating to between about 125,000 and 75,000 years ago and the other to roughly 55,000 years ago. The older site probably hosted *H. sapiens*, possibly a group that left Africa, Groucutt suggests.

The youngest KAM 4 artifacts could represent *H. sapiens* or Neandertals, he says. Neandertals reached the Middle East by about 70,000 years ago and could have reached a green Arabia by 55,000 years ago. If so, Neandertals may have interbred with *H. sapiens* in Arabia, a possibility not raised before.

Despite uncertainties about which hominids reached KAM 4, the site's tools generally look more like similarly aged African tools than artifacts found in southern Arabia or at eastern Mediterranean sites, Henry says. Migrations from Africa, he says, appear more likely to have wended through northern Arabia than across a narrow Red Sea crossing to southern Arabia, often regarded as a major dispersal route. ■



Stone tools excavated at the Jubbah oasis (shown) in northern Saudi Arabia, along with nearby lake bed finds, indicate that hominids periodically traveled through the region when the climate was wetter than today.

FROM TOP: IAN CARTWRIGHT/PALAEODESERTS PROJECT; CERI SHIPTON/PALAEODESERTS PROJECT

ATOM & COSMOS

Perseverance snags Mars' rocks

The samples might shed light on the Red Planet's wet past

BY LISA GROSSMAN

The Perseverance rover has captured its first two slices of Mars.

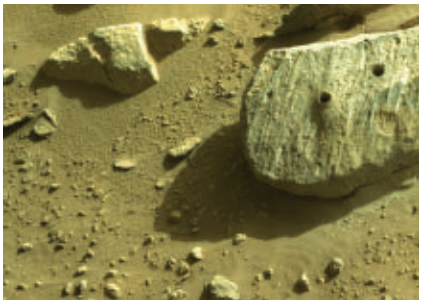
NASA's latest Mars rover drilled into a flat rock nicknamed Rochette in Jezero crater on September 1 and filled a roughly finger-sized tube with stone. The sample is the first ever destined to be sent to Earth for further study. On September 8, the rover snagged a second sample from the same rock. Both are now stored in airtight tubes inside the rover's body.

Getting pairs of samples from every rock it drills is "a little bit of an insurance policy," says deputy project scientist Katie Stack Morgan of NASA's Jet Propulsion Lab in Pasadena, Calif. It means the rover can drop identical stores of samples in two different places, boosting chances that a future mission will be able to pick up at least one of the sets.

The successful drilling is a comeback story for Perseverance. The rover's first attempt to take a bit of Mars ended with the sample crumbling to dust, leaving an empty tube (*SN: 9/11/21, p. 32*). That rock was too soft to hold up to the drill, scientists suspect. Nevertheless, the rover persevered.

Rochette is a hard rock that appears to have been less severely eroded by millennia of Martian weather (*SN: 7/4/20 & 7/18/20, p. 24*). Rover measurements of the rock's texture and chemistry suggest that Rochette is made of basalt and may have been part of an ancient lava flow. That's useful because volcanic rocks preserve their ages well, Stack Morgan says. When scientists on Earth get their hands on the samples, they'll be able to use the concentrations of certain elements and isotopes to figure out exactly how old the rock is — something that's never been done for a pristine Martian rock.

Rochette also contains salt minerals that probably formed when the rock interacted with water over long time periods. That could suggest water moving through the Martian subsurface, maybe creating habitable environments within the rocks there, Stack Morgan says. "It really feels like this rich treasure trove of information for when we get this sample back."



The Perseverance rover drilled two cylinders of stone out of a Martian rock in September. The samples may eventually come to Earth for further study.

Once the rocks are on Earth, scientists plan to search inside the salts for fluid-filled bubbles. Finding such bubbles would "give us a glimpse of the Jezero crater at the time when it was wet and was able to sustain ancient Martian life," said planetary scientist Yulia Goreva, also of NASA's Jet Propulsion Lab, in a September 10 news briefing.

Scientists will have to be patient, though. The earliest any samples will make it to Earth is 2031. But it's still a historic milestone, says planetary scientist Meenakshi Wadhwa of Arizona State University in Tempe. "We've talked about Mars sample return for decades, and now it's starting to actually feel real." ■

MATTER & ENERGY

Scientists spin up large-particle beams

Twisting streams of atoms and molecules mark a physics first

BY EMILY CONOVER

Like soft serve ice cream, beams of atoms and molecules now come with a swirl.

Scientists already knew how to dish up spiraling beams of light or electrons, known as vortex beams. Now, the first vortex beams of atoms and molecules are on the menu, researchers report in the Sept. 3 *Science*.

Vortex beams made of light or electrons have shown promise for making special types of microscope images and for transmitting information using quantum physics (*SN: 9/5/15, p. 14*). But vortex beams of larger particles such as atoms or molecules are so new that the possible applications aren't yet clear, says physicist Sonja Franke-Arnold of the University of Glasgow in Scotland.

According to quantum physics, particles travel through space as waves. But vortex beams' waves don't slosh up and down like ripples on water. Instead, the beams' particles move in a corkscrewlike fashion. That means vortex beams carry a rotational oomph known as orbital angular momentum. "This is something really very strange," says physicist Edvardas Narevicius of the Weizmann Institute of Science in Rehovot, Israel.

Narevicius and colleagues created the new beams by passing helium atoms through a grid of specially shaped slit patterns, each pattern just 600 nanometers wide. The team detected a hallmark of vortex beams: a row of rings imprinted by the atoms on a detector, in which each ring corresponds to a beam with a different orbital angular momentum. Another set of rings revealed vortex beams made of helium excimers, molecules created when a helium atom in an energized state pairs up with another helium atom.

Scientists might next study what happens when the beams collide with light, electrons or other atoms or molecules.

In physics, "most important things are achieved when we are revisiting known phenomena with a fresh perspective," says physicist Ivan Madan of the Swiss Federal Institute of Technology in Lausanne. "This experiment allows us to do that." ■

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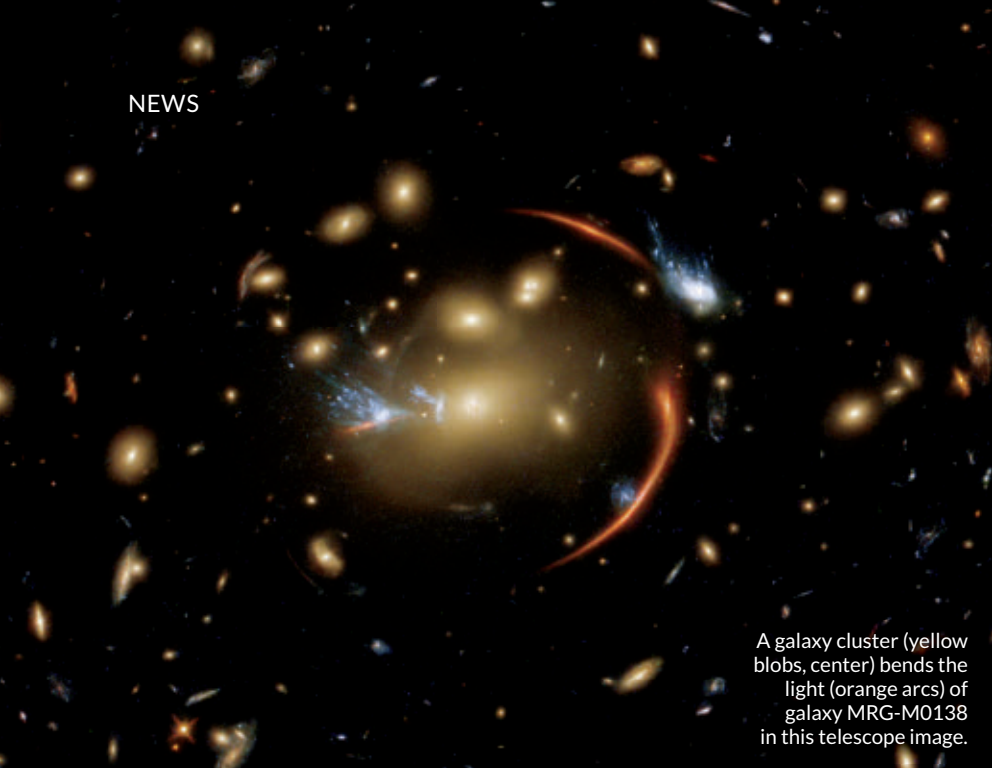

A galaxy cluster (yellow blobs, center) bends the light (orange arcs) of galaxy MRG-M0138 in this telescope image.

A. NEWMAN, M. AKHSHIK, K. WHITAKER, HUBBLE/NASA, ESA

ATOM & COSMOS

Supernova's return may take decades

The delay could end a debate over the universe's expansion rate

BY KEN CROSWELL

A meandering trek taken by light from a remote supernova in the constellation Cetus may help researchers pin down how fast the universe is expanding — in another decade or two.

About 10 billion years ago, a star exploded in a far-off galaxy named MRG-M0138. Some of the light from that explosion later encountered a gravitational lens, a cluster of galaxies whose gravity sent the light on multiple diverging paths. In 2016, the supernova appeared in Earth's sky three times, each time as a distinct point of light that took a different path to get here.

Now, researchers predict that the supernova will appear again in the late 2030s. The time from when the supernova's light last appeared in 2016 to when the light is predicted to appear again — the longest delay ever seen from a gravitationally lensed supernova — could provide a more precise estimate for the distance to the supernova's host galaxy, the team reports September 13 in *Nature Astronomy*. And that, in turn, may let astronomers refine estimates of the Hubble constant, the parameter that describes how fast the universe is expanding and helps estimate the universe's age.

The first three points of light appeared in images from the Hubble Space Telescope. "It was purely an accident," says astronomer Steve Rodney, who did the work while at the University of South Carolina in Columbia. Three years later, when the telescope again observed the galaxy, astronomer Gabriel Brammer of the University of Copenhagen discovered that all three points of light had vanished, indicating a supernova.

By calculating how the gravity of the intervening cluster alters the paths of the supernova's light, Rodney, Brammer and colleagues predict that a fourth point of light — much delayed by the cluster's gravity — will appear in 2037, give or take a couple of years. Around that time, the Hubble Space Telescope may burn up in Earth's atmosphere, so the team has dubbed the supernova SN Requiem.

"It's a requiem for a dying star and a sort of elegy to the Hubble Space Telescope itself," Rodney says. A fifth point of light that will be too faint to see with current telescopes may arrive around 2042, the team calculates.

Not everyone agrees with the team's forecast of a 21-year delay. "It is very difficult to predict what the time delay will be," says Rudolph Schild, an astrophysicist at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. The distribution of matter, which affects gravity, in the supernova's host galaxy and the cluster bending the supernova's light is so uncertain, Schild says, that the next point of light from SN Requiem could appear outside the years the team has specified.

When the supernova does eventually appear again, "that would be a phenomenally precise measurement" of the time delay, says astronomer Patrick Kelly of the University of Minnesota in Minneapolis who was not involved with the work. That's because the uncertainty in the time delay will be small compared with the tremendous length of the time delay itself.

That delay, coupled with an accurate description of how light weaves through the galaxy cluster, could affect a debate over the Hubble constant (*SN: 9/14/19, p. 22*). Numerically, the Hubble constant is the speed a distant galaxy recedes from us divided by the distance to that galaxy. For a given galaxy with a known speed, a larger estimated distance from Earth therefore leads to a lower number for the Hubble constant.

Decades ago, the Hubble constant was in dispute by a factor of two. Today the range is much tighter, from about 67 to 74 kilometers per second per 3 million light-years. But that spread still leaves the universe's age uncertain. The frequently quoted age of 13.8 billion years corresponds to a Hubble constant of 67.4. But if the Hubble constant is 74, then the universe could be about a billion years younger.

The longer it takes for SN Requiem to reappear, the farther from Earth the host galaxy is — which means a lower Hubble constant and an older universe. If the debate over the Hubble constant persists into the 2030s, the exact date the supernova shows itself again could help resolve the dispute and nail down a fundamental cosmological parameter. ■

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EARTH & ENVIRONMENT

Amazon fires intrude on wildlife spaces

Burnings affect up to 85 percent of the area's threatened species

BY JAKE BUEHLER

Much of the Amazon's biodiversity is under fire — literally.

In the last two decades, deforestation and forest fires have encroached on the ranges of thousands of plant and animal species in the Amazon rainforest, scientists report September 1 in *Nature*. Fire has singed the ranges of up to 85 percent of threatened species in the region.

Since much of the rainforest is within Brazil's borders, the extent of the damage is closely tied to the enforcement, or lack thereof, of the country's regulations aimed at protecting the rainforest from widespread logging and fires often used to clear open space. The findings illustrate the key role that forest use regulations have in the fate of the Amazon rainforest, the researchers argue.

Threats to the survival of this biodiversity could have long-term effects. Biodiversity boosts a forest's resilience to drought, says ecologist Arie Staal of Utrecht University in the Netherlands. A deep bench of tree species allows the plants to replace those that may not survive drought conditions, he says. "If fire-impacted area continues to rise, not only does the Amazon lose forest cover, but also some of its capacity to cope with the changing climate."

As fires advance deeper into the rainforest, more species will experience fire for the first time, Staal says. "These species, including many threatened ones, have not evolved under circumstances with regular fires, so the consequences for those species can be severe." Such consequences may include increased risk of population declines or extinction, similar to what was feared following wildfires in Australia in 2019 and 2020 (*SN: 4/10/21, p. 14*).

In recent decades, ongoing deforestation and periodic drought in the Amazon basin have been associated with intensifying fires there. In 2019, a particularly severe series of fires scorched the region.

"But we do not know how fires are impacting the biodiversity across the Amazon basin," says biogeographer Xiao Feng of Florida State University in Tallahassee. The Amazon "is a huge area, and it is generally impossible for people to go there and count the number of species before the fire and after," he says.

So Feng and colleagues instead investigated the extent to which Amazonian plant and animal species' geographic ranges have been exposed to recent fires. The team compiled range maps of 11,514 plant and 3,079 vertebrate species, creating what may be the most comprehensive dataset of range maps for the Amazon. Comparing these maps with satellite images of Amazon forest cover and fire location data let the team track how logging and fires degraded rainforest habitat from 2001 to 2019.

Fire impacted up to 190,000 square kilometers — an area roughly the size of Washington state — the team found. Up to about 95 percent of the species in the study had ranges that overlapped with fires during this nearly two-decade period, though for many species, burned areas made up less than 15 percent of their overall range. In 2019 alone, over 12,000 species experienced fire somewhere in their geographic range.

Affected species include up to 85 percent of the 610 in the region that the International Union for Conservation of Nature considers threatened. This category includes as many as 264 kinds of plants, 107 amphibians and 55 mammals.

Starting in 2009, when the Brazilian government began enforcing a series of regulations aimed at reducing deforestation, the extent of fires generally decreased, the team found. Then in 2019, fires ticked back up, coinciding with a relaxation of regulations. Much of the fire-driven forest loss was congregated in Brazil, along the rainforest's intensely logged southern reaches.

The shift suggests that effective forest preservation policies can slow destruction, and may be crucial for preventing the region from reaching a tipping point. That point would occur when the cycle of deforestation, drying and fire triggers transformation of large parts of the Amazon basin into a savanna-like habitat.

While the team couldn't track the fate of specific plants or animals, Feng plans to look at fire's impact on groups of species that may have different vulnerabilities to an increasingly flammable Amazon. "We know some trees may be more resistant to burns, but some may not. So it may also be really important to distinguish differences," he says. ■

A fire burns in the Amazon in Brazil's Maranhão state in 2014. Fires like this are searing the geographic ranges of thousands of plant and animal species, a study finds.

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Satellites like SpaceX's Starlink constellations will leave streaks in sky photos taken by researchers and amateurs alike. This photo shows Mars (far left) and the Pleiades star cluster (center) with light trails from two Starlinks crisscrossing the scene.

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ATOM & COSMOS

Satellite swarms will alter night sky

'Mega-constellations' may mar even casual stargazers' views

BY LISA GROSSMAN

Fleets of private satellites orbiting Earth will be visible to the naked eye in the next few years, sometimes all night long.

Companies such as SpaceX and Amazon have launched hundreds of satellites into orbit since 2019, with plans to launch thousands more. The goal of these satellite "mega-constellations" is to bring high-speed internet around the globe, but these bright objects threaten to disrupt astronomers' ability to observe the cosmos (*SN: 3/28/20, p. 24*).

"For astronomers, this is kind of a pants-on-fire situation," says radio astronomer Harvey Liszt of the National Radio Astronomical Observatory in Charlottesville, Va.

A new simulation of these satellites suggests that, contrary to earlier predictions, casual skywatchers will have their views disrupted too, Samantha Lawler, an astronomer at the University of Regina in Canada, and colleagues report in a paper posted September 9 at arXiv.org.

"We humans have been looking up at the night sky and analyzing patterns there for as long as we've been human," Lawler says. These mega-constellations could mean "we'll see a human-made pattern more than we can see the stars, for the first time in human history."

Lawler and colleagues built the simulation with data about the launch plans of four companies — SpaceX's Starlink, Amazon's Project Kuiper, OneWeb and StarNet/GW — that were filed with the U.S. Federal Communications Commission and the International Telecommunications Union. The filings detail the expected orbital heights and angles of 65,000 satellites that could be launched over the next few years.

"It's impossible to predict the future, but this is realistic," says Meredith Rawls, an astronomer at the University of Washington in Seattle. "A lot of times when people make these simulations, they pick a number out of a hat."

Satellite numbers are increasing fast. There are about 5,800 satellites in low Earth orbit now, says study coauthor Aaron Boley, an astronomer at the University of British Columbia in Vancouver. That's up from about 3,000 in 2019, he says.

The researchers computed how many satellites will be in the sky at different times of the year, at different hours of the night and from different positions on Earth's surface. Satellites' flat, smooth surfaces can reflect sunlight depending on the position in the sky. The team estimated how bright the satellites were likely to be at different hours of the day and times of the year.

Places where naked-eye stargazing will probably be most affected are at latitudes 50° N and 50° S — regions that cross lower Canada, Kazakhstan, Mongolia, much of Europe and the southern tips of Chile and Argentina. "The geometry of sunlight in the summer means there will be hundreds of visible satellites all night long," Lawler says.

Closer to the equator, where many research observatories are located, there will be a period of about three hours per night in the winter and near the time of the spring and fall equinoxes with few or no sunlit satellites visible. But there will be hundreds of sunlit satellites at dusk and dawn at these locations year-round.

Companies have been testing ways to reduce reflectivity, like shading the satellites with a visor. Other proposed strategies include limiting the satellites to lower in the sky, where they move faster across the sky and leave a fainter streak in telescope images. Such satellites would be better for astronomy, Rawls says. "They move out of the way quick."

But that lower-altitude strategy will mean more visible satellites for other parts of the world, and more that are visible to the naked eye. "There's not some magical orbital altitude that solves all our problems," Rawls says. "The only way out of this is fewer satellites."

There are no regulations concerning how bright a satellite can be or how many satellites a company can launch. Scientists are grateful that companies say they are willing to work together, but nervous that cooperation is voluntary. "We need to get some kind of regulation as soon as possible," Rawls says. Representatives from Starlink, Project Kuiper and OneWeb did not respond to requests for comment.

Efforts are under way to bring the issue to the United Nations' attention and to use existing environmental regulations to place limits on satellite launches, Boley says. Other global pollution problems, like space junk, can provide inspiration and precedents, he says. "We shouldn't just lose hope. We can do things about this." ■

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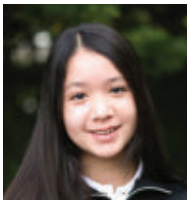

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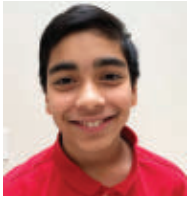

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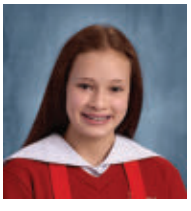

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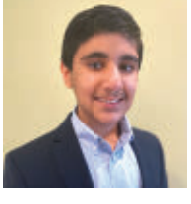

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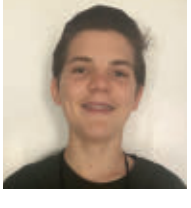

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LIFE & EVOLUTION

Baby elephants left ancient trail

Fossilized footprints in Spain may reveal an Ice Age nursery

BY SID PERKINS

Fossilized footprints found on a beach in southern Spain betray what may have been a nursery for a now extinct species of elephant.

The track-rich coastal site, which scientists have dubbed the Matalascañas Trampled Surface, is typically covered by at least 1½ meters of sand, says Clive Finlayson, an evolutionary biologist at the Gibraltar National Museum. But storm surges in the spring of 2020 washed away much of that sand and exposed the preserved footprints of elephants, cattle, deer, pigs, wolves, water birds and even Neandertals, Finlayson and colleagues report September 16 in *Scientific Reports*. The sandy-clay sediments hosting this trove of tracks were probably laid down about 106,000 years ago, previous studies suggest.

Among the tracks are the first footprints discovered of newborn straight-tusked elephants (*Palaeoloxodon antiquus*), a species that probably died out during the last ice age. The teeny footprints — which measure 9.6 centimeters from heel to toe, about the size of a drink coaster — suggest that the petite, possibly 2-month-old pachyderms stood up to about 66 centimeters tall at their shoulders and weighed as much as 70 kilograms, slightly heftier than a Newfoundland dog.

Based on previous finds elsewhere of actual bones, adult straight-tusked elephants may have weighed 5.5 metric tons for females and a whopping 13 tons for males.

The mix of elephant tracks at the site suggests that family groups including newborns, juveniles and adult females frequented the area and possibly used it as a nursery, the researchers say. Other fossils found at the site, including those preserving traces of ancient roots, hint that the area was rich in vegetation and speckled with lakes and ponds.

The findings make for "a thrilling study," says Anthony Martin, a trace fossil expert at Emory University in Atlanta who wasn't involved in the research. The series of footprints shows how the ancient elephants were moving, offers insight into their social structure and even provides a glimpse of their reproductive ecology, he says.

What's more, the presence of preserved Neandertal footprints at the site suggests that the ancient hominids foraged there and may have preyed on young elephants or scavenged dead elephants or other creatures, Martin says. The Neandertals, he adds, "probably were not foolhardy enough to take on a full-sized elephant." ■

HUMANS & SOCIETY

Stone Age tools turned hides into clothes

Discoveries in North Africa provide a rare look at how Stone Age people may have turned animal skins into clothing. Roughly 90,000- to 120,000-year-old bone tools, including hide scrapers, were unearthed in Morocco's Contrebandiers Cave, archaeologist Emily Hallett and colleagues report September 16 in *iScience*.

"Prior to major successful dispersals out of Africa and into Eurasia, *Homo sapiens* [were] making tools for various specialized functions, and those behaviors would have aided them [in] new environments," says Hallett, of the Max Planck Institute for the Science of Human History in Jena, Germany. Different types of bone tools from around the time of the new finds have been discovered at a handful of other African sites, though uses for many of those items remain unclear.

Of 62 bone tools from the Moroccan cave, seven were hide scrapers (one shown from different angles) crafted from animal ribs that were split in half lengthwise and worked into flat, spatula-like shapes. Short, deep grooves and polish on these items resulted from scraping hides, the researchers say. Patterns of stone-tool incisions on nearby jawbones and limbs of sand foxes, golden jackals and wildcats resulted from detaching skin at the paws and pulling it over the head in one piece, the scientists say.

Ancient humans could have put animal hides, presumably worked into leather or pelts, to various uses, though clothing seems especially likely, Hallett says. — *Bruce Bower*

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HUMANS & SOCIETY

Ancient DNA alters migration timeline

East Asians arrived at Indonesian islands surprisingly early

BY BRUCE BOWER

A young woman who lived on the Indonesian island of Sulawesi as early as around 7,300 years ago had a surprisingly ancient East Asian pedigree, mixed with a dash of Denisovan ancestry, a new study finds.

Researchers excavated the woman's partial skeleton from South Sulawesi's Leang Panninge cave. An analysis of her DNA shows that she was a descendent of mainly East Asian *Homo sapiens* who probably reached the tropical outpost at least 50,000 years ago, researchers report in the Aug. 26 *Nature*.

Until now, many scientists thought that skilled mariners and farmers called Austronesians first spread East Asian genes through Wallacea — a group of islands between mainland Asia and Australia that includes Sulawesi, Lombok and Flores — around 3,500 years ago.

The ancient Sulawesi woman's DNA provides the first indication that an Asian ancestry was present in Wallacea long before Austronesians, says archaeologist Adam Brumm of Griffith University in Brisbane, Australia.

Indonesian archaeologists who unearthed the skeleton — and who coauthored the new study with Brumm and other colleagues — nicknamed the young woman, who was 17 or 18 years old when she died, Besse (pronounced BESS-eh). In ethnic communities of South Sulawesi, Besse is an affectionate term for individual girls and women.

After arriving on Sulawesi, the woman's ancestors mated with Denisovans who already inhabited the island, the investigators suspect. Known mainly from ancient DNA samples, Denisovans are a group of mysterious ancient hominids who date to as early as around 300,000 years ago in Siberia and survived on nearby Papua New Guinea until as late as 30,000 to 15,000 years ago (*SN: 4/27/19, p. 15*).

The discovery of Besse shows that the peopling of Southeast Asian islands was much more complex than has typically been appreciated, says population geneticist Lluis Quintana-Murci of Collége de France and the Pasteur Institute, both in Paris. "Wallacea was probably a key habitat region for Denisovan-related groups," says Quintana-Murci, who did not participate in the research.

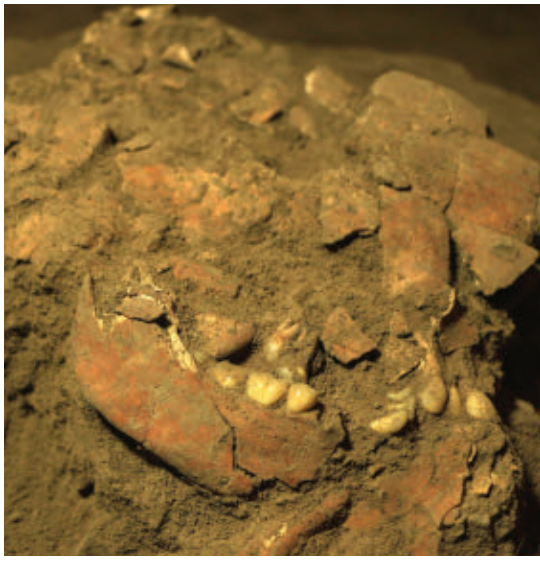
Brumm and colleagues estimate that the ancient Sulawesi woman inherited about 2.2 percent of her DNA from Denisovans. That's a bit less than some other groups in the region. Indigenous groups in the Philippines carry the highest known levels of Denisovan ancestry, topping out at about 5 percent (*SN: 9/11/21, p. 16*).

Earlier genetic evidence suggested that different Denisovan populations interbred with *H. sapiens* groups in the Philippines and on a landmass that included what's now Papua New Guinea and Australia. The Sulawesi woman's DNA indicates that interbreeding occurred in Wallacea as some Stone Age *H. sapiens* made their way toward Papua New Guinea and Australia.

"The major gene flow from Denisovans into ancestors of Papuans and Aboriginal Australians most likely took place once [*H. sapiens*] reached the Wallacea islands," says population geneticist and study coauthor Cosimo Posth of the University of Tübingen in Germany.

The woman's DNA more closely resembles that of present-day Papuans and Indigenous Australians than of any current mainland East Asians, the scientists say. Those comparisons indicate that she belonged to a previously unknown, distinct genetic line of humans that emerged around 37,000 years ago, roughly the same time as a previously estimated evolutionary split of Papuans from Indigenous Australians.

Carefully crafted stone points that had been placed in the ancient woman's grave identify her as a member of South Sulawesi's Toalean hunter-gatherer people, Brumm says. Toalean stone artifacts date to between roughly 8,000 and 1,500 years ago. Evidence of Toalean culture disappears after that.



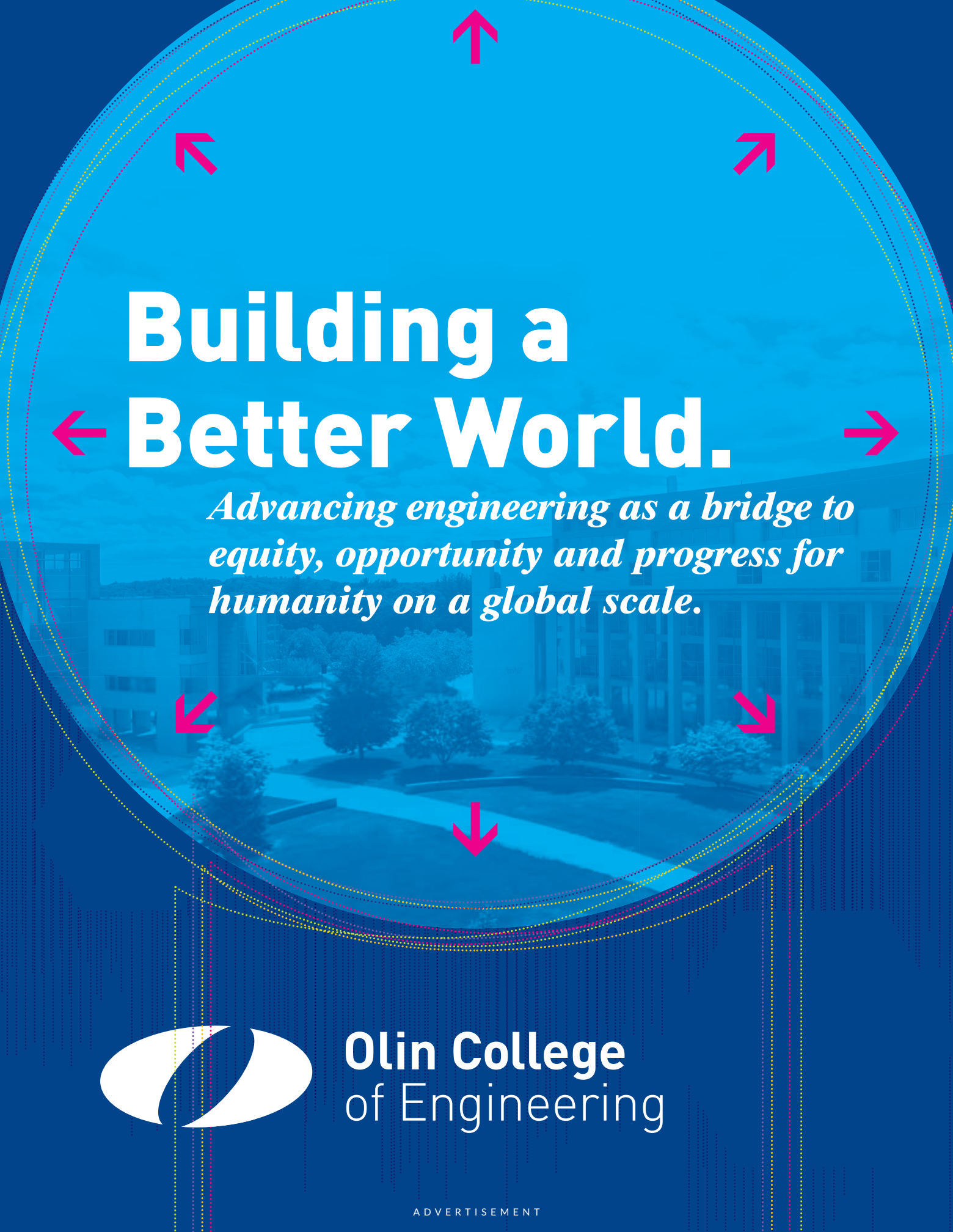
DNA from an Indonesian woman's 7,300-year-old skull (fragments shown) may help shed light on ancient human interbreeding with Denisovans on certain Southeast Asian islands.

UNIV. OF HASANUDDIN

The Indonesian coauthors of the new study excavated the ancient woman's partial skeleton from 2015 to 2018. Surviving fossils mainly came from the skull and pelvis. The team extracted DNA from a dense bone in the base of the skull that's known to preserve genetic material especially well. Fossils in tropical climates like Indonesia's rarely yield ancient DNA because the fragile genetic material doesn't typically survive those conditions.

Radiocarbon dating of a burned seed from a common Southeast Asian tree, which was found near the skeleton, provided an age estimate of between around 7,300 and 7,200 years.

It's not known if ancestors of Besse created previously discovered Sulawesi rock art of a pig that dates to at least 45,500 years ago, one of the oldest known artistic depictions of a real-world organism (*SN: 2/13/21, p. 32*). So the artists of that work remain a mystery, for now. ■



EARTH & ENVIRONMENT

AI helps predict sea ice losses

IceNet accurately forecasts Arctic ice months in advance

BY GLORIA DICKIE

On September 16, the sea ice floating atop the Arctic Ocean shrank to its lowest extent of the year, as summer-warmed waters ate away at the ice's edges.

This year's minimum was the Arctic's 12th-lowest sea ice extent since satellite record keeping began in 1979. It's an unexpected finish considering that in early summer, sea ice hit a record low for that time of year.

The surprise comes in part because, though the best current statistical- and physics-based forecasting tools can closely predict sea ice extent a few weeks in advance, the accuracy of long-range forecasts falters. A new tool that uses artificial intelligence promises to boost accuracy, researchers report August 26 in *Nature Communications*.

IceNet is "95 percent accurate in forecasting sea ice two months ahead — higher than the leading physics-based model SEAS5 — while running 2,000 times faster," says Tom Andersson, a data scientist at the British Antarctic Survey's Artificial Intelligence Lab.

Whereas SEAS5 takes about six hours on a supercomputer to produce a forecast, IceNet can do the same in less than 10 seconds on a laptop. The system also shows a surprising ability to predict anomalous ice events — unusual highs or lows — up to four months in advance.

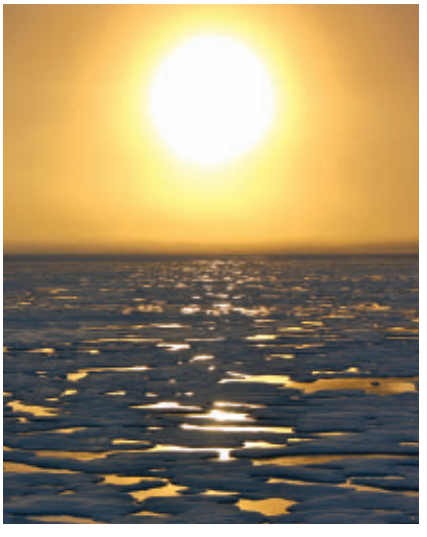
Tracking sea ice is crucial to keeping tabs on climate change's impacts. While that's more of a long game, the advanced notice provided by IceNet could have more immediate benefits too. It could give the lead time needed to plan for risks of Arctic fires or wildlife-human conflicts, and provide data that Indigenous communities need to make economic and environmental decisions.

Existing forecast tools put the laws of physics into computer code to predict how sea ice will change. But partly due to uncertainties in scientists' understanding of the physical systems governing the ice, these models struggle to produce accurate long-range forecasts. "Forecasting sea ice is really hard because sea ice interacts in complex ways with the atmosphere above and ocean below," Andersson says.

To create IceNet, Andersson and colleagues used a method called deep learning. Observational sea ice data from 1979 to 2011 and climate simulations covering 1850 to 2100 were loaded into the algorithm to train IceNet how to predict the state of future sea ice by processing data from the past. The team compared IceNet's outputs with the observed sea ice extent from 2012 to 2020, and with forecasts made by SEAS5. IceNet was as much as 2.9 percent more accurate than SEAS5, corresponding to an additional 360,000 square kilometers of ocean being correctly labeled as "ice" or "no ice."

What's more, in 2012, a sudden crash in summer sea ice extent heralded a new annual record low in September of that year. In running through past data, IceNet saw the dip coming months in advance. SEAS5 had inklings too but its projections that far out were off by a few hundred thousand square kilometers.

Andersson says it's possible that IceNet has better learned the physical processes that determine the evolution of sea ice from the training data while physics-based models still struggle to understand this information.



Forecasting summer sea ice, seen here in the Chukchi Sea near Alaska, is a challenge.

KATHRYN HANSEN/NASA

"These machine learning techniques have only begun contributing to [forecasting] in the last couple years, and they've been doing amazingly well," says Uma Bhatt, an atmospheric scientist at the University of Alaska Fairbanks.

Bhatt says that good seasonal ice forecasts are important for assessing the risk of wildfires in the Arctic, which are tied strongly to the presence of sea ice. "Knowing where the sea ice is going to be in the spring could potentially help you figure out where you're likely to have fires — in Siberia, for example, as soon as the sea ice moves away from the shore, the land can warm up very quickly and help set the stage for a bad fire season."

Any forecasting improvement can also help economic, safety and environmental planning in northern and Indigenous communities. For example, tens of thousands of walruses haul out on land to rest when the sea ice disappears. Human disturbances can trigger deadly stampedes and lead to many walrus deaths. With seasonal forecasts, biologists can anticipate rapid ice loss and manage haul-out sites.

Still, limitations remain. At four months of lead time, IceNet was about 91 percent accurate in predicting September's ice edge. Increasing accuracy of summer forecasts made early in the year is difficult, in part, due to what's called the "spring predictability barrier." It's crucial to know the sea ice's condition at the start of the spring melting season to be able to forecast end-of-summer conditions.

Another limit is "that the weather is so variable," says Mark Serreze, director of the National Snow and Ice Data Center in Boulder, Colo. Though sea ice seemed primed to set a new annual record low at the start of July, the speed of ice loss ultimately slowed due to cool atmospheric temperatures. "We know that sea ice responds very strongly to summer weather patterns, but we can't get good weather predictions. Weather predictability is about 10 days in advance." Until long-term weather forecasts improve, there will be limits on sea ice forecasts. ■

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HUMANS & SOCIETY

Young infants laugh like chimps

As babies age, giggles start to sound more like those of adults

BY CAROLYN WILKE

A few months after birth, babies may laugh like some apes before transitioning to chuckling more like human adults, a study finds.

Human adults tend to laugh while exhaling, but chimpanzees mainly laugh in two ways. One is like panting, with sound produced on both in and out breaths, and the other has outbursts occurring on exhales, like human adults.

Less is known about how babies laugh. So Mariska Kret, a cognitive psychologist at Leiden University in the Netherlands, and colleagues scoured the internet for videos with laughing 3- to 18-month-olds, and asked 15 speech specialists and hundreds of novices to judge the laughs.

After evaluating dozens of audio clips, experts and about 100 nonexperts both found that younger infants laughed during inhalation and exhalation, while older infants laughed more on the exhale. That finding suggests that laughter becomes less apelike with age, the researchers report in the September *Biology Letters*.

Babies' maturing vocal tracts and their social interactions may influence the development of the sounds, the researchers say.

A second trial with different audio clips and a new group of 100 novices also found that older infants laughed more on exhales. Participants in both trials reported that the more adultlike laughs were more pleasing to hear, as well as contagious. That finding suggests that the shift in laughter may partly happen due to subconscious affirmations from parents, Kret says. In general, laughs during exhalation are clearer and louder than during inhalation, she says, sending a stronger signal that may be better for bonding.

The idea that social interactions shape babies' laughs matches observations from chimps, says Marina Davila Ross, a comparative psychologist at the University of Portsmouth in England. Davila Ross has found that among chimps in different social groups, laughs can have somewhat different sounds and social functions. Humans and chimps alike adjust their laughs based on peer feedback, she says.

Still, the small number of audio clips analyzed makes discerning trends hard, says D. Kimbrough Oller, a theoretical biologist at the University of Memphis in Tennessee. All together, listeners in the trials heard 108 clips, with each one lasting four to seven seconds. The intense examples in this study probably aren't all that representative, he says. All-day recordings suggest babies rarely laugh. So scientists should listen to babies for longer periods of time to better understand the range of early laughter, he says.

Reading into laughter's pleasantness may also be problematic, says Carolyn McGettigan, a cognitive neuroscientist at University College London. What people rate as enjoyable may relate to how they perceive kids' ages. Individuals who think toddlers are more fun than young infants may enjoy older infants' laughs more.

Still, the research provides a good starting place, she says. "Studying these kinds of infant vocal behaviors gives us this window into the evolution of what we can do with our voices." ■

RYAN GARRETT

LIFE & EVOLUTION

Metal gives ant jaws an edge

It may seem incredible that something as small as a biting insect can so easily slice human skin. Now, a study published September 1 in *Scientific Reports* shows how some ant jaws form extremely sharp cutting edges.

Researchers used a microscope to examine the "teeth" that line the jaws of leaf-cutter ants called *Atta cephalotes* (one shown). These teeth naturally contain the metal zinc. The team discovered that zinc atoms are dispersed homogeneously, not in chunks, throughout a single tooth. This uniformity allows the ants to grow thin, sharp blades, the researchers say. The team also estimates that zinc-infused teeth allow a leaf-cutter ant to puncture and cut using only about 60 percent of the energy and muscle mass it would otherwise require. By having sharp, precisely sculpted tools, ants and other small animals can make up for their tiny muscles. — *Jake Buehler*

Listen to how baby laughs change over time at **bit.ly/SN_laugh**

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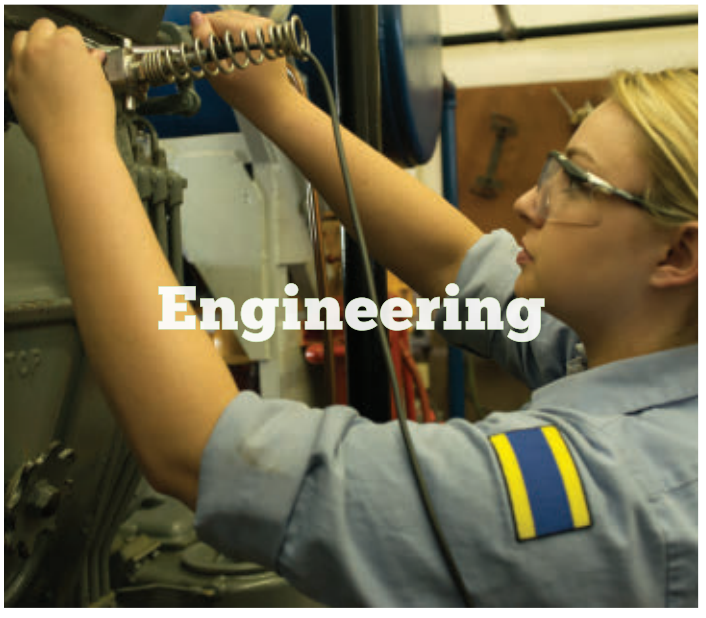

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EARTH & ENVIRONMENT

Cows use stalls when nature calls

Capturing cattle urine could reduce pollution, scientists say

BY MARIA TEMMING

You can lead a cow to a water closet, but can you make it pee there? It turns out that yes, you can.

Researchers successfully trained cows to use a small, fenced-in area with artificial turf flooring as a bathroom stall. Setups like this could allow farms to easily capture and treat cow urine, which often pollutes air, soil and water, researchers report in the Sept. 13 *Current Biology*. Components of that urine, such as nitrogen and phosphorus, could also be used to make fertilizer (*SN: 4/10/21, p. 29*).

The average cow can urinate up to tens of liters per day, and there are some 1 billion cattle worldwide. In barns, cow urine typically mixes with feces on the floor to create a slurry that emits the air pollutant ammonia. Out in pastures, cow urine can leach into nearby waterways and release the potent greenhouse gas nitrous oxide.

"I'm always of the mind, how can we get animals to help us in their management?" says Lindsay Matthews, a self-described cow psychologist who studies animal behavior at the University of Auckland in New Zealand. Matthews and colleagues set out to potty train 16 calves, which had the free time to learn a new skill. "They're not so involved with milking and other systems," he says. "They're basically just hanging out, eating a bit of food, socializing and resting."

Matthews was optimistic about the cows' potty training prospects. "I was convinced that we could do it," he says. Cows "are much, much smarter than people give them credit for." Each calf got 45 minutes per day of what the researchers call "MooLoo training." At first, the team enclosed the calves inside the makeshift bathroom stall and fed the animals a treat every time they urinated.

Once the calves made the connection between using the bathroom stall and receiving a treat, the researchers positioned the calves in a hallway leading to the stall. Whenever animals visited the little cows' room, they got a treat; whenever calves urinated in the hallway, the team spritzed them with water. Within 10 days, 11 of the 16 calves were potty trained, Matthews says. The remaining cows "are probably trainable too," he adds. "It's just that we didn't have enough time."

Lindsay Whistance, a livestock researcher at the Organic Research Centre in Cirencester, England, is "not surprised by the results." With proper training and motivation, "I fully expected cattle to be able to learn this task," says Whistance, who was not involved in the study. The practicality of potty training cows on a large scale, she says, is another matter.

For MooLoo training to become a widespread practice, "it has to be automated," Matthews says. "We want to develop automated training systems, automated reward systems." Those systems are still far from reality, but Matthews and colleagues hope they could have big impacts. If 80 percent of cow urine were collected in latrines, for instance, that could cut associated ammonia emissions in half, previous research suggests.

"It's those ammonia emissions that are key to the real environmental benefit, as well as potential for reducing water contamination," says Jason Hill, a biosystems engineer at the University of Minnesota in St. Paul who was not involved in the work. "Ammonia from cattle is a major contributor to reduced human health," he says. So potty training cattle could help create cleaner air as well as a cleaner, more comfortable living space for cows themselves. ■

Scientists trained 11 calves (one shown) to use a latrine when they need to urinate. Potty training cattle on a large scale may help curb ammonia emissions.

FBN (CC BY-SA)

2–20

Number of times per day a cow typically urinates

15

liters

How much a typical cow urinates per day

SOURCE: A. VAUGHAN *ET AL/APPLIED ANIMAL BEHAVIOUR SCIENCE* 2014

Watch a video of a calf using a latrine at **bit.ly/SN_MooLoo**

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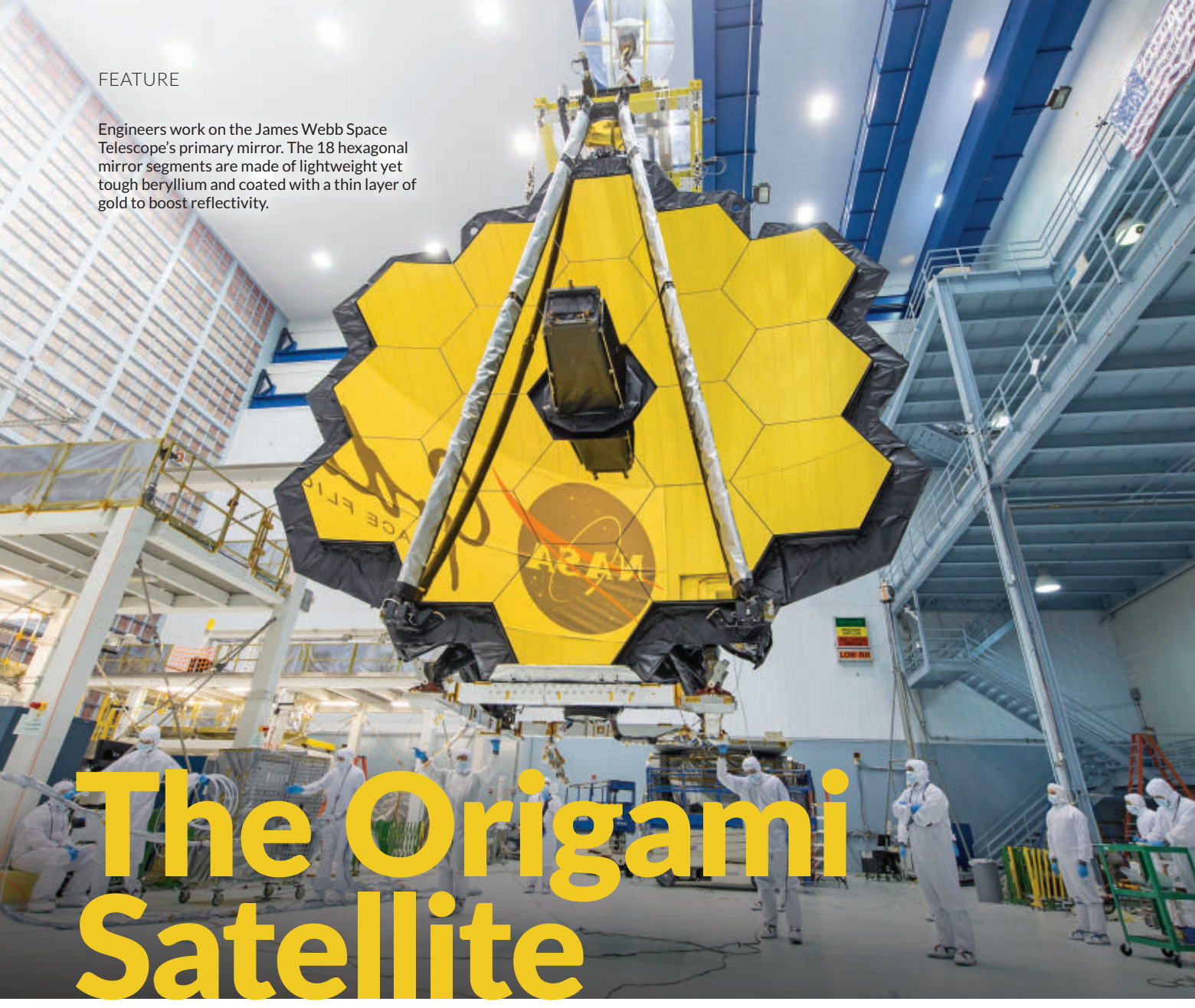


Engineers work on the James Webb Space Telescope's primary mirror. The 18 hexagonal mirror segments are made of lightweight yet tough beryllium and coated with a thin layer of gold to boost reflectivity.

DESIREE STOVER/NASA

The Origami Satellite

Amid high expectations, the James Webb Space Telescope is finally ready to explore the distant universe

By Lisa Grossman

The James Webb Space Telescope has been a long time coming. When it launches later this year, the observatory will be the largest and most complex telescope ever sent into orbit. Scientists have been drafting and redrafting their dreams and plans for this unique tool since 1989.

The mission was originally scheduled to launch between 2007 and 2011, but a series of budget and technical issues pushed its start date back more than a decade. Remarkably, the core design of the telescope hasn't changed much. But the science that it can dig into has. In the years of waiting for Webb to be ready, big scientific questions have emerged. When Webb was an early glimmer in astronomers' eyes, cosmological revolutions like the discoveries of dark energy and planets orbiting stars outside our solar system hadn't yet happened.

"It's been over 25 years," says cosmologist Wendy Freedman of the University of Chicago. "But I think it was really worth the wait."

An audacious plan

Webb has a distinctive design. Most space telescopes house a single lens or mirror within a tube that blocks sunlight from swamping the dim lights of the cosmos. But Webb's massive 6.5-meter-wide mirror and its scientific instruments are exposed to the vacuum of space. A multilayered shield the size of a tennis court will block light from the sun, Earth and moon.

For the awkward shape to fit on a rocket, Webb will launch folded up, then unfurl itself in space (see Page 29, What could go wrong?).

"They call this the origami satellite," says astronomer Scott Friedman of the Space Telescope Science Institute, or STScI, in Baltimore. Friedman is in charge of Webb's postlaunch choreography. "Webb is different from any other telescope that's flown."

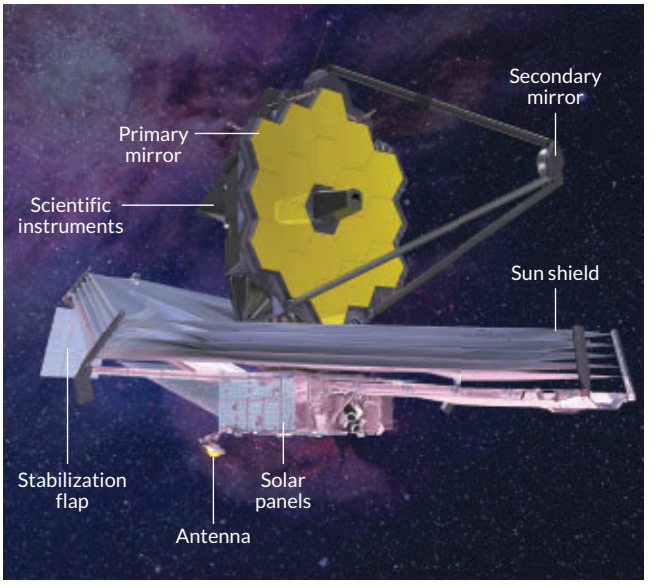
Its basic design hasn't changed in more than 25 years. The telescope was first proposed in September 1989 at a workshop held at STScI, which also runs the Hubble Space Telescope.

At the time, Hubble was less than a year from launching, and was expected to function for only 15 years. Thirty-one years after its launch, the telescope is still going strong, despite a series of computer glitches and gyroscope failures (*SN Online: 10/10/18*).

The institute director at the time, Riccardo Giacconi, was concerned that the next major mission would take longer than 15 years to get off the ground. So he and others proposed that NASA investigate a possible successor to Hubble: a space telescope with a 10-meter-wide primary mirror that was sensitive to light in infrared wavelengths to complement Hubble's range of ultraviolet, visible and near-infrared.

Infrared light has a longer wavelength than light that is visible to human eyes. But it's perfect for a telescope to look back in time. Because light travels at a fixed speed, looking at distant objects in the universe means seeing them as they looked in the past. The universe is expanding, so that light is stretched before it reaches our telescopes. For the most distant objects in the universe — the first galaxies to clump together, or the first stars to burn in those galaxies — light that was originally emitted in shorter wavelengths is stretched all the way to the infrared.

Giacconi and his collaborators dreamed of a telescope that would detect that stretched light from the earliest galaxies. When Hubble started sharing its views of the early universe, the dream solidified into a science plan. The galaxies Hubble saw at great distances "looked different from what people were expecting," says astronomer Massimo Stiavelli, a leader of the James Webb Space Telescope project who has been at STScI since 1995. "People started thinking that there is interesting science here."



A novel design Once all is unfolded, the James Webb Space Telescope's sun shield will span the length of a tennis court to protect the main and secondary mirrors from the sun, moon and Earth's light and heat. The solar panels, exposed to the sun, will convert light to electricity to power the instruments. Webb's antenna will keep it communicating with scientists on Earth, sending data from the scientific instruments. The stabilization flap keeps the machine from veering off course.

In 1995, STScI and NASA commissioned a report to design Hubble's successor. The report, led by astronomer Alan Dressler of the Carnegie Observatories in Pasadena, Calif., suggested an infrared space observatory with a 4-meter-wide mirror.

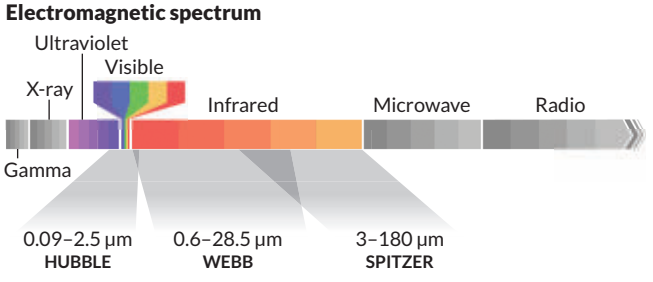
The bigger a telescope's mirror, the more light it can collect, and the farther it can see. Four meters wasn't that much larger than Hubble's 2.4-meter-wide mirror, but anything bigger would be difficult to launch.

Dressler briefed then-NASA Administrator Dan Goldin in late 1995. In January 1996 at the American Astronomical Society's annual meeting, Goldin challenged the scientists to be more ambitious. He called out Dressler by name, saying, "Why do you ask for such a modest thing? Why not go after six or seven meters?" (Still nowhere near Giacconi's pie-in-the-sky 10-meter wish.) The speech received a standing ovation.

Six meters was a larger mirror than had ever flown in space, and larger than would fit in available launch vehicles. Scientists would have to design a telescope mirror that could fold, then deploy once it reached space.

The telescope would also need to cool itself passively by radiating heat into space. It needed a sun shield — a big one. The origami telescope was born. It was dubbed James Webb in 2002 for NASA's administrator from 1961 to 1968, who fought to support research to boost understanding of the universe in the increasingly human-focused space program. (In response to a May petition to change the name, NASA is investigating allegations that James Webb persecuted

Mixed views Webb will observe the universe in wavelengths that are mostly longer than what humans can see (0.38 to 0.7 micrometers) and what the Hubble Space Telescope can observe, yet shorter than most of the Spitzer Space Telescope's range. This infrared view lets telescopes observe farther and see through dust clouds. SOURCE: NASA, J. OLMSTED/STSCI



FROM TOP: NORTHROP GRUMMAN; C. CHANG

gay and lesbian people during his government career.)

Goldin's motto at NASA was "Faster, better, cheaper." Bigger was better for Webb, but it sure wasn't faster — or cheaper. By late 2010, the project was more than $1.4 billion over its $5.1 billion budget (*SN: 4/9/11, p. 22*). And it was going to take another five years to be ready. Today, the cost is estimated at almost $10 billion.

The telescope survived a near-cancellation by Congress, and its timeline was reset for an October 2018 launch. But in 2017, the launch was pushed to June 2019. Two more delays in 2018 pushed the takeoff to May 2020, then to March 2021. Some of those delays were because assembling and testing the spacecraft took longer than NASA expected.

Other slowdowns were because of human errors, like using the wrong cleaning solvent, which damaged valves in the propulsion system. Recent shutdowns due to the coronavirus pandemic pushed the launch back a few more months.

"I don't think we ever imagined it would be this long," says University of Chicago's Freedman, who worked on the Dressler report. But there's one silver lining: Science marched on.

The age conflict

The first science goal listed in the Dressler report was "the detailed study of the birth and evolution of normal galaxies such as the Milky Way." That is still the dream, partly because it's such an ambitious goal, Stiavelli says.

"We wanted a science rationale that would resist the test of time," he says. "We didn't want to build a mission that would do something that gets done in some other way before you're done."

Webb will peek at galaxies and stars as they were just 400 million years after the Big Bang, which astronomers think is the epoch when the first tiny galaxies began making the universe transparent to light by stripping electrons from cosmic hydrogen.

But in the 1990s, astronomers had a problem: There didn't seem to be enough time in the universe to make galaxies much earlier than the ones astronomers had already seen. The standard cosmology at the time suggested the universe was 8 billion or 9 billion years old, but there were stars in the Milky Way that seemed to be about 14 billion years old.

"There was this age conflict that reared its head," Freedman says. "You can't have a universe that's younger than the oldest stars. The way people put it was, 'You can't be older than your grandmother!' "

In 1998, two teams of cosmologists showed that the universe is expanding at an ever-increasing rate. A mysterious substance dubbed dark energy may be pushing the universe to expand faster and faster. That accelerated expansion means the universe is older than astronomers previously thought — the current estimate is about 13.8 billion years old.

"That resolved the age conflict," Freedman says. "The discovery of dark energy changed everything." And it expanded Webb's to-do list.

Dark energy

Top of the list is getting to the bottom of a mismatch in cosmic measurements. Since at least 2014, different methods for measuring the universe's rate of expansion — called the Hubble constant — have been giving different answers. Freedman calls the issue "the most important problem in cosmology today."

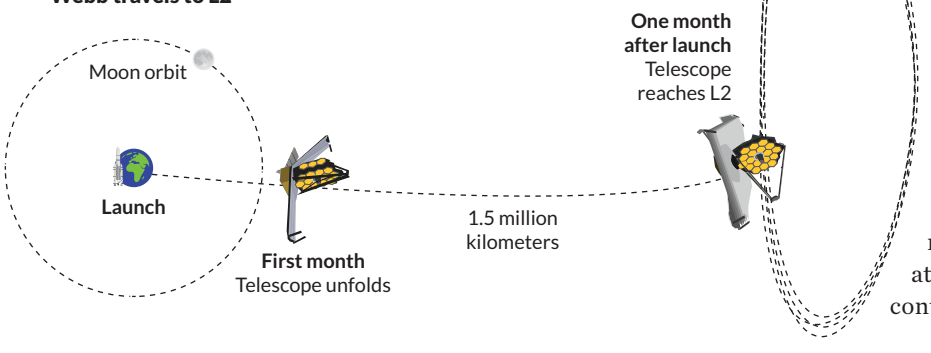
The question, Freedman says, is whether the mismatch is real. A real mismatch could indicate something profound about the nature of dark energy and the history of the universe. But the discrepancy could just be due to measurement errors.

Webb can help settle the debate. One common way to determine the Hubble constant is by measuring the distances and speeds of far-off galaxies. Measuring cosmic distances is difficult, but astronomers can estimate them using objects of known brightness, called standard candles. If you know the object's actual brightness, you can calculate its distance based on how bright it seems from Earth.

Studies using supernovas and variable stars called Cepheids as candles have found an expansion rate of 74.0 kilometers per second for approximately every 3 million light-years, or megaparsec, of distance between objects. But using red giant stars, Freedman and colleagues have gotten a smaller answer: 69.8 km/s/Mpc.

Other studies have measured the Hubble constant by looking at the dim glow of light emitted just 380,000 years after the Big Bang, called the cosmic microwave background. Calculations based on that glow give a smaller rate still: 67.4 km/s/Mpc. Although these numbers may seem close, the fact that they disagree at all could alter our understanding of the contents of the universe and how it evolves

Getting there Webb will orbit the sun from a stable point in space called L2, 1.5 million kilometers from Earth. The telescope will spend its first month after launch getting to this point and unfolding its sun shield and mirrors. The sun shield will face Earth and the sun at all times, keeping their light and heat away from the telescope's sensitive instruments. Once at L2, the telescope will spend another five months turning on and testing its scientific instruments before collecting data.



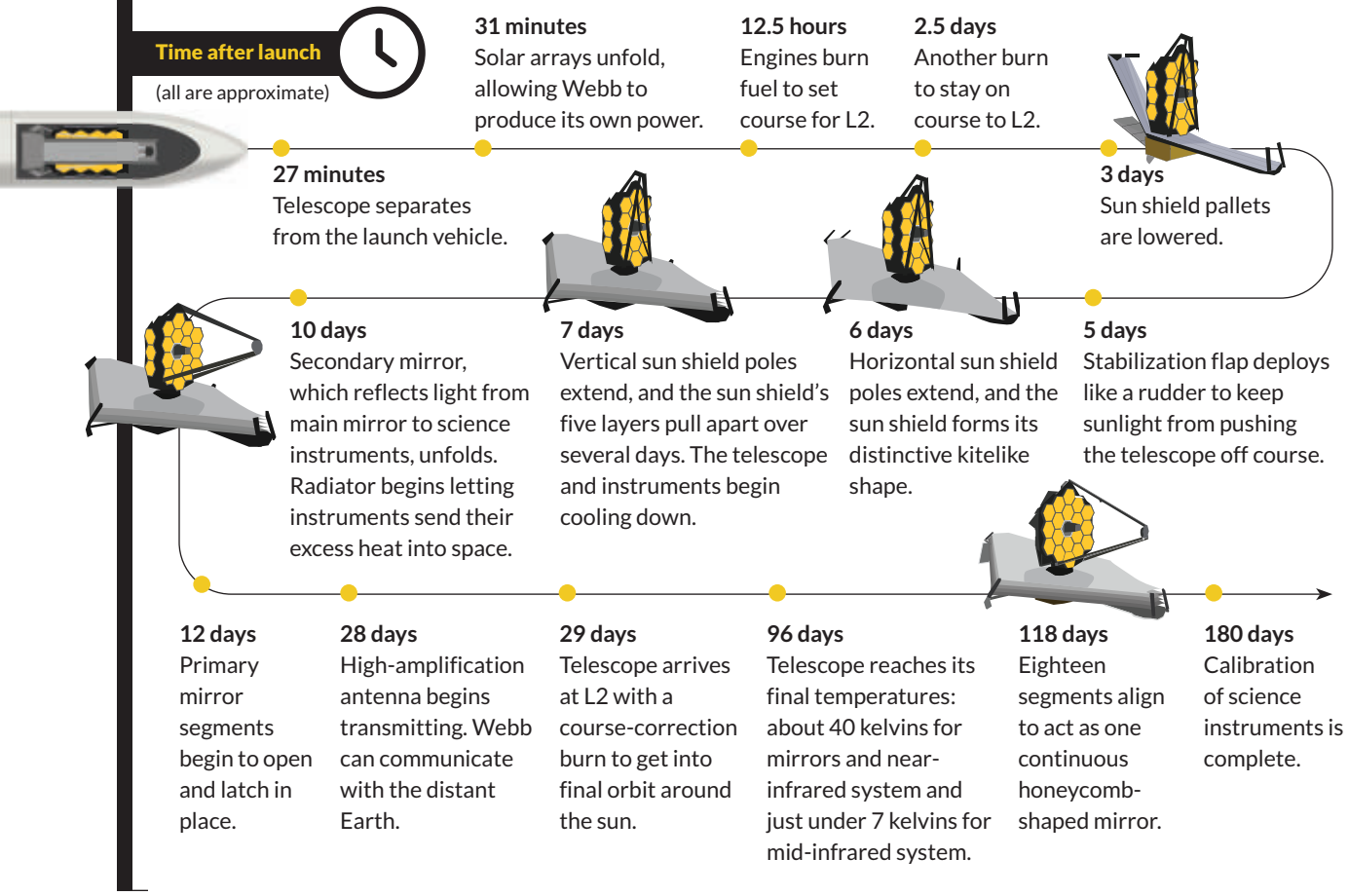
ESA

What could go wrong?

For the James Webb Space Telescope, getting into space is just step one. The telescope must complete a complicated series of unfolding steps before it can observe the cosmos. The entire sequence, including getting the science instruments ready, will take about six months.

"A lot has to go right, that's for sure," says astronomer Scott Friedman of the Space Telescope Science Institute in Baltimore, who is in charge of this timeline. Webb will be heading to a point in space called L2, which is too far from Earth for astronauts to visit and make repairs. "There's every reason to believe things will go very well," Friedman says. "But we won't know until we get there."

Here's a timeline of what has to go right (all times are approximate).



ESA

over time. The discrepancy has been called a crisis in cosmology (*SN: 9/14/19, p. 22*).

In its first year, Webb will observe some of the same galaxies used in the supernova studies, using three different objects as candles: Cepheids, red giants and peculiar stars called carbon stars.

The telescope will also try to measure the Hubble constant using a distant gravitationally lensed galaxy. Comparing those measurements with each other and with similar ones from Hubble will show if earlier measurements were just wrong, or if the tension between measurements is real, Freedman says.

Without these new observations, "we were just going to argue about the same things forever," she says. "We just need better data. And [Webb] is poised to deliver it."

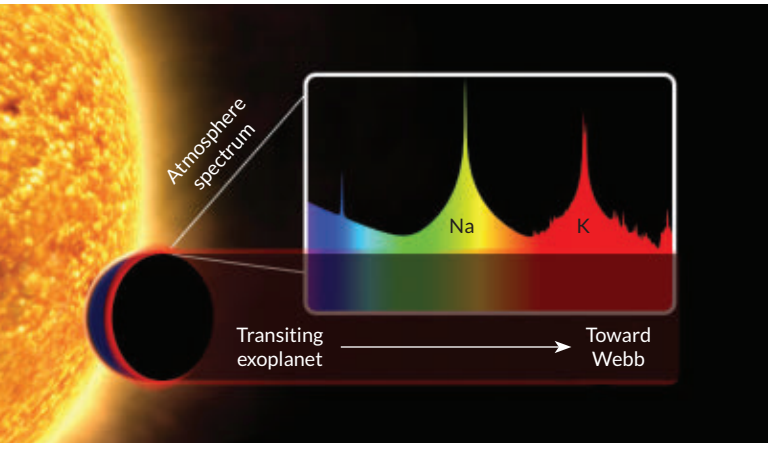
Exoplanets

Perhaps the biggest change for Webb science has been the rise of the field of exoplanet explorations.

"When this was proposed, exoplanets were scarcely a thing," says STScI's Friedman. "And now, of course, it's one of the hottest topics in all of science, especially all of astronomy."

The Dressler report's second major goal for Hubble's successor was "the detection of Earthlike planets around other stars and the search for evidence of life on them." But back in 1995, only a handful of planets orbiting other sunlike stars were even known, and all of them were scorching-hot gas giants — nothing like Earth at all.

Since then, astronomers have discovered thousands of exoplanets orbiting distant stars. Scientists now estimate that,



Transit advantages Webb will measure the composition of exoplanet atmospheres by looking at the light from the planet's host star as the planet crosses in front of the star. Atoms and molecules in the atmosphere, such as sodium (Na) and potassium (K), absorb certain wavelengths of the starlight, leaving a unique fingerprint in the spectrum of light that reaches Webb's detectors.

on average, there is at least one planet for every star we see in the sky. And some of the planets are small and rocky, with the right temperatures to support liquid water, and maybe life.

Most of the known planets were discovered as they crossed, or transited, in front of their parent stars, blocking a little bit of the parent star's light. Astronomers soon realized that, if those planets have atmospheres, a sensitive telescope could effectively sniff the air by examining the starlight that filters through the atmosphere.

The infrared Spitzer Space Telescope, which launched in 2003, and Hubble have started this work. But Spitzer ran out of coolant in 2009, keeping it too warm to measure important molecules in exoplanet atmospheres. And Hubble is not sensitive to some of the most interesting wavelengths of light — the ones that could reveal alien life-forms.

That's where Webb is going to shine. If Hubble is peeking through a crack in a door, Webb will throw the door wide open, says exoplanet scientist Nikole Lewis of Cornell University. Crucially, Webb, unlike Hubble, will be particularly sensitive to several carbon-bearing molecules in exoplanet atmospheres that might be signs of life.

"Hubble can't tell us anything really about carbon, carbon monoxide, carbon dioxide, methane," she says.

If Webb had launched in 2007, it could have missed this whole field. Even though the first transiting exoplanet was discovered in 1999, their numbers were low for the next decade.

Lewis remembers thinking, when she started grad school in 2007, that she could make a computer model of all the transiting exoplanets. "Because there were literally only 25," she says.

Between 2009 and 2018, NASA's Kepler space telescope raked in transiting planets by the thousands. But those planets were too dim and distant for Webb to probe their atmospheres.

So the down-to-the-wire delays of the last few years have actually been good for exoplanet research, Lewis says. "The launch delays were one of the best things that's happened for exoplanet science with Webb," she says. "Full stop."

That's mainly thanks to NASA's Transiting Exoplanet Survey Satellite, or TESS, which launched in April 2018. TESS' job is to find planets orbiting the brightest, nearest stars, which will give Webb the best shot at detecting interesting molecules in planetary atmospheres.

If it had launched in 2018, Webb would have had to wait a few years for TESS to pick out the best targets. Now, it can get started on those worlds right away. Webb's first year of observations will include probing several known exoplanets that have been hailed as possible places to find life. Scientists will survey planets orbiting small, cool stars called M dwarfs to make sure such planets even have atmospheres, a question that has been hotly debated.

If a sign of life does show up on any of these planets, that result will be fiercely debated, too, Lewis says. "There will be a huge kerfuffle in the literature when that comes up." It will be hard to compare planets orbiting M dwarfs with Earth, because these planets and their stars are so different from ours. Still, "let's look and see what we find," she says.

A limited lifetime

With its components assembled, tested and folded at Northrop Grumman's facilities in California, Webb is on its way by boat through the Panama Canal, ready to launch in an Ariane 5 rocket from French Guiana. The most recent launch date is set for December 18.

For the scientists who have been working on Webb for decades, this is a nostalgic moment.

"You start to relate to the folks who built the pyramids," Stiavelli says.

Other scientists, who grew up in a world where Webb was always on the horizon, are already thinking about the next big thing.

"I'm pretty sure, barring epic disaster, that [Webb] will carry my career through the next decade," Lewis says. "But I have to think about what I'll do in the *next* decade" after that.

Unlike Hubble, which has lasted decades thanks to fixes by astronauts and upgrade missions, Webb has a strictly limited lifetime. Orbiting the sun at a gravitationally fixed point called L2, Webb will be too far from Earth to repair, and will need to burn small amounts of fuel to stay in position. The fuel will last for at least five years, and hopefully as much as 10. But when the fuel runs out, Webb is finished. The telescope operators will move it into retirement in an out-of-the-way orbit around the sun, and bid it farewell. ■

Explore more

- Space Telescope Science Institute. "General Observer Programs in Cycle 1." bit.ly/WebbObserverCycle1
- Alan Dressler *et al*. "Exploration and the search for origins: A vision for ultraviolet-optical-infrared space astronomy." Report of the "HST & Beyond" Committee. May 15, 1996.

ESO, DAVID SING

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KATTY HUERTAS

The SN 10 *Times of change*

We ask how recent events have refocused our Scientists to Watch

Each year since 2015, *Science News* has featured the work of outstanding early- and mid-career scientists in our SN 10: Scientists to Watch list. They're nominated by Nobel laureates and members of the National Academy of Sciences, and are recognized because of their curiosity, passion, determination and, of course, their discoveries.

But we decided that 2021 begs for something different. The coronavirus pandemic continues to rage worldwide, with its burdens falling hardest on those least able to bear them — inequities already on our minds due to Black Lives Matter, #MeToo and other social movements. At the same time, we're learning that the window to reverse some of climate change's most devastating effects is closing fast (*SN: 9/11/21, p. 8*). With all the upheaval, we wondered: How do these extraordinary times change a scientist's work?

Here, we catch up with 10 noteworthy Scientists to Watch alumni. Emily Fischer, who studies wildfire smoke, has faced the threat of fires firsthand, cognitive neuroscientist Jessica Cantlon is fighting sexual harassment in the sciences and economist Parag Pathak is taking his efforts to make institutions more equitable from schools to hospitals. Other scientists reveal how their work has gained new urgency and meaning for them. The interviews that follow have been edited for length and clarity. — *Elizabeth Quill*

Speaking out for women in science

Jessica Cantlon, featured in 2016, studies the evolution and development of complex mathematical thinking, including the traits that set humans apart from other primates (*SN: 10/1/16, p. 18*). In 2017, she was recognized as a *Time* Person of the Year, as a "silence breaker" speaking out against sexual harassment during the height of the #MeToo movement.

JESSICA CANTLON

Cognitive neuroscientist
Carnegie Mellon University

What has been the most notable progress in your research since 2016?

We've expanded our repertoire to compare people across different cultures, who have different educational practices. We've been going to Bolivia to work with this group of people called the Tsimane, who live in rural parts of the Amazon forest. They don't have the rigid, formal schooling where kids go through these particular curricula to achieve mathematical cognition. Instead, education there is more organic and more deeply connected to their way of life. That allows us to try to understand what effect does a particular type of education have on numerical thinking.

There was one study that we did, comparing species — nonhuman primates and humans — to understand the evolution of these concepts. Across all species and stages of development and cultural groups, there's this bias that when you're looking at a set of objects, and you're trying to quantify it, you think about that set numerically. And you don't have to; you can think about that set of objects spatially, as an amount of stuff, you can think about how much surface area is there, or the perimeter around it. But primates, including humans, [tend to] think about that set as a set of discrete objects, and count them up.

What is something that excites you right now in your work?

We've looked at the similarities and differences between boys and girls as their brains develop. We've done some of the first, early studies comparing children's brains that can truly allow us to collect evidence on the trajectory of similarity between boys and girls.... We've shown that very early in development, between around 3 and 8 years of age, there's evidence during mathematical processing that most of the brain — over 95 percent — shows functional similarity in that processing between boys and girls.

But as we know, much later on in development, we see a severe underrepresentation of girls in mathematics-related fields. What's happening? There's evidence in the field ... that what happens in late childhood and adolescence is that children's interests are shaped culturally.

What are some of the greatest challenges you've faced since 2016?

In 2016, [some of my colleagues at the University of Rochester and I] filed a sexual harassment complaint against a faculty member in our department who was sexually harassing women — undergraduate and graduate students and faculty. It became this situation that hijacked my career for a number of years.... We went public with our complaint, partly to protect ourselves, but also partly to let people know at other universities that this kind of thing is happening to students, and it's affecting women's career paths in ways that are discriminatory and unequal.

Ultimately, it was really important. Our complaint went public in September of 2017. In October 2017, the Harvey Weinstein story came out in the *New York Times*, and that kicked off a series of reactions that ultimately culminated in millions of people saying #MeToo, which I think was really powerful and important, and was something that we got to be a part of.

I've had dozens of women reach out to me for advice, about how to file a complaint at their university, how to take legal action, if that's what they're thinking, what the risks and benefits are. And so, part of my career now — and I'm excited by it, and I think it's really important work — is to be an advocate for women who are experiencing discrimination and harassment at universities.

One response that we thought was really great was that the National Academies of Sciences, Engineering and Medicine did a full study on sexual harassment in the sciences.... It has a lot of ideas about what might effect larger-scale change.
— Interview by Aina Abell

CARNEGIE MELLON UNIV.

From fair schools to vaccine distribution

Parag Pathak, featured in 2019, strives to make public education more equitable (*SN: 10/12/19 & 10/26/19, p. 38*). He has used data and algorithms to overhaul school choice systems in Boston, New York and other U.S. cities. Now he's applying his research to the question of how to equitably distribute vaccines and other medical resources.

PARAG PATHAK

Economist
MIT

What's the most notable progress in your work since 2019?

Since we last talked, I released a paper on the effects of universal preschool. A lot of people are interested right now because [universal preschool, which is open to everyone with no income rule,] is part of the White House's agenda. Because of the work we had done with Boston with their school choice algorithm over the years, we had some files on school admissions going back to the late 1990s. Boston was a leader nationwide in expanding slots for children in preschool. But, like many cities, there weren't enough slots for demand, so they had to ration. And that's where the lotteries come in.

Fast forward to now. We linked these applicant cohorts to standardized test scores and educational outcomes all the way into college. And what we found was pretty exciting: Those who won the [preschool] lottery are more likely to graduate high school, they score higher on SATs and they're more likely to enroll in college. Boston has continued to refine and try to improve [the lottery system]. It's a model for other cities that are expanding public preschool.

L. BARRY HETHERINGTON

Are you pursuing any new questions or projects?

COVID-19 was this huge shock. We all were looking around for how we could be useful, using our respective toolboxes. Tayfun Sönmez, M. Utku Ünver and M. Bumin Yenmez, all of Boston College — the four of us — started to study how scarce medical resources are rationed. And it turns out, there are some parallels with the way school seats are rationed.

One of the ideas that we've explored is the idea of a reserve system. In cases where people can't agree on what's fair, who should get a vaccine first? It's very similar to who should get into a school. And the way that [schools] have handled that is they set up more elaborate versions of priority systems. With a vaccine reserve system, you basically have a [supply] that's reserved for cardiac communities, and one that's reserved for frontline medical personnel, so on and so forth.... States like California and Massachusetts have used some of our ideas [for their reserve systems].

My wife [Ruma Rajbhandari] is a medical doctor, and my sister [Sapana Adhikari] is an emergency room physician. A big part of my interest in medical rationing guidelines was their having to go to the hospital in March 2020 not knowing what the risks were and not having personal protective equipment. That was something that got me really keen on this debate about frontline health care workers, do they get first priority or not?

How has the pandemic shifted how you view your work in the area of education?

I have a kindergartner who was virtual this past year. And he did an amazing job with it. I think what the pandemic has done is rip the Band-Aid off on these lingering problems in society — inequitable access to health care, inequitable access to education, inefficiencies in both of the systems — and has made them much more pronounced. That's been the theme of our research throughout. We hope more people take these issues on, because the way COVID-19 played out was really a scarring event in terms of haves and the have-nots.

— Interview by Cassie Martin

How social stressors mark our genes

Jenny Tung, featured in 2018, studies how social environments — including social status, relationships and isolation — influence primates' genes and health (*SN: 10/13/18, p. 29*). Her study subjects have included captive rhesus macaques and wild baboons.

JENNY TUNG

Evolutionary anthropologist
Duke University

What has been the most notable progress in your work since 2018?

We have built layers of complexity onto [our] initial story. A few years ago we were showing that it's possible for social interactions to have profound effects on the function of our genome. And now we're trying to derive a much better understanding of how and why and when, and what are the exceptions.

The other thing I'm really excited about is our ability to move away from this very powerful but very artificial system using captive primates and to ask about what's going on in the field with wild monkeys. I've studied wild baboons in Kenya for many, many years. We know a lot about the social environments, the social experiences. And now with the ability to collect some simple blood samples, we're also seeing strong signatures of things like social status and social integration, social bonds, social connectedness in the function of these animals' genomes. That's pretty exciting because lab studies are powerful and wonderful, but there's always this question of, "Well, is this real in the real world?"

You were named a MacArthur Fellow in 2019. What have you been pursuing since?

It was a real honor. It has encouraged us to continue down some of these paths ... and to also do some more comparative work and think about species beyond the ones that I have traditionally studied. So in the past few years, I've picked up work in other social mammals — wild meerkats and these very social rodents called mole rats — that have their own advantages in giving us insight into how our social world has shaped both how we came to be, our evolutionary past, and how we do day to day in our present.

I've been doing more work on something that's an old love of mine: trying to understand the evolutionary consequences of intermixing between different primates. The population of baboons that I study in Kenya actually sits right at the edge of where the ranges of two different species of baboons meet. And so this population is intermixed between one species, the Anubis baboon, and this other species, the yellow baboon.... We know that [humans] have also intermixed a lot with some groups that don't even exist today, like Neandertals and Denisovans. That process of admixture that we observe right now in living primates [is] potentially relevant to understanding our species's history.

What are some of the greatest challenges you've faced since 2018?

In many ways, I felt very fortunate during the pandemic; as an academic with tenure, I have a secure job. But we were also home with a 3-year-old for a long stretch. I spend usually at least a month a year in Kenya, and I have since 2006. But not in 2020. We had to figure out some way of keeping [the research] continuous without any ability to travel there. We have a permanent staff in Kenya — they are Kenyan — who are very important to us and have been working with our project in some cases for many decades, and they were having their own issues, and isolation, and risks in the face of a lot of uncertainty.

I spend a lot of time in my research life thinking about social interactions. And every species that I study ... they live in groups. And humans, to a large extent, we live together. We didn't evolve to be on our own for a long period of time. And so I spent a lot of time reading and thinking and working on, "Why when you don't have the right sort of social connections, why does your risk of death just shoot up? What's the consequence of chronic social stress?" One of the things that I really appreciate in a more visceral manner [now] is how important my social network is to me. I think that we're all looking for ways to connect during the pandemic. And that's when your personal experience and the things that you're writing papers about and thinking about really collide.
— Interview by Aina Abell

MEGAN MENDENHALL/DUKE UNIV.

One test that can detect many cancers

ISAAC KINDE

Molecular biologist
Thrive Early Detection

Isaac Kinde, featured in 2015, is developing tests to detect cancer early, when treatment is more likely to be successful (*SN: 10/3/15, p. 22*). In 2019, PapGene, a small biotech start-up where he was chief scientific officer, was acquired by Thrive, cofounded by Kinde. Just this year, it got the backing of the much larger cancer diagnostics firm Exact Sciences.

Could you tell us about Thrive and what spurred this transition?

Thrive basically acquired the predecessor company [PapGene].... There was a lot more money, there's a lot more expertise, but the core mission didn't change, which is to develop cancer diagnostic products that we think will have an impact on the lives of people with cancer. We have essentially turbocharged and focused our efforts, leading with the most promising product, which is CancerSEEK.

The premise is we can reduce cancer morbidity and mortality through earlier detection. CancerSEEK is a blood test, and it is a multicancer test. That contrasts with the current paradigm, which is one test, one cancer.... Right now, all of our efforts are on making it commercially available.

CancerSEEK, which is still in testing, picks up on DNA mutations and proteins associated with cancer. How many cancers can it detect at this time?

There's good evidence for detecting over 60 to 70 percent of the cancers that cause the most deaths per year. That boils down to ... colon, breast, lung.... But the [full] range is bigger than those three. There's esophageal, gastric, kidney, pancreatic. There's data that support maybe 12 to 13 different cancers.

You published what you've referred to as a "landmark study" in *Science* last year. What did it find?

We call it a landmark study because it was the first demonstration in a prospective setting of how a multicancer blood test could be used in real time to report results to patients with cancer.

We looked at 10,000 women in the Geisinger Health system. It's primarily women who are in Pennsylvania.... In the study, 24 [women had cancers] detected with standard-of-care screening: colonoscopy, mammography or low-dose CT scan for lung. Then there were 26 cancers in which the CancerSEEK test detected the cancer first.... Sixty-five percent of the cancers we detected were at a stage prior to stage 4. So [the addition of CancerSEEK] doubled the number of cases that were [found before symptoms were reported] — in many, many cases early enough where some effective therapies could be implemented.

And then it was also safe.... There were very few false positives, and we could very quickly resolve the false positives with whole-body PET-CT imaging. At least two patients [who first had detections from CancerSEEK] had their cancers successfully removed and are thriving as of the last time we checked.

Routine cancer screenings fell during the pandemic. Has this affected your work?

It fans the flame, right? The reason why cancer screening went down is not because there was less cancer. It was [just] more difficult for whatever reason to get the appropriate standard-of-care test.... All this did was just strengthen the case that more tools, easier tools are needed for cancer screening. And I think maybe the other feeling is just wishing we could go even faster, but balancing a commercial launch with having all the right pieces in place that will set us up for success.

— Interview by Ashley Braun

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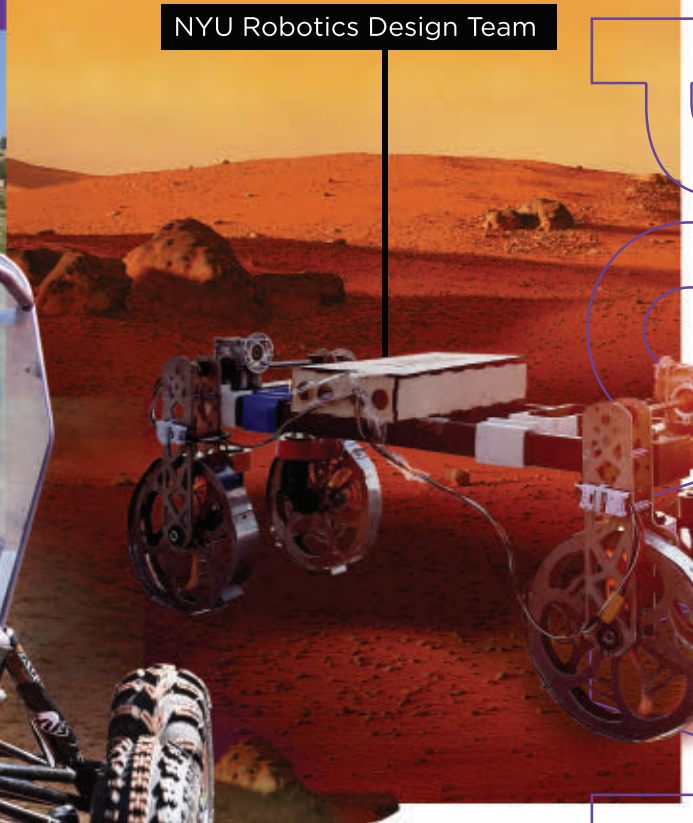

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Pig organs for people move closer to reality

When featured in 2017, Luhan Yang had cofounded and was chief scientific officer of eGenesis, a biotech start-up (*SN: 10/14/17, p. 26*). She is now cofounder and CEO of Qihan Biotech, based in Hangzhou, China, which aims to develop animal organs that are safe for human transplant and to make cell therapies that can treat conditions such as cancer and autoimmune diseases more widely accessible.

LUHAN YANG

Biologist
Qihan Biotech

What is some of the most notable progress in your work since 2017?

The concept of xenotransplantation is to use animal organs as an alternative resource for human transplantation, since there is a huge unmet need for organs. There are two fundamental issues to be addressed. One is [that] there are endogenous retroviruses in the pig genome — some virus sequences — and they can jump around within the pig genome. The viruses can also jump from the pig cell to the human cell. So there is a potential cross-species transmission, which is a huge safety and regulatory concern.... The second hurdle of using pig organs for human transplant, as you can imagine, is rejection, and it is tremendous.

Those are the two fundamental problems ... and that's where we think gene editing can come into play. By 2017, our team had knocked out 62 [retrovirus copies]. Since then, there are three notable milestones: First, we have created our Pig 2.0, with 15 modifications for immunology.... Last year in *Nature Biomedical Engineering*, we showed that those modifications are properly expressed in the pig cell, and the resulting pig is healthy, as well as fertile, and the genetic modification can be passed to the offspring. The second part is we combined the [retrovirus] knockout and the immune rejection–related modification in a single pig. We call it Pig 3.0. So that is a prototype close to clinical trial.

The third part is the most exciting part for us: We need to test the function.

[In a recent study published in the *American Journal of Transplantation*,] we put the pig kidney into a monkey. If it's a normal pig kidney, it will be rejected in a few minutes. And right now the longest survival of our monkey is about one year.... The monkey experiment demonstrates the possibility of achieving long-term xenotransplantation.

QIHAN BIOTECH

What was it like to move from the lab to leading a company?

Being a leader in biotech is not all business. There are three components that are needed. The first part is to set the vision and strategy of the company. In such an innovative area, I think the scientific knowledge, the breadth of the exposure, I think that's my strength.... The second part is to recruit, retain and train people. And the last part is some business judgment.... I have to admit, I'm not the expert. But I think at my position, the key is to recruit the best people to do the job.... And I started to embrace that every leader has different strengths and weaknesses.

How has the pandemic influenced your company's international collaborations?

I was hoping we could have more in-person meetings or travels, but right now, China still has the quarantine policy that makes it super inconvenient for international travel. Hopefully with the vaccine, the world will become what it was.

I feel the world is more divided compared with 10 years before. And I hope at least for medicine, we can see that our enemy is not a different country, but our enemy is cancer, is organ failure, is COVID, that we can keep and strengthen the collaboration across borders. — *Interview by Aina Abell*

Seeking solutions to climate change

When he was featured in 2016, Jeremy Freeman was developing new tools and methods to help scientists better analyze brain data (*SN: 10/1/16, p. 20*). Now he is executive director of CarbonPlan, a nonprofit organization that he founded in March 2020 to tackle the climate crisis through open-source data and research.

JEREMY FREEMAN

Scientist and designer
CarbonPlan

You've shifted gears since 2016. Tell us about it.

I moved very far from neuroscience, and I'm now exclusively working on climate change. Our focus [at CarbonPlan] is the scientific integrity and transparency of climate solutions. [We do] a combination of research on different areas of climate science and strategies for addressing climate change. We [also] produce a variety of resources and tools for both the research community and the public at large.

Despite being a radically different field, there are some interesting commonalities, in terms of the value of having very accessible, open, publicly available data that speaks to critical issues. [For climate change,] issues around both what is changing in the climate and how we might address that, in different strategies we might take. Having as much of that information be developed in the open, in a way that others can contribute to, and making work available for others to read and evaluate and criticize and engage with — those are [also] values I felt really strongly about in the world of biomedical science.

AMY PERL PHOTOGRAPHY

What CarbonPlan work are you most proud of right now?

We have done a lot of analysis identifying very specific ways in which the implementation of forest carbon offset programs [the planting or preservation of trees to attempt to compensate for carbon emissions] haven't worked. We did a comprehensive analysis of the role of forest carbon offsets in California's cap-and-trade program, which is a massive sort of market of offsets on the order of $2 billion, and we identified about $400 million worth of offset credits that in our analysis do not reflect real climate benefits because of errors in how they were calculated with respect to issues that involve fundamental problems in statistics and ecology.

That team effort, led by Grayson Badgley and Danny Cullenward, along with a lot of other work that we've done on the role of offsets, is really starting to change the conversation, and wake people up to the fact that these approaches to dealing with climate change haven't been working.

What other questions are you looking at?

There's an area known as carbon removal, which refers to any mechanisms that draw down CO_2 from the atmosphere. And carbon removal is really, really complicated, because there are a lot of different ways to potentially accomplish that.... So that's an area where we've been very involved, studying, analyzing, comparing. We helped write, edit and produce a book called the *CDR Primer* — carbon dioxide removal primer. It's, of course, a publicly available resource.

Have recent social justice movements influenced your work?

Absolutely.... Climate change is so fundamentally an issue of equity and an issue of justice. The burdens of climate change are going to be borne by those who were not directly responsible for it, and those who in many ways have been responsible for it will be more able to avoid its impacts. And there's a deep injustice in that.... How to think about that is an important aspect of our work.... We're interested in finding a way to be really complementary to a lot of existing community efforts around these issues.

— Interview by Aina Abell

Astrophysicist writes about the stars for Spanish speakers

PAULA JOFRÉ

Astrophysicist
Universidad Diego Portales

Paula Jofré, featured in 2018, used the chemical composition of stars across the Milky Way like DNA to map the stars' family tree (*SN: 10/13/18, p. 26*). She recently filled in some details of the tree — and is filling a gap in the publishing world by writing a book about stars in Spanish.

What progress have you made on your stellar family tree?

In the first paper, the tree had three main branches. There was one that we could associate with a young thin disk, which is one of the populations in the Milky Way. Another was associated with an old, thick disk, which was the older component of the Milky Way. And then we had something in between.... Now, because we had more stars and more chemical elements and we made a better selection of which chemical elements to include, we could find that this strange population was actually an ancestor population of the thin disk. And one of the interpretations we had in the second paper [published in January in the *Monthly Notices of the Royal Astronomical Society*] was that they were produced all very quickly.

Other groups have found striking evidence of a galaxy that was merged into the Milky Way [billions of years ago]. And that [merging and mixing of gas] could have triggered what is called a star formation burst — lots of stars [forming] at the same time. So, it's kind of exciting that we find in the tree a feature that could be attributed to a star formation burst ... a few gigayears after the [merger of these two galaxies] that we know happened.

You're also writing a popular book on stars. Can you tell me more about the book, *Fósiles del cosmos: descifrando la historia de la Vía Láctea*, or *Fossils of the Cosmos: Deciphering the History of the Milky Way*, and why you decided to write it?

It's going to be published in November [in Chile]. It's a book in Spanish for the public. I am teaching a class about stars in the Milky Way, a general astronomy class. And I've been finding that there is no proper literature in Spanish for the students.... The level is sometimes way too basic or too complex. So I wanted to write something for their level.

[The book] explains how stars create the chemical elements, what's the role of Gaia [a satellite mission to map the galaxy], what's the role of the Milky Way Mapper [another survey using Earth-based telescopes], about all these big surveys, why we care, what's going on.

When I started writing it, of course, I started reading other books.... In all these general astronomy books, women are never highlighted. In my book, I have lots of quotes from 40 different women all around the world, working in my field.... I want to make the point that you can be a woman, you can be clever, you can dedicate yourself to something that is mentally challenging. You can be like any of these 40 women.

What's the greatest challenge that you've faced since 2018?

The biggest challenge has been to promote hiring more women at the faculty level. Chile's a very small country and they love new figures, young figures being highlighted by the United States. The moment I was in *Science News*, I became very popular [in Chile] very quickly. They needed the inspirational woman. And I kept saying, "I don't want to be the only one. I want more women."

I don't know if you were aware of this collective Las Tesis; they made a dance for the social unrest that we had in Chile before the pandemic. It was a feminist movement that resonated for so many people in the world. The movement [says]: We want to be treated with respect, we want the same salary, we want the same opportunities, we want to feel safe on the streets.... But then, when you are fewer in academia, you're not going to start jumping on the table and dancing, right? You have to argue ... it's difficult. — *Interview by Ashley Braun*

MARIANA SOLEDAD

A clever genetic tool tackles new troubles

By disabling the DNA-cutting enzyme in the CRISPR system, Stanley Qi, featured in 2019, created a new and versatile tool (*SN: 10/12/19 & 10/26/19, p. 33*). Attaching a range of molecules to these "dead Cas" enzymes has yielded an entire toolbox worth of DNA and RNA manipulators.

STANLEY QI

Bioengineer
Stanford University

S. QI

Is the strategy of disabling Cas molecules still popular among researchers?

I feel it's getting more popular, for a number of reasons: One, people use ... this tool to study how the genome works. Two, there are some new efforts using the tool to treat some genetic diseases. And three, there are some other exciting uses of this tool to think about other diseases, other topics that we can possibly tackle.

For example, this CRISPR system came from bacteria cells, right? They were used as weapons by the bacteria to fight against invading viruses. So we said, "OK, humans also have many foes like invading viruses. Can we repurpose this CRISPR to help us fight our infectious diseases?" That was the idea before the COVID-19 pandemic. We practiced first on influenza, seasonal flu.... We adapted a type of CRISPR system that targets a specific RNA molecule, and it works pretty well. I remember it working in January [2020] when the news started reporting, "Oh, there's a new virus, it's an RNA virus," and we thought immediately, "What if we use this tool on this new RNA virus?"

Instead [of using the live virus], we used synthetic biology to mimic the RNA sequence.... [And we found] we can still very rapidly cleave and destroy this RNA virus and its fragments in the human lung cells. We were really excited. Since then we've been working very hard to follow up on the idea, to make this as fast as possible into a possible antiviral. We called it PAC-MAN.

Can you talk a bit about how the dead Cas, or dCas, approach has been improved and adapted?

One bigger use is for treating disease like a gene therapy. However, there's still a number of features that have not been ideal for easy use or testing in clinics.... [For patient care,] people always think about making the system very, very compact and suitable into a nanoparticle or into a viral particle, so we can deliver them with ease into the human body. So that requires a miniaturization of the CRISPR system. And we actually did some work on that.... They are like two-thirds smaller than what people use.

And second is, many of these natural proteins from bacteria don't work very well [in human cells].... So we did some protein engineering. Following these efforts, we actually created some highly compact, yet highly efficient dCas systems that can be easily delivered into the human body to turn on or off genes.

What are the greatest challenges you've faced in the last couple of years?

We are bioengineers and we think our strength is in creating stuff, modifying. Now as we step into the domain of applying these tools to solve real-world problems, the challenge is how to build a bridge between where we are to where we want to go. That usually requires learning a significant amount about a disease, about a new field, and thinking creatively on how to interface two fields.

— Interview by Ashley Braun

With the Cameron Peak Fire, research on wildfire smoke hits close to home

Emily Fischer, featured in 2020, is in the midst of one of the most comprehensive analyses of wildfire smoke ever attempted (*SN: 10/10/20 & 10/24/20, p. 29*). Since we last chatted with Fischer, her wildfire research and the way she talks about it have become more personal.

BILL COTTON, COLORADO STATE UNIV. PHOTOGRAPHY

EMILY FISCHER

Atmospheric chemist
Colorado State University

Have you started any projects since 2020?

We're looking at the impact of smoke on the visible light range where photosynthesis occurs. There's smoke blanketing the U.S. in summers now. Regardless of whether it's at the ground, it's somewhere in the atmosphere between the sun and the plants on the ground. In the Midwest, for example, over our corn and soybean belt, there's smoke between a third to half of the days on average in July and August, during peak growing season. What does that mean for crops? How is that changing the light at the surface? If it's boosting the diffuse fraction of radiation, and not decreasing the total radiation, that's a boost to productivity.

Last year, you helped launch a national group called Science Moms. What is that?

We are a nonpartisan group of scientists who are also mothers. The goal of Science Moms is for us to speak directly [via a website, videos and events] on climate change to other mothers in ways that are accurate, digestible and also engaging. While roughly 60 percent of the U.S. population is worried about climate change, like 85 percent of moms are worried about climate change. But they don't feel comfortable talking about it, or know how to talk to their representatives about it or even talk to their book club about it.

How have people responded to your outreach efforts?

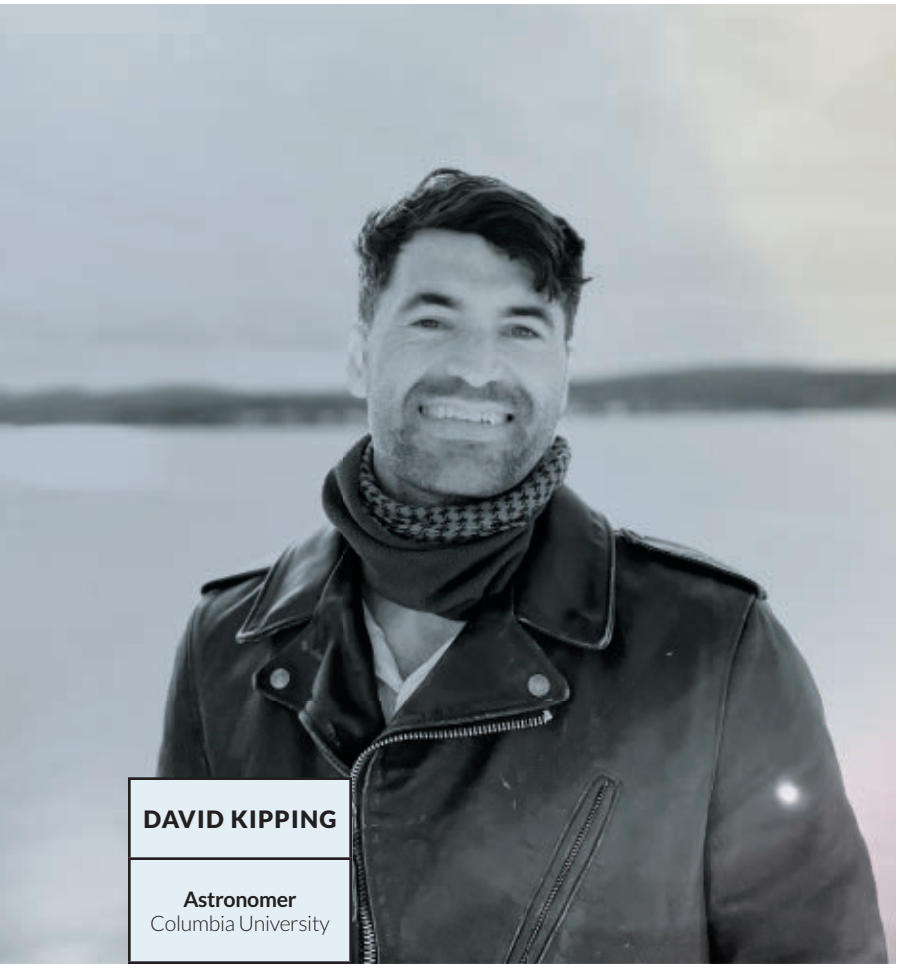
I get all sorts of messages: "This is so different than any other climate communication that I've ever seen." We're trained as scientists to take the emotion out of things, but actually it's very important for people to understand the feeling of climate change.

Last summer [2020], extreme fires impacted my own home. We had smoke here for multiple months, and my family ran from the Cameron Peak Fire.... For me, there was a shift from "These are the numbers, these are the graphs," to "Oh, this is what my graphs feel like, this is what this trend feels like."

Did your experience fleeing a wildfire shift your perspective around your science?

I'm the kind of person who studies what I see.... And so I should not have been surprised by that fire. I was out backpacking with my family, and it started one range over and my kids and I ran out, and we made it. So it was OK, but I was not sure it would be OK. When something like that happens to you, you have to respond to it. [Now] I think, when we calculate a change in something going forward, what does that mean? What are all the impacts that that could have?

Also, seeing the incident management teams working together to help people [during the fire] was very inspiring. I would say to my husband, "These teams are beautiful. They are functioning at such a high level under such hard conditions. If we could just harness this level of cooperation toward climate change action, or toward eliminating the pandemic, we [could] do anything."
—Interview by Cassie Martin



DAVID KIPPING

Astronomer
Columbia University

The search for exomoons continues

After being featured in 2017 (*SN: 10/14/17, p. 22*), David Kipping and his colleagues formally reported in *Science Advances* the first detection of a potential exomoon — a moon orbiting a planet outside of the solar system. Signs of the Neptune-sized moon were spotted around a Jupiter-sized planet 8,000 light-years from Earth. Kipping has been hunting for more ever since, and has also become a hit on YouTube.

Have you found any more exomoons?

Well, I can't really talk about that. We are close to releasing the results of a new survey of the ensemble of Jupiter-like planets discovered by the Kepler space telescope. Such planets are thought to be the best hunting ground for moons, being far from the gravitational influence of their star and large enough to support potentially massive moons. Unfortunately, the results are still not quite ready.

How have other scientists reacted?

The community is naturally skeptical. That was kind of the story of exoplanets. When researchers first discovered a hot Jupiter, no one believed it. It wasn't until they discovered about 10 of them that people started to say that, actually, maybe these are real. I don't know how it's going to go with any exomoon candidate. Maybe what we've found is genuinely bogus, but I obviously hope not. We did our due diligence, and we're very careful with the results.

It's maybe not surprising that the first ones we find are going to be so large, because after all, they're going to be the easiest to detect.... Actually, less than 1 percent of sunlike stars have hot Jupiters, but they dominated all of the first exoplanet detections just because they were so easy to find. Maybe the same thing will play out here.

In 2017, you had just launched a YouTube channel called Cool Worlds. How is that outreach going?

It's been pretty overwhelming to us, because I'd never expected to get anywhere near the number of people watching who have watched. The last video [on what's called the red sky paradox] got 200,000 views, and the one before it got 500,000. I mean, that's just bonkers. I get e-mails from people, really amazing e-mails, that say how much the channel and the videos mean to them. That's really incredible.

We have lots of people actually financially supporting us now. We give them special access to the videos and early access to the papers we're writing. We hang out with some of them once every two months on a livestream and chat about science. It's starting to be enough that I'm funding students through donations. I have this dream that I do research, it produces cool ideas, I talk about it on my outreach channel, people get excited about it and they support us, which enables me to do more research.

What are the greatest challenges you've faced since 2017?

I'm still [working to earn] tenure. It's obviously one of the most stressful periods of your career because you don't have that safety net yet that some young tenured colleagues enjoy. At the same time, you're trying to raise a family and make sure you see your kids growing up. You don't want to be a ghost at home. And so that's been tricky, but [the pandemic] enabled me to spend a lot more time at home with the family. — *Interview by Cassie Martin*

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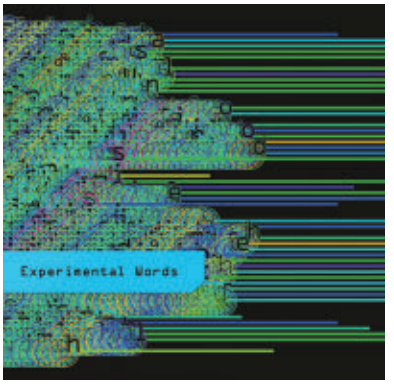
A spoken word album weaves rhyme with reason

"Science asks the questions. / And poetry marks the spot."

This line from "Unweaving Science," the opening track of the spoken word album *Experimental Words*, illuminates the connections between science and art. The album, an eclectic collection of 10 poems birthed from collaborations between researchers and spoken word artists, is a celebration of the craft and creativity that drives scientists and poets alike.

The album comes from the minds of coproducers Sam Illingworth and Dan Simpson, themselves embodiments of the bow shock between the two disciplines. Illingworth, who has a Ph.D. in atmospheric physics, is an interdisciplinary researcher at Edinburgh Napier University examining poetry as a science communication tool. Simpson, former poet in residence at Imperial College London, is known for writing poems that are influenced by science.

Illingworth calls *Experimental Words* a "dance. It's an experiment." Every part of the album, from the collaborations to the "music videos" that accompany some of the tracks, evinces the experimentation and exploration that defines both the scientific and creative processes. Even the album cover is experimental, created from an interactive algorithm that visualizes the words of the poems. Online, listeners can play around with the algorithm, developed by graphic and web designer Ben Gregory, to create their own versions of the cover.



Experimental Words
STREAM AT BANDCAMP, SPOTIFY, APPLE MUSIC AND YOUTUBE

The album, available on streaming services such as Bandcamp, Spotify, Apple Music and YouTube, aims to shatter the preconception that science and poetry mix like oil and water, Simpson says. "Poets and scientists go out into the world to try to understand it, internalize it and then try and give it back," he says. "We're communicators and interpreters and revealers of truth on some level."

Whether scientist, poet, both or neither, listeners will likely discover some truth in *Experimental Words* that resonates. The poems have wide-ranging themes, exploring humans' sometimes-harmonious, sometimes-contentious history with the ocean; the wonders of the universe's plethora of sounds; the perceptions and realities of artificial intelligence; and the unsung heroism of civil engineers.

Each piece, anchored by its own distinct spoken word style, is colored with unique sounds and music that run the gamut from satellite audio recordings of space to a rendition of a famed 1975 performance by American jazz musician Keith Jarrett.

"Glass Bridge," for instance, written and recorded by civil and environmental engineer Sunday Popo-Ola of Imperial College London and spoken word artist Malaika Kegode, features an original instrumental piece written by Kegode and her sister, Handina Dutiro. A meditation on the everyday innovations many people take for granted — clean water, well-lit roads, trains, shoes — the poem opens with a challenge: "It is true that we shouldn't walk on glass. But what if that glass is a bridge, and it is your only way to cross the valley?" A playful percussive motif that evokes a person tinkering with metal tools invites the listener to "meet on that glass bridge / in all its translucent strength / and talk about the invisible, / visible things that keep us alive."

In "Mechanisms & Multitudes," a piece about artificial intelligence, computer scientist Ruth Aylett of Heriot-Watt University in Edinburgh and poet Momtaza Mehri play with synthetic and human voices for the poem's three characters. Daedalus, the mythical Greek architect and craftsman, and PARRY, an early chatbot relic from 1972, don mechanical voices that contrast with the human inflections of Ada Lovelace, widely considered the first computer programmer and who was known for her philosophy of "poetical science."

Experimental Words features poets and scientists from various personal, artistic and scientific backgrounds. All of the collaborators live in the United Kingdom — which is not surprising since the project originated as a set of live performances there. These roots in the local U.K. sphere left me curious about how the project might evolve in the future, perhaps incorporating more international collaborations or even different media.

Still, the album's themes are universal. And listeners are dared to "realize that science and poetry are not mutually exclusive entities, but complementary ways of understanding the world in which we live," Illingworth says.

The album asserts this message on the final track. In "Shapeshifter," entomologist and science communicator Adam Hart of the University of Gloucestershire in England and poet Desree personify science and art as entities that "carry life, uphill, on their backs / and yet still have to beg for a sustainable rucksack."

The piece, which begins with an argument between the two disciplines about their values to humankind, concludes with the resolution that they are, indeed, one and the same: "I am a shapeshifter / Tell me what you need, / And that, that I'll be." — *Aina Abell*

B. GREGORY

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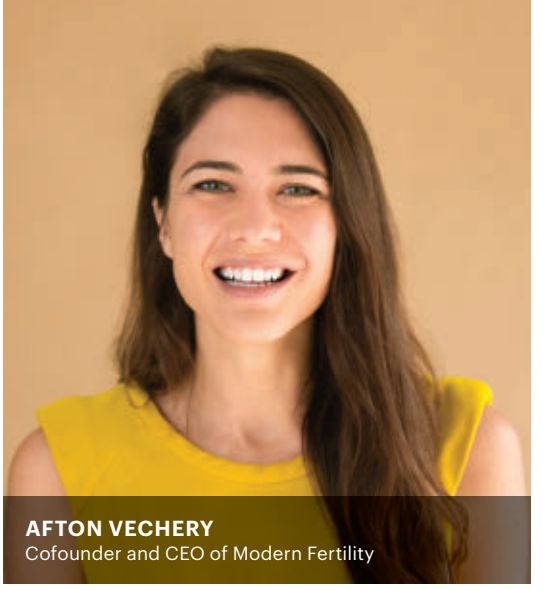


AFTON VECHERY
Cofounder and CEO of Modern Fertility

Maya Ajmera, President & CEO of the Society for Science and Publisher of *Science News*, chatted with Afton Vechery, an alumnus of the 2005 International Science and Engineering Fair (ISEF). Vechery is cofounder and CEO of Modern Fertility, a reproductive health company making personalized fertility information and support more accessible. Recently acquired by the telehealth company Ro, Modern Fertility is building a vertically integrated platform for women to own every part of their health. We are thrilled to share an edited summary of their conversation.

You are an alum of ISEF 2005, where you competed with your project called "Contamination of Proximate Wells in the Piedmont Region." How did that competition impact your life?

ISEF was really one of the most formative experiences of my life to date. It was the first time that I learned what it meant to truly be an expert in something. Becoming a subject matter expert in a very narrow slice of science when I was only in high school gave me a lot of confidence and taught me the sheer power of applying science in a business framework. Scientific developments are some of the most impactful ways to improve society, but if we don't think about them with a business mind set, the learnings can stay isolated in academia.

A lot of ISEF alumni have founded their own companies. Do you think there's a link between participating in science fair and the start-up world?

Absolutely. I think there are a lot of parallels between participating in science fair and the entrepreneurial journey. Nothing can prepare you for starting a company, but when I think back on things that prepared me along the way, science fair is at the top of the list. It's the persistence and grit to continue to move forward with the scientific process without knowing what the outcome may be and the skill set you get when presenting and defending your findings to experts and the broader public.

The company you launched, Modern Fertility, introduced its first fertility testing kits in August 2017. Please tell us about the company and your impetus for launching it.

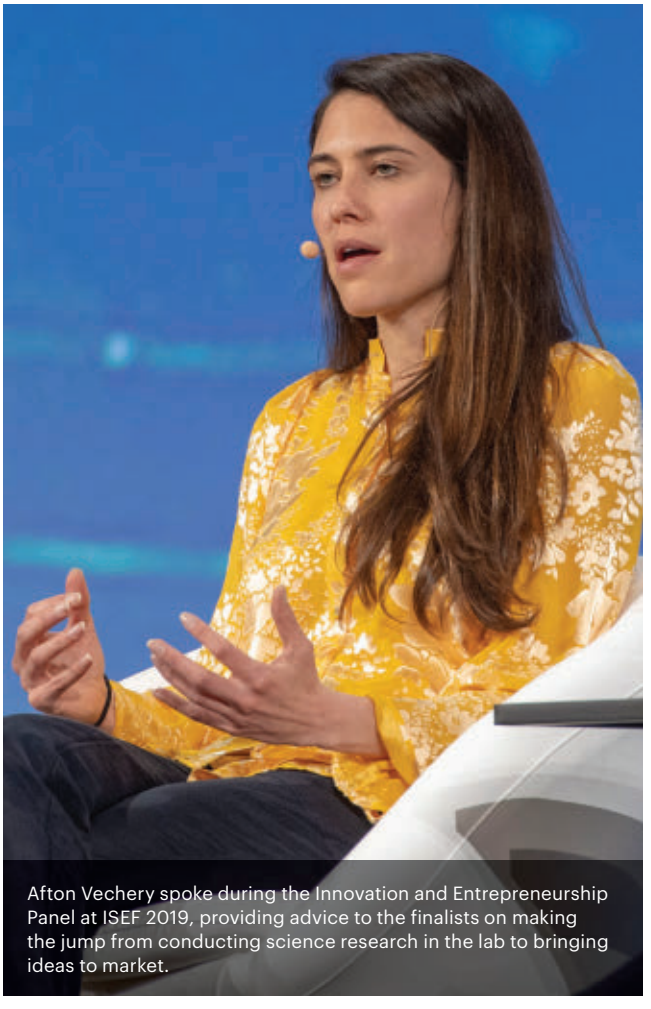
My introduction to the fertility and infertility space started when I was working in health care private equity where I identified sectors of health care that were growing fast and had consolidation potential. Because of my personal passion for women's health, I spent a lot of time in that industry and stumbled upon the infertility space. While I had to learn the business and science of infertility, it was the emotional aspect that stuck with me. I would go to infertility clinics and talk to women who had never been told that fertility declined with age or that in vitro fertilization wouldn't work for everyone. Something about the model didn't sit well with me—it was focused on growth of a reactive approach, with infertility treatments coming at extremely high costs, largely out of pocket for women. Women felt blindsided, particularly because they had little to no proactive education.

I was 22 at the time. I don't think I really knew what to do with those conversations, but I did feel like I had a secret window into conversations that I was definitely not having with my girlfriends. Fast forward to working at 23andMe, and I realized that I was waiting until later in life to start my family. I tried to request a baseline fertility test and my doctor said no because I wasn't actively trying or failing to start a family. I ended up going to an infertility clinic to request the test and

had to pay out of pocket. When I finally got my test results, it was so empowering to have a conversation with my doctor, my partner and myself.

This all clicked with the cultural shift that's been under way: Women are demanding more information about their bodies to have more power over what impacts their health and lives.

We wanted to start as a fertility information company because we believe that awareness and education is the critical first step. How could women own the decisions impacting their bodies and futures, whatever those might be? We took the exact same tests typically done in infertility clinics, took them out of the clinics and made them available to women on their own terms. We launched our hormone test with a clinical study that demonstrated the concordance and interchangeability of our at-home test and a traditional venous blood draw, providing women with an easier and more accessible format for hormone testing. Our full concordance study was published by the *Green Journal*, the official publication of the American College of Obstetricians and Gynecologists. Since launching that test, Modern Fertility has expanded into other areas to help women gain more insight into reproductive health.



Afton Vechery spoke during the Innovation and Entrepreneurship Panel at ISEF 2019, providing advice to the finalists on making the jump from conducting science research in the lab to bringing ideas to market.

Women's health and their control over their own health is a hotly debated topic right now. I would love to get your thoughts on the issue.

Women's health has been highly debated and politicized for centuries, and it's certainly coming to a head in many ways right now. I think what this really tells us is that our health care system is not set up to give women all of the tools that they need for them to play an active role in their health. The Modern Fertility point of view is that we need to put the power of fertility knowledge directly in the hands of women.

The Femtech Industry, which focuses on technology connected to women's health is growing at a rapid pace. Why do you think that's the case?

I think there's so much more work and growth that we need to see, but I believe the momentum to date comes down to a few key facts. In order for the industry to grow, there has to be women leaders creating the tools, products and services that women everywhere want—whether they've known they've wanted it all along or are realizing now that there are finally more options. The increase in women leaders, although still relatively small and in need of support, is giving women a taste of what it looks like to have businesses and products created specifically for us. This taste is opening the floodgates, inspiring more women to start companies or projects that solve our problems and setting a new standard for women everywhere in what they expect of products. This is showing that there is a rapidly growing market here, and venture capitalists are realizing that this is a sector that can make money.

Modern Fertility was recently acquired. What is your current role in the company and what is next for you?

A big part of the decision to move forward with the acquisition was to accelerate everything that we were doing at Modern Fertility and the change we want to see in women's health. We were acquired by Ro, a $5 billion telehealth company, to be their women's health vertical. As part of that acquisition, there's a commitment to continued investment in women's health, because we believe it can and should be even bigger than men's health. There is just so much work that needs to be done, and we do not have time to lose. There are massive gaps in care that women everywhere are facing today. I am personally motivated to do everything I can in my lifetime to continue to close that gap. I joined Ro as President of their women's health division. My cofounder and I are continuing on alongside the Modern Fertility team, and we're doubling the size of the Modern Fertility team by year-end.

There are many challenges in the world today. What's keeping you up at night?

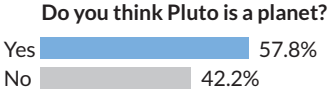
As an industry, we are not making progress fast enough. We are just too far behind in women's health care and research, and we have no time to lose. This is about access to excellent health care for all people, which should be a human right.

AUGUST 28, 2021

SOCIAL MEDIA

Passion for Pluto

Pluto's status in the solar system continues to be a sore point for many, **Lisa Grossman** reported (see "Clearing the air," right). A *Science News* poll on Twitter asked users their opinion on whether Pluto is a planet. The results from nearly 5,000 respondents reveal the perennial divide:



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Viral buzz cut

*The coronavirus razes cells' hairlike cilia, which protect a person's respiratory tract from foreign objects, **Erin Garcia de Jesús** reported in "How COVID-19 sabotages cells"* (SN: 8/28/21, p. 18).

Reader **Ron Kern** asked if the mowed-down cilia can grow back.

The cilia can eventually regrow, says viral immunologist **Lisa Chakrabarti** of the Pasteur Institute in Paris. While the coronavirus destroys cells' cilia, the cells themselves seem to live on. **Chakrabarti** compares the regrowth to a forest recovering after a fire. "The roots are still there, and it will grow back." By the time cilia regrow, though, the virus may have already invaded the lungs, potentially causing severe COVID-19, she says.

Clearing the air

*Pluto became a dwarf planet 15 years ago when the International Astronomical Union, or IAU, instituted a new definition for a planet, which requires a celestial body to clear other objects from its orbit, **Lisa Grossman** reported in "Pluto's place"* (SN: 8/28/21, p. 20).

Several readers expressed confusion over why planets that share their orbits with asteroids, such as Jupiter and its Trojan asteroids, weren't also demoted.

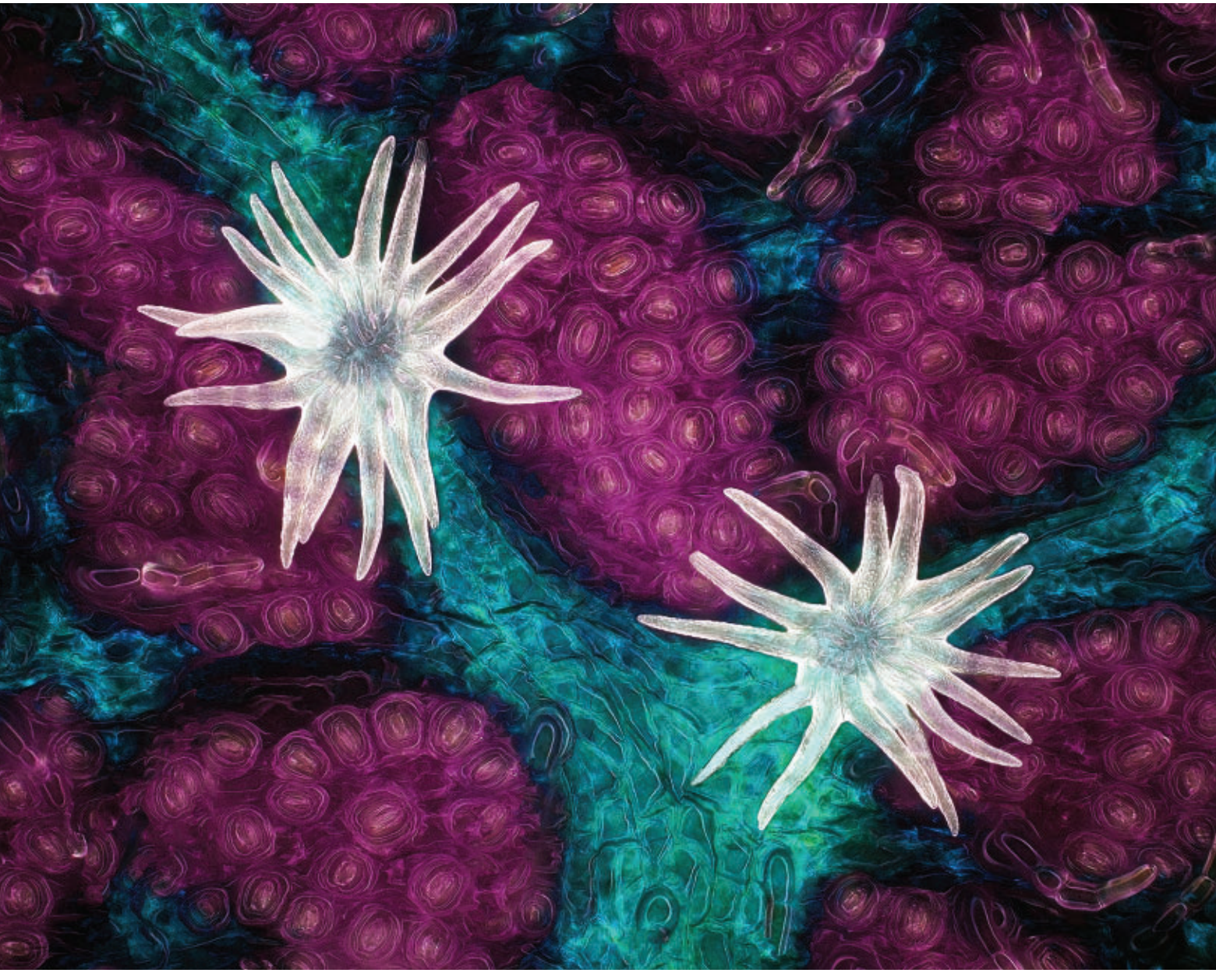
Such asteroids are effectively in the same category as satellites, **Grossman** says. "These cases don't violate the IAU's definition because the planets are still the most gravitationally significant objects around," she says. Jupiter, for instance, controls the Trojans' orbit. In contrast, Pluto's gravity does not significantly affect the objects in its Kuiper Belt neighborhood.

Balding black holes

*Black holes born with magnetic fields quickly shed those fields, **Emily Conover** reported in "Magnetized black holes go bald"* (SN: 8/28/21, p. 18).

Reader **Dave Foss** wondered how a black hole could exhibit a magnetic field if nothing can escape its gravity.

"Scientists don't expect a black hole itself to exhibit a magnetic field since anything inside the black hole that could generate that field would be cut off from the outside world," **Conover** says. But if a massive object that already has a magnetic field, such as a neutron star, collapses to form a black hole, that field won't disappear instantly, she says. In such cases, plasma surrounding the black hole maintains the magnetic field until the field blasts outward or falls into the black hole, simulations suggest.



How to make an oak leaf look like an underwater oasis

A zoomed-in view can make even the most mundane objects look spectacular.

This glimpse of the underside of a leaf from a southern live oak tree (*Quercus virginiana*), shown at 60 times magnification, is just one example. Jason Kirk, a self-described microscope enthusiast and director of Baylor College of Medicine's Optical Imaging & Vital Microscopy Core in Houston, took this photo with a microscope that he finished building in the early days of the coronavirus pandemic.

Kirk tested his homemade device with a variety of objects from his yard, including tree leaves. "A lot of times, you stick weird stuff under the microscope and see what it looks like," Kirk says. "That's what happened with this."

His young daughter remarked that the leaf's trichomes — structures that help protect plants from extreme weather and insects — looked like sea anemones. That comment inspired Kirk to craft a photo using false color that made the leaf's underside look like an underwater landscape.

The picture is a composite of about 200 images stacked together. The leaf's trichomes are colored white and stick out of cyan-colored vessels, which carry water. Surrounding stomata, colored purple, regulate the flow of gases such as carbon dioxide. The photo won first place in the 2021 Nikon Small World photomicrography competition, the results of which were announced September 13. — *Erin Garcia de Jesús*

J. KIRK/BAYLOR COLLEGE OF MEDICINE, NIKON SMALL WORLD

See more winners of this year's contest at **bit.ly/SN_Nikon2021**

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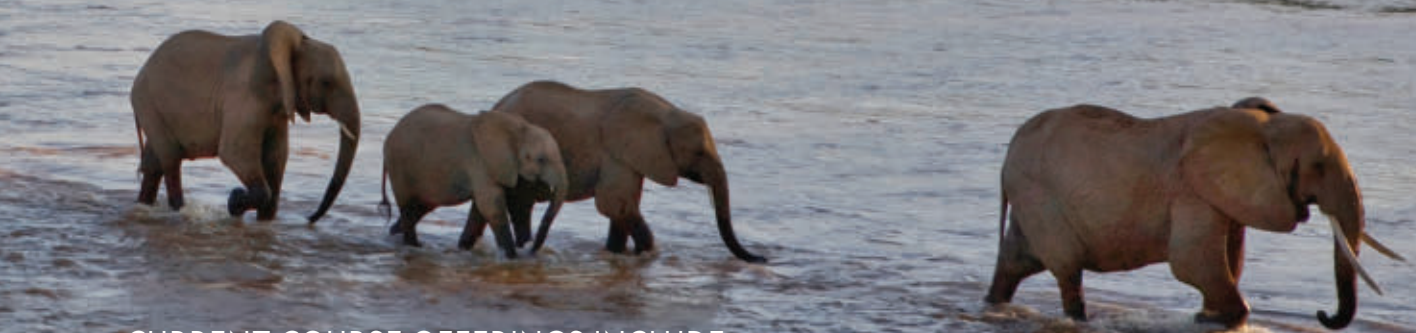

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