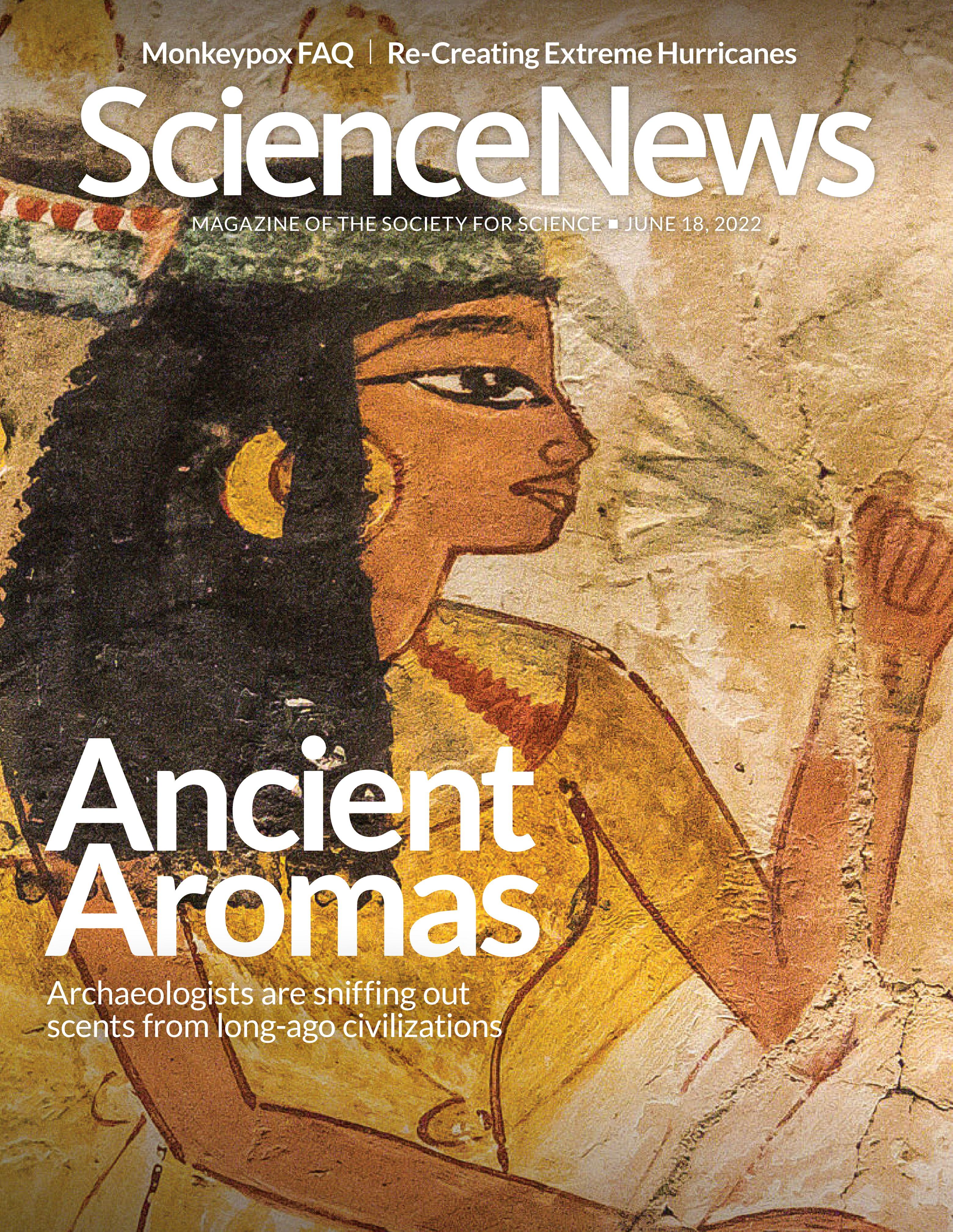
Monkeypox FAQ | Re-Creating Extreme Hurricanes

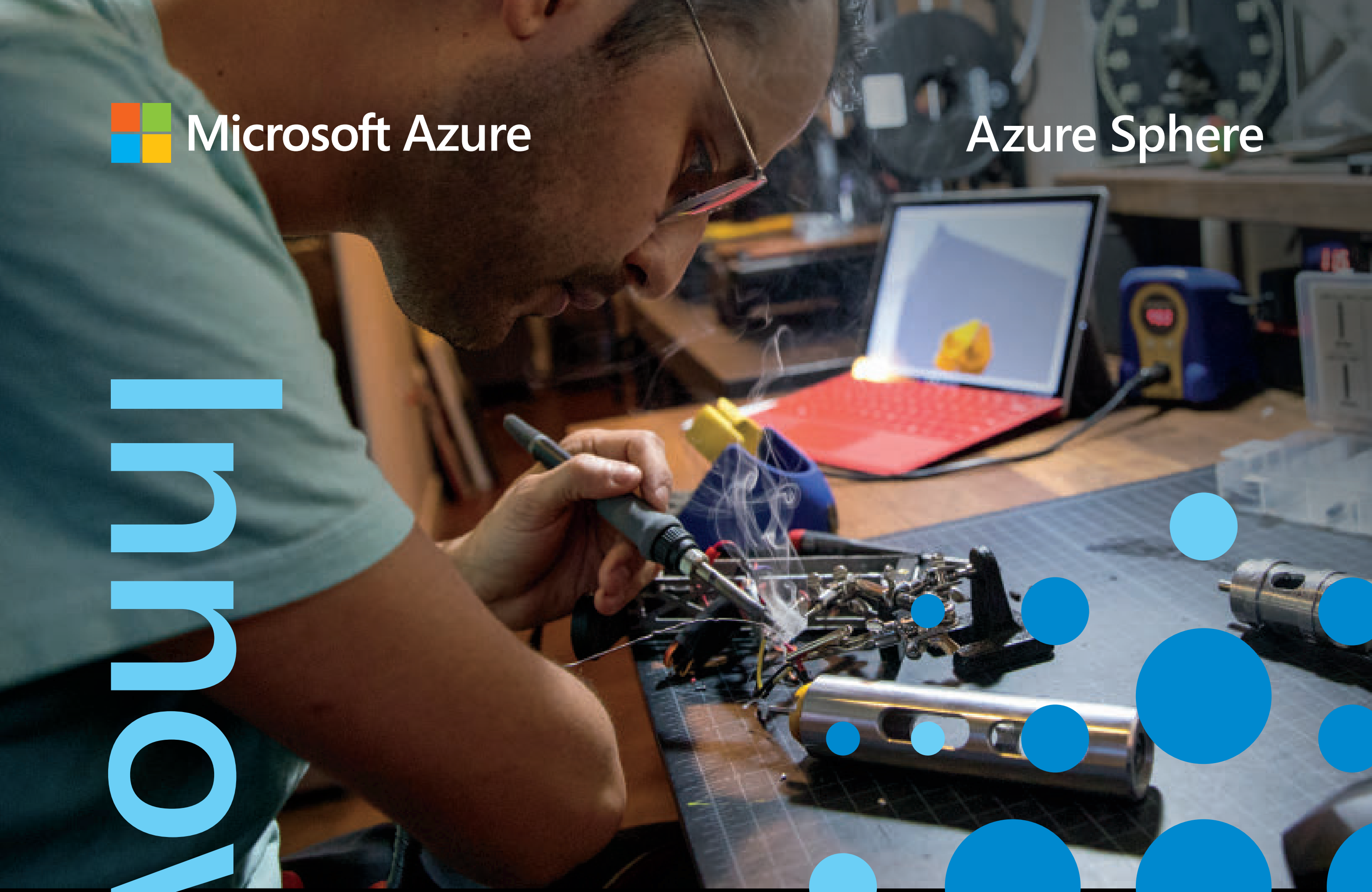
Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ JUNE 18, 2022



Ancient Aromas

Archaeologists are sniffing out scents from long-ago civilizations



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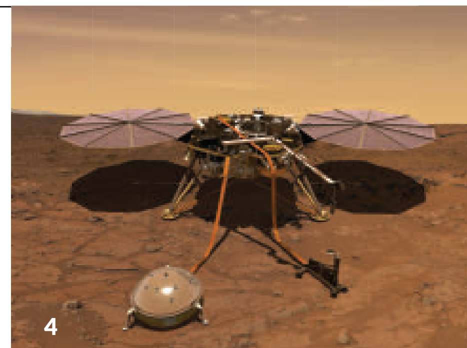
Science News

Features

News



Departments

COVER Painted in an ancient Egyptian tomb, a woman holds a lotus blossom to her nose, signaling the importance of scents. *Alain Guilleux/ Alamy Stock Photo*

FROM TOP: JOSH EDELSON/AFP VIA GETTY IMAGES; JPL-CALTECH/NASA; KEN S.H. CHING

Predicting the damage caused by extreme storms

Growing up in Miami, *Science News* earth and climate writer Carolyn Gramling knew that hurricanes were a part of life. When Hurricane Andrew hit in 1992, she and her mom huddled in the innermost room of their house, listening all night to a battery-powered radio as winds of more than 250 kilometers per hour shook the house. "I was listening to people calling and saying the hurricane was in their house, what do they do?" Gramling told me.

Her family's house survived, but many other families weren't as lucky. The Category 5 storm destroyed or damaged more than 125,000 homes, leaving 160,000 people homeless. "It was transformational for Miami," Gramling says. After the storm, Florida adopted some of the nation's strictest building codes to reduce wind damage.

The winds and rain from tropical storms are expected to get more intense as the planet warms. Hurricane Dorian hit the Bahamas in 2019 with winds up to 300 km/h, flattening entire neighborhoods. And as Gramling reports in this issue, scientists are racing to figure out what communities will need to do to survive the coming megastorms fueled by climate change (Page 10).

To learn more about that effort, Gramling visited the Wall of Wind at Florida International University, or FIU, her alma mater, while on a recent trip to Miami. It's an airplane hangar kitted out with humongous fans that can generate wind speeds of up to 252 km/h. Engineers from around the world visit the Wall of Wind to test how models of buildings and landscapes fare in the blast, with the goal of designing and developing infrastructure that can better withstand extreme forces.

A new facility to be built at FIU, funded by the National Science Foundation, will be an even more powerful tool. It will test structures against stronger winds and against water, adding giant water tanks to the mix. That's essential since storm surges cause much of a hurricane's damage and loss of life. "We really don't know what Mother Nature is going to do," Gramling says. Researchers will be able to combine data from the facility, which is still in the planning stages, with field observations after natural disasters and computer simulations to predict how different regions could be affected.

Experiencing Hurricane Andrew helped shape her career as a scientist, Gramling says. She studied geology in college, and then oceanography in graduate school. "Living in Miami, climate and ocean are part of your formative experience," she says. "I wanted to understand it, and I wanted to help other people understand it."

I'm glad Gramling has put her scientific chops and reporting skills to work for *Science News* and our readers. Earth's climate and weather systems are dauntingly complex, and so is the research about them. Gramling has a knack for describing that science in a way that even this lowly magazine editor can understand, while also sharing her fascination with how the world around us works (see, for instance, her admiration for the epic story of mammals, in the book review on Page 28). And if a visit to the Wall of Wind helps us grasp it, so much the better. —*Nancy Shute, Editor in Chief*

Science News
1719 N Street NW, Washington, DC 20036
(202) 785-2255

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SOCIETY FOR SCIENCE

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Excerpt from the June 24, 1972 issue of *Science News*

50 YEARS AGO

Does the eel use electric fields to navigate?

Many species of ocean fish [such as American eels] migrate over large distances. Some of them do so with such extreme accuracy that they can come thousands of miles to return to the stream or area where they were born. Naturalists naturally wonder how they do it. One of the suggestions is that they use electricity.

UPDATE: It's still a mystery how the American eel (*Anguilla rostrata*) navigates to its breeding grounds. But a growing body of evidence has shifted focus from electricity to magnetic fields. Experiments suggest that the American eel's European cousin, *A. anguilla*, seems to follow a magnetic map to the North Atlantic's Sargasso Sea, guided by an internal compass (*SN Online: 4/13/17*). In March, scientists proposed that freshly spawned American and European eels follow paths of increasing magnetic intensity from the Sargasso Sea to their freshwater homes. As adults, the eels may sense decreasing intensity to retrace the path to their birthplace.

RETHINK

Revising Leonardo da Vinci's rule for how trees branch

The branching structure of a leafy tree, such as this southern live oak in South Carolina, is dictated by the surface area of its limbs, physicists say.

Leonardo da Vinci was wrong about trees.

More than 500 years ago, the multitalented Renaissance genius wrote down his "rule of trees," describing the way he thought that trees branch. It was a brilliant insight that helped him to draw realistic landscapes, but Leonardo's rule breaks down for many types of trees. A new branching rule — dubbed "Leonardo-like" — works for virtually any leafy tree, researchers reported in the April *Physical Review E*.

"The older Leonardo rule describes the thickness of the branches, while the length of the branch was not taken into account," says physicist Sergey Grigoriev of the Petersburg Nuclear Physics Institute in Gatchina, Russia. "The description using the older rule is not complete."

Leonardo's rule says that the thickness of a limb before it branches into smaller ones is the same as the combined thickness of the limbs sprouting from it. But according to Grigoriev and colleagues, it's the surface area that stays the same.

Using surface area as a guide, the new rule incorporates limb widths and lengths, and predicts that long branches end up being thinner than short ones. Unlike Leonardo's guess, the updated rule works for trees that range from slender to sturdy, the team reports.

The connection between the surface area of branches and overall tree structure shows that it's the living, outer layers that guide tree structure, the researchers say. And two factors are key for determining structure: the width of each limb and the length between branchings on a limb. As a result, when trees are rendered in two dimensions in a painting or on a screen, the new rule describes them particularly well.

The new Leonardo-like rule is an improvement, says botanist Kate McCulloh of the University of Wisconsin–Madison. But she has doubts about the team's rationale. In most trees, the living portion extends much deeper than the thin surface layer, she says. "A giant, old oak tree might have a centimeter of living wood … [but] there are certainly tropical tree species that have very deep sapwood and may have living wood for most of their cross sections."

Still, the fact that the new rule appears to hold for many trees intrigues McCulloh. "Why are [trees] conserving this geometry for their external tissue, and how is that related to the microscopic-level differences that we observe in wood?" she wonders.

To test their rule, Grigoriev and colleagues took photos of trees from a variety of species and analyzed the branches to confirm that the real-world patterns matched predictions. Though the team has yet to study evergreens, the rule holds for deciduous trees including maple, linden, apple and chestnut.

Leonardo da Vinci's tree branching rule, recorded in a notebook of his (shown), accounts for branch thickness but not length. Thus, the rule doesn't apply to many types of trees.

While it's possible to confirm the rule by measuring branches by hand, that would be a risky exercise for trees and scientists. "Note," the team writes, "that not a single tree was harmed during these experiments."

— James R. Riordon

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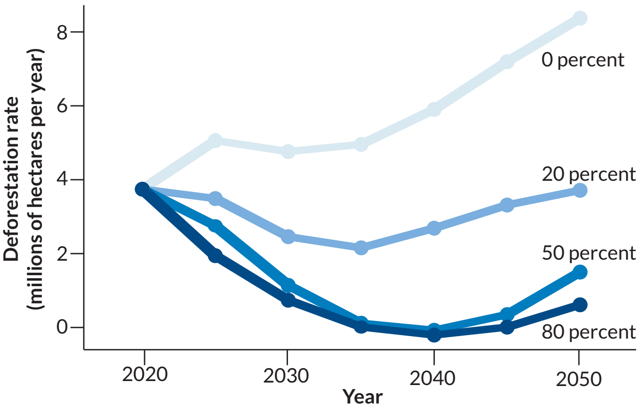
SCIENCE STATS

Swapping meat for microbial protein may take a bite out of climate change

"Fungi Fridays" might save a lot of trees. Eating one-fifth less red meat and instead munching on fungi- and algae-derived microbial proteins could cut annual deforestation in half by 2050, researchers report in the May 5 *Nature*. Florian Humpenöder of Potsdam Institute for Climate Impact Research in Germany and colleagues simulated land use and deforestation from 2020 through 2050, substituting microbial protein for 0 percent, 20 percent, 50 percent or 80 percent of the global red meat diet by 2050 (see graph below). Just 20 percent microbial protein substitution cut annual deforestation rates — and associated greenhouse gas emissions from clearing trees for cattle pastures — by 56 percent. So eating more microbial proteins could help address global warming. — *Carolyn Gramling*

Deforestation rates if microbial protein replaced a percentage of red meat consumption, 2020–2050



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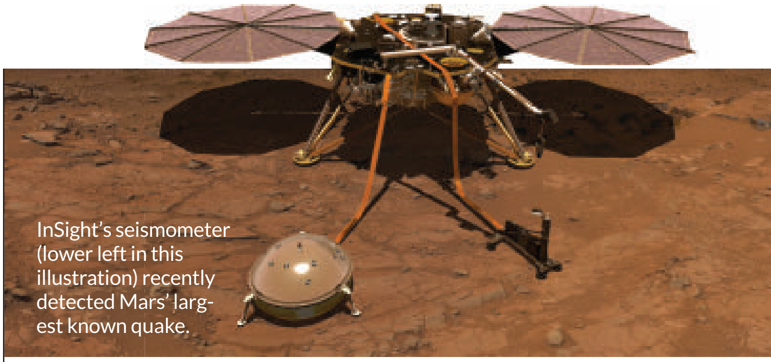


InSight's seismometer (lower left in this illustration) recently detected Mars' largest known quake.

THE –EST

NASA's InSight lander has recorded the largest known Marsquake

Any Martians out there should learn to duck and cover. On May 4, the Red Planet was rocked by a roughly magnitude 5 temblor, the largest Marsquake detected to date, researchers at NASA's Jet Propulsion Laboratory in Pasadena, Calif., report. The shaking lasted more than six hours and released more than 10 times the energy of the previous largest quake.

The InSight lander recorded the event, which originated near the Cerberus Fossae region more than 1,000 kilometers away. Marsquakes can be used to probe the planet's interior structure (*SN: 8/14/21, p. 9*), and scientists should learn a lot from studying this whopper, says Philippe Lognonné, a geophysicist at Institut de Physique du Globe de Paris in France and principal investigator of InSight's seismometer.

After nearly four years of listening to Mars' innards, InSight will soon retire, the mission team announced May 17 at a news conference. The spacecraft is rapidly losing power and can't recharge due to dust on its solar panels. The team expects that InSight will be defunct by the end of the year. — *Katherine Kornei*

THE EVERYDAY EXPLAINED

Physics hints at what makes bird nests sturdy

To build its nest, a bird won't go for any old twig. Somehow, birds pick and choose material that will create a cozy, sturdy nest.

"That's just totally mystifying to me," says Hunter King, a physicist at the University of Akron in Ohio. Birds seem to have a sense for how the properties of an individual stick will translate to the characteristics of the nest. That relationship "is something we don't know the first thing about predicting," King says.

A bird's nest is a special version of a granular material: a substance, such as sand, made up of many smaller objects. King and colleagues combined laboratory experiments and computer simulations, described in the May 13 *Physical Review Letters*, to better understand the quirks of nestlike granular materials.

In the experiments, a piston repeatedly compressed 460 bamboo rods scattered inside a cylinder. The simulations analyzed the points where sticks touched, which is key to understanding the material, the team says.

As the piston applied more force, the pile became stiffer and more resistant to deforming. Sticks slid against one another and the contact points between them rearranged. More contact points forming between sticks prevented the pile from flexing further, the simulations showed.

Changes in the pile's stiffness seemed to lag behind the piston's motion, a phenomenon called hysteresis. That effect caused the pile to be stiffer when the piston pushed in than when the material bounced back as the piston retracted. The simulations suggest that hysteresis arose because the initial friction between sticks needed to be overcome before the contact points started to rearrange.

Beyond bird nests, this research could be applied to other materials made of disordered arrangements of long fibers, such as felt. With a better grasp of the physical qualities of such materials, engineers could use them to create new structures designed to protect other cargo that humans consider precious.
— *Emily Conover*

FROM TOP: JPL-CALTECH/NASA; T. TIBBITTS

BODY & BRAIN

What to know as monkeypox cases rise

The virus doesn't spread easily and is unlikely to fuel a pandemic

BY TINA HESMAN SAEY

An outbreak of monkeypox has some people worried that the world is on the brink of another pandemic. That's not likely, experts say.

The concern has been fueled by more than 700 confirmed or suspected cases of the disease cropping up since May 7 in at least 30 countries outside Central and West Africa, where monkeypox is endemic. It's the most widespread outbreak of the disease, which causes flulike symptoms (fever, headaches and body aches), profound weakness, back pain, swollen lymph nodes and rashes that erupt into pus-filled blisters.

Spain, Portugal, Canada and England have recorded most of the cases. In the United States, the U.S. Centers for Disease Control and Prevention has confirmed 15 cases as of May 30. Those cases have been in California, Colorado, Florida, Massachusetts, New York, Utah, Virginia and Washington.

Monkeypox spreads through close contact. "Anyone — anyone — can develop and spread monkeypox infection," John Brooks, a medical epidemiologist at the CDC, said May 23 during a news briefing. But "many of those affected in the current global outbreak identify as gay or bisexual men."

Some of those cases have been linked to a Pride celebration and a sauna in Spain, and a fetish festival in Belgium. CDC officials hope to raise awareness of the sometimes deadly disease because June is Pride Month in the United States and many other countries, Brooks said.

Right now, men who have sex with men may be at greater risk of contracting the virus, but "infectious diseases don't care about borders or social networks," Brooks said. Most people are at low risk of catching monkeypox but should still be aware that it is circulating in the community, he said.

"There's no need for panic. There's no need for fear, and there's no need to stigmatize anyone who has this disease," says Adesola Yinka-Ogunleye, an epidemiologist at the Institute for Global Health at University College London and a monkeypox expert with the Nigeria Centre for Disease Control.

With cases on the rise, you probably have questions; here's what to know.

What is monkeypox?

Monkeypox is a DNA virus in the genus *Orthopoxvirus*, which includes smallpox, cowpox and camelpox. It's not a new disease. The virus was discovered in monkeys in 1958. The first known human case appeared in 1970.

Mostly, monkeypox is transmitted from animals to humans. That's what happened in the United States in 2003, when 47 people in the Midwest got monkeypox from pet prairie dogs that had been housed with infected rodents from West Africa (*SN: 6/14/03, p. 374*).

> "There's no need for fear, and there's no need to stigmatize anyone who has this disease."
> ADESOLA YINKA-OGUNLEYE

There are two types, or clades, of monkeypox. The more deadly type is the Central African or Congo Basin clade, which sickens hundreds of people each year in Congo and the Central African Republic. That clade, which kills about 10 percent of infected people, hasn't spread outside the region where it is normally found, Yinka-Ogunleye says.

The West African clade is causing the current global outbreak. This version tends to be milder, killing about 1 to 3.6 percent of infected people.

How did the outbreak start?

The current outbreak is the latest resurgence of monkeypox, Yinka-Ogunleye says. "Before 2017, it used to be known as a rare disease," she says. Fewer than 10 cases had popped up in West Africa before then. For instance, Nigeria hadn't had a case since 1978. But then a 2017 outbreak there caused 42 confirmed cases and 146 suspected cases, she and colleagues reported in 2018 in *Emerging Infectious Diseases*.

The researchers found evidence that the virus was being passed person-to-person through close contact with family members, though most cases probably came from animals. No one knows which animals are the reservoirs for monkeypox, though several rodents and other small animals are suspected to carry the virus.

Since 2017, Nigeria has had sporadic cases of monkeypox, mostly in urban areas, Yinka-Ogunleye says. As of May 29, the country had confirmed 21 of 66 suspected cases. One person died.

From time to time, travelers have carried monkeypox from Nigeria to other countries, but those have been mainly isolated cases. The current outbreak may also have started with a traveler.

Genetic evidence from viruses isolated from patients in Portugal, the United Kingdom and the United States suggests that the multinational outbreak may have had a single source, researchers in Portugal reported May 23 at virological.org.

"Our virus definitely comes from Portugal," says Philippe Selhorst, a virologist at the Institute of Tropical Medicine in Antwerp, Belgium. On May 20, he posted the genetic makeup of the monkeypox virus from a Belgian patient to virological.org. The virus's DNA sequence is very similar to ones from Portugal. The patient had traveled to Lisbon shortly before developing a rash, further solidifying the link.

Because monkeypox has DNA as its genetic material, it mutates more slowly than RNA viruses, such as SARS-CoV-2, the coronavirus that causes COVID-19. "I would expect all cases ... in the outbreak to be very similar," Selhorst says.

Still, virologists have noted mutations

in the virus taken from different patients. That's to be expected. "There's always going to be differences between viruses," Selhorst says. "The question is, 'Is that difference relevant?'" Nothing in the viral DNA indicates that the virus has mutated to spread more easily from person-to-person, he says.

How is the virus spreading?

This outbreak seems to be driven by human-to-human transmission. "This virus has used a sexual network to spread around the world," says Amesh Adalja, an infectious diseases physician and a senior scholar at the Johns Hopkins Center for Health Security.

That doesn't mean monkeypox is a sexually transmitted disease — one that is passed through semen or other bodily fluids exchanged during sex, he says. "You can catch the flu if you make out with somebody, and people kiss during sex, but that doesn't make influenza a sexually transmitted infection." Similarly, close skin-to-skin contact during sex can spread monkeypox.

People infected with monkeypox may not have a visible rash but could have lesions in the mouth or throat that harbor the virus, the CDC's Brooks said. Selhorst and colleagues are collecting semen and other body fluids from people infected with monkeypox to see if it is possible for the virus to be sexually transmitted.

In this outbreak, rashes have appeared first in people's groin and anal regions, and have been mistaken for herpes or other STDs, Brooks said during the news briefing. And monkeypox cases are sometimes confused with chicken pox, Yinka-Ogunleye says. Doctors need to be aware that a patient with a rash may have something more exotic, Adalja and Hopkins colleague Tom Inglesby warned May 24 in the *Annals of Internal Medicine*. If monkeypox is suspected, doctors should contact their state or local health department.

How can the outbreak be stopped?

In Nigeria, monkeypox outbreaks are controlled by isolating infected people and tracing close contacts, Yinka-Ogunleye says. Vaccines and antiviral medications exist, but are not available there for limiting the disease's impact or spread, she says. Most of the time antiviral medication is not needed because the body eventually clears the virus on its own, but other drugs may be given as part of supportive care.

In Europe and the United States, close contacts of infected people may be vaccinated with either ACAM2000, an older vaccine against smallpox, or with a newer vaccine called Jynneos. Made by vaccine company Bavarian Nordic, Jynneos was approved by the U.S. Food and Drug Administration in 2019 for use against smallpox and monkeypox. That vaccine has fewer side effects than the older vaccine and is safer for people with eczema or weakened immune systems.

More than 1,000 doses of Jynneos are available in the U.S. Strategic National Stockpile, Jennifer McQuiston, deputy director of the CDC's Division of High Consequence Pathogens and Pathology, said during the May 23 news briefing. The company expects to produce more soon. More than 100 million doses of the older vaccine are available.

So far, cases in the current outbreak have been mild. But two antiviral drugs, brincidofovir and tecovirimat, developed to treat smallpox could be used to treat people with severe monkeypox (SN: 5/26/18, p. 10).

Most of the evidence that the drugs will work against monkeypox come from animal studies. But in a tiny study in the United Kingdom, three people who got brincidofovir as monkeypox treatment developed liver problems and had to be taken off the drug, researchers report May 24 in *Lancet Infectious Diseases*. One person given tecovirimat spent only 10 days in the hospital, compared with five other patients who stayed in the hospital between 22 and 39 days because they were still producing virus. Those numbers are too small to draw any conclusions about the treatment's effectiveness.

People previously vaccinated against smallpox may still have some protection against monkeypox too, says Aaron Glatt, an infectious diseases epidemiologist at Mount Sinai South Nassau in Oceanside, N.Y., and a spokesperson for the Infectious Diseases Society of America. But those numbers are dwindling. Smallpox was declared eradicated in 1980 and most countries stopped vaccinating against the virus in the 1970s. That means many people 50 and younger have no immunity to smallpox or monkeypox.

"This is a negative to the eradication of smallpox," he says. "But in the overall scheme of things, it's a positive that we eradicated smallpox. Even if we have a handful of monkeypox cases as a consequence of not vaccinating for smallpox, it is [still] a very, very good exchange." ■

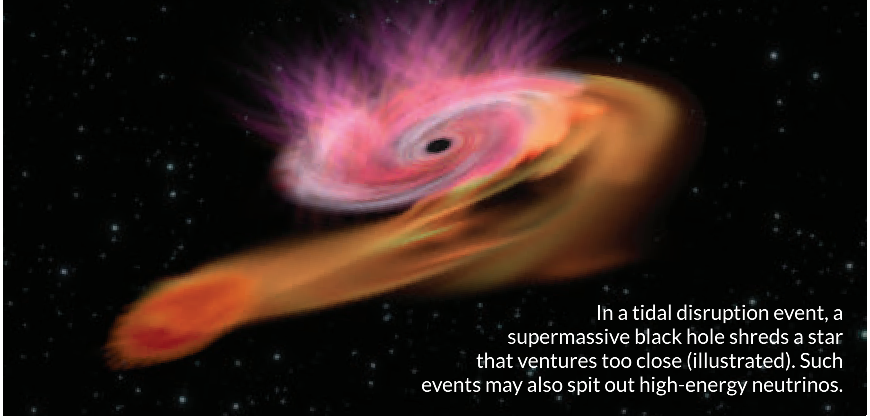
Lesions, such as these seen on a person's hands, are a hallmark of monkeypox. Infectious virus is released from these lesions and can spread to other people.

BRIAN W.J. MAHY/CDC

ATOM & COSMOS

Zippy neutrino linked to a source

Tidal disruption events may beget the high-energy particles



In a tidal disruption event, a supermassive black hole shreds a star that ventures too close (illustrated). Such events may also spit out high-energy neutrinos.

BY EMILY CONOVER

When a star gets too close to a black hole, sparks fly. And, potentially, so do subatomic particles called neutrinos.

A dramatic light show results when a supermassive black hole rips apart a wayward star. Now, for the second time, a high-energy neutrino has been spotted that may have come from one of these "tidal disruption events," researchers report in a study accepted in *Physical Review Letters*.

These lightweight particles, which have no electric charge, careen across the cosmos and can be detected upon their arrival at Earth. The origins of such zippy neutrinos are a big mystery. Conditions must be just right to drastically accelerate charged particles, which would then produce neutrinos. Scientists have begun lining up likely candidates for cosmic particle accelerators. In 2020, researchers reported the first high-energy neutrino linked to a tidal disruption event (SN: 6/20/20, *p.* 9). Other high-energy neutrinos have been tied to active galactic nuclei, bright regions at the centers of some galaxies (SN: 8/4/18, *p.* 6).

Discovered in 2019, the tidal disruption event reported in the new study stood out. "It's really one of the brightest transients ever seen," says astroparticle physicist Marek Kowalski of Deutsches Elektronen-Synchrotron, or DESY, in Zeuthen, Germany. Transients are short-lived flares in the sky, such as tidal disruption events and exploding stars called supernovas.

Roughly a year after the flare's discovery, the Antarctic neutrino observatory IceCube spotted a high-energy neutrino. By tracing the particle's path backward, researchers determined that the neutrino came from the flare's vicinity.

The matchup between the two events could be a coincidence. But the previous neutrino tied to a tidal disruption event makes the case stronger. The probability of finding two such associations by chance is only about 0.034 percent, the researchers say.

It's not clear how tidal disruption events would produce high-energy neutrinos. In one proposed scenario, a jet of particles flung from the black hole could accelerate protons, which could interact with surrounding radiation to make the neutrinos.

"We need more data ... to say that these are real neutrino sources or not," says astrophysicist Kohta Murase of Penn State, a coauthor of the new study. If the link between the neutrinos and tidal disruption events is real, he's optimistic that researchers won't have to wait too long. "If this is the case, we will see more."

But scientists don't all agree that the flare was a tidal disruption event. It could have been an especially bright supernova, astrophysicist Irene Tamborra of the University of Copenhagen and colleagues suggest in the April 20 *Astrophysical Journal*. Protons accelerated by the supernova's shock wave could collide with protons in the region surrounding the star, producing other particles that could decay to make neutrinos.

It's only recently that observations of high-energy neutrinos and transients have improved enough to reveal potential links between the two. "It's exciting," Tamborra says. But as the debate over the newly detected neutrino's origin shows, "at the same time, it's uncovering many things that we don't know." ■

ATOM & COSMOS

Space ripples give black hole the boot

High-speed kick probably ejected the behemoth from its home

BY EMILY CONOVER

This black hole knows how to kick back.

Scientists recently observed two black holes uniting into one and getting a kick that flung the newly formed black hole away at high speed. It zoomed off at about 5 million kilometers per hour, researchers report in the May 13 *Physical Review Letters*. That's blazingly quick: The speed of light is just 200 times as fast.

Ripples in spacetime, called gravitational waves, launched the black hole on its exit. As any paired-up black holes spiral inward and coalesce, they emit these ripples, which stretch and squeeze space. If those waves shoot off in one direction preferentially, the resulting black hole will recoil. It's like a gun kicking back after shooting a bullet, says astrophysicist Vijay Varma of the Max Planck Institute for Gravitational Physics in Potsdam, Germany.

Gravitational wave observatories LIGO, in the United States, and Virgo, in Italy, detected the black holes' ripples in January 2020. Those waves revealed details of how the black holes merged, hinting that a large kick was probable. As the black holes orbited one another, the plane in which they orbited rotated, or precessed, similar to how a top wobbles as it spins. Precessing black holes are expected to get a bigger kick when they merge.

To estimate the kick velocity, Varma and colleagues compared the data with various predicted versions of black hole mergers,

ESA, C. CARREAU

ATOM & COSMOS

Moon’s ice may have volcanic origin

Eruptions could have produced water and brief atmospheres

BY ANNA GIBBS

Four billion years ago, lava spilled onto the moon’s crust, etching the man in the moon we see today. But the volcanoes may have also left another legacy: ice.

Two billion years of eruptions may have created many short-lived atmospheres that contained water vapor. That vapor could have traveled through the atmosphere before settling as ice at the poles, researchers report in the May *Planetary Science Journal*.

The existence of lunar ice was confirmed in 2009. In addition to volcanoes, scientists have suggested asteroids, comets and electrically charged atoms carried by the solar wind as sources of the water.

Planetary scientist Andrew Wilcoski of the University of Colorado Boulder and colleagues investigated volcanism’s viability as an ice source. During their peak, eruptions happened about once every 22,000 years. Assuming that water constituted about a third of volcanic gases, based on samples of ancient lunar magma, the eruptions may have released 20 trillion metric tons of water vapor in total, the team calculates.

Some water would have been lost to space as sunlight broke down its molecules or the solar wind blew them away. But at the frigid poles, water could have stuck to the surface as ice.

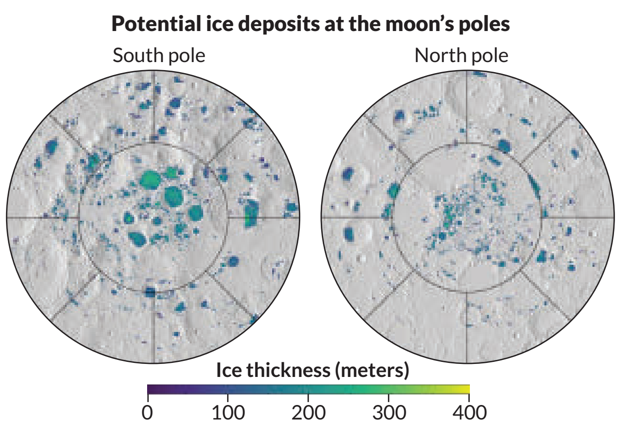
For that to happen, the rate at which the water vapor condensed would have needed to surpass the rate at which it escaped the moon. A computer simulation developed by the team suggests that about 40 percent of the total erupted water vapor could have accumulated as ice. At their thickest, current ice deposits may be as much as hundreds of meters thick.

An atmospheric transit system would have allowed water molecules to travel around the moon while also making it more difficult for them to flee into space. On average, each eruption would have triggered a new atmosphere that lingered for about 2,500 years before disappearing until the next eruption 20,000 years later, the researchers calculate.

“It’s a really interesting act of imagination,” says Parvathy Prem, a planetary scientist at the Johns Hopkins Applied Physics Laboratory in Laurel, Md. “How do you create atmospheres from scratch? And why do they sometimes go away?”

The ice itself may record clues to its origin. Finding sulfur in the ice, for example, would indicate the water probably came from a volcano, not, say, an asteroid.

Looking for sulfur could be important to future missions. Lunar ice could someday be harvested by astronauts for water or rocket fuel. If the water is contaminated with sulfur, “that’s a pretty critical thing to know if you plan on bringing a straw with you to the moon,” says study coauthor Margaret Landis, a planetary scientist at the University of Colorado. ■



Ice on the moon
Ice might have arrived at the moon’s poles in the form of water vapor released by volcanic eruptions billions of years ago. A computer simulation suggests that the south pole retains more ice today because it has more cold traps, where temperatures can keep water frozen for billions of years, than the north pole.

A.X. WILCOSKI, P.O. HAYNE AND M.E. LANDIS/*PLANETARY SCIENCE JOURNAL* 2022

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created based on computer simulations that solve the equations of general relativity, Einstein’s theory of gravity. The recoil was so large, the researchers found, that the black hole was probably ejected from its home and kicked to the cosmic curb.

Dense groups of stars and black holes called globular clusters are one locale where black holes are thought to partner up and merge. The probability that the kicked black hole would stay within a globular cluster, if that’s where it originated, is only about 0.5 percent, the team calculated. If in another type of dense environment, called a nuclear star cluster, the probability is about 8 percent.

The black hole’s great escape could have big implications. LIGO and Virgo detect mergers of stellar-mass black holes, which form when a star explodes in a supernova and collapses into a black hole. Scientists want to understand if black holes that partner up in crowded clusters could partner up again, going through multiple rounds of melding. If they do, that might help explain some surprisingly bulky black holes previously seen in mergers (SN: 9/26/20, *p.* 7). But if merged black holes commonly get rocketed away from home, that would make multiple mergers less likely.

LIGO and Virgo data had previously revealed evidence of black holes getting small kicks. But the new study is the first to report using gravitational waves to spot a black hole on the receiving end of a large kick. That big kick isn’t a surprise, says astrophysicist Manuela Campanelli of the Rochester Institute of Technology in New York. Theoretical predictions by Campanelli and colleagues suggested that such kicks were possible. “It’s always exciting when someone can measure from observations what you predicted from calculations.” ■

EARTH & ENVIRONMENT

Lab aims to mimic extreme hurricanes

Future facility will help communities prepare for stronger storms

BY CAROLYN GRAMLING

Winds howl at over 300 kilometers per hour, battering a two-story wooden house and ripping off its roof. Then comes the water. A 6-meter-tall wave engulfs the structure, knocking the house off its foundation and washing it away.

That's the terrifying vision of researchers planning a facility to re-create the havoc wreaked by the most powerful hurricanes on Earth. In January, the group received $12.8 million from the National Science Foundation to design a facility that can both simulate wind speeds of at least 290 km/h and produce towering storm surges.

No existing facility can create such a one-two punch of extreme wind and water. But it's an idea whose time has come — and not a moment too soon.

"It's a race against time," says disaster researcher Richard Olson, director of extreme events research at Florida International University, or FIU, in Miami.

Human-caused climate change is intensifying hurricanes: They're getting bigger, wetter, stronger and slower (*SN: 12/5/20, p. 14*). Coastal communities need to know how to design buildings, bridges, roads and other infrastructure that are resilient to such punishing winds and waves.

To help communities prepare, FIU researchers are leading a team of engineers, computational modelers and resilience experts to work out how best to simulate these behemoths.

Such superstorms aren't just hypothetical. In just the last few years, Atlantic Ocean hurricanes Dorian (2019) and Irma (2017) have had wind speeds well over 290 km/h. Such ultraintense storms are sometimes called "Category 6" hurricanes, though that's not an official designation. (The U.S. National Oceanic and Atmospheric Administration's hurricane scale tops off at Category 5, which includes any storm with winds of 252 km/h or above.)

Labels aside, the need to prepare for these stronger storms is clear, Olson says. "I don't think anybody wants to be explaining 20 years from now why we didn't do this," he says. "We have challenged nature. Welcome to payback."

FIU already hosts the Wall of Wind, a huge hurricane simulator housed in a hangar anchored at one end by an arc of 12 giant fans. At full blast, the fans generate wind speeds of up to 252 km/h — equal to a low-grade Category 5 storm.

Inside, researchers populate the hangar with shapes representing trees, houses, or even the bumps and dips of the land surface, all of which affect wind flow.

Fans tower over one end of the Wall of Wind, a facility in Florida where researchers simulate hurricane winds. A future facility may re-create even stronger winds plus storm surges.

NSF-NHERI WALL OF WIND/FIU

Engineers from around the world visit the facility to test the wind resistance of their structural designs, watching as the winds pummel their creations.

It's one of eight facilities in a network of labs that study the potential impacts of wind, water and earthquake hazards, collectively called the U.S. Natural Hazards Engineering Research Infrastructure.

The Wall of Wind is designed for full-scale wind testing of entire structures. Another wind machine, at the University of Florida in Gainesville, can zoom in on the turbulent behavior of winds at the boundary between the atmosphere and ground. Then there are the giant tsunami- and storm surge–simulating water wave tanks at Oregon State University in Corvallis.

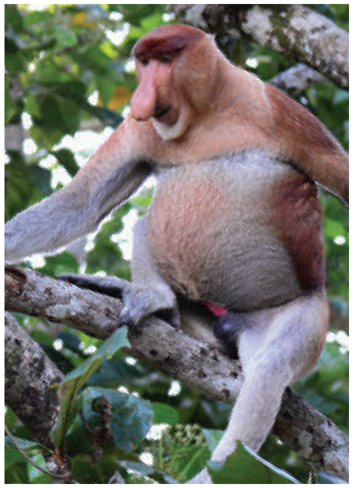
FIU's new facility aims to build on the shoulders of these giants. The design phase is projected to take four years as the team ponders how to ramp up wind speeds — possibly with more, or more powerful, fans than the Wall of Wind has — and how to combine those winds and water tanks in one experimental space.

This design phase will also include building a scaled-down version of the future lab as proof of concept. Building the full-scale facility would require a new round of funding and several more years.

Past approaches to studying the impacts of strong wind storms have tended to use one of three approaches: making field observations of the aftermath of a given storm, building experimental facilities to re-create storms' impacts or using computational simulations to visualize how those impacts might play out over large geographic regions. Each approach has strengths and limitations, says Tracy Kijewski-Correa, a disaster risk engineer at the University of Notre Dame in Indiana.

"In this facility, we want to bring together all of these methodologies" to get as close as possible to re-creating what Mother Nature can do, she says.

It's a challenging engineering problem, but an exciting one. "There's a lot of enthusiasm for this in the broader scientific community," says Forrest Masters, a wind engineer at the University of Florida. "If it gets built, nothing [else] like it will exist." ■



A young monkey (far left) being groomed by a female silvered leaf monkey may be a hybrid, perhaps born after the female mated with a male proboscis monkey (one shown, right).

FROM LEFT: KEN S.H. CHING; KINMATSU LIN/INATURALIST (CC BY-NC 4.0)

LIFE & EVOLUTION

Mystery monkey may be a rare hybrid

Habitat loss in Borneo could have driven two species to mate

BY ANNE PINTO-RODRIGUES

Six years ago, tour guide Brenden Miles was traveling down the Kinabatangan River in the Malaysian part of Borneo when he spotted a primate he had never seen before. He snapped a few pictures and checked the images at home.

At first, Miles says, he thought the primate might be a silvered leaf monkey with a rare color variation. But then he noticed other little details. "Its nose was long like that of a proboscis monkey, and its tail was thicker than that of a silvered leaf [monkey]," he says. He posted a picture of the animal on Facebook and forgot all about it.

An analysis of that photo and others suggests that the mystery individual is a hybrid of two distantly related monkey species that share the same fragmented habitat.

The putative offspring was produced when a male proboscis monkey (*Nasalis larvatus*) mated with a female silvered leaf monkey (*Trachypithecus cristatus*), researchers suggest April 26 in the *International Journal of Primatology*. That conclusion has the scientists worried about the creature's parent species.

Hybridization between closely related organisms is observed in captivity and occasionally in the wild. "But hybridization across genera, that's very rare," says conservation practitioner Ramesh Boonratana, the regional vice chair for Southeast Asia for the International Union for Conservation of Nature's primate specialist group.

Severe habitat loss, fragmentation and degradation caused by expanding oil palm plantations along the Kinabatangan River could explain how the possible hybrid came to be, says primatologist Nadine Ruppert of Universiti Sains Malaysia in Penang Island.

"Different species — even from the same genus — when they share a habitat, they may interact with each other, but they may usually not mate. This kind of cross-genera hybridization happens only when there is some ecological pressure," Ruppert says.

The Kinabatangan River is in the state of Sabah, which lost about 40 percent of its forest cover from 1973 to 2010, with logging and oil palm plantations being the main drivers of deforestation, a study published in 2014 found.

"In certain areas, both [monkey] species are confined to small forest fragments along the river," Ruppert says. This leads to competition for food, mates and other resources. "The animals cannot disperse and, in this case, the male of the larger species — the proboscis monkey — can easily displace the male silvered leaf monkey."

Since 2016, there have been more documented sightings of the mystery monkey, though these have been sporadic. The infrequent sightings and the COVID-19 pandemic have, for now, prevented researchers from gathering fecal samples for genetic analysis to confirm the monkey's identity. Instead, Ruppert and colleagues compared images of the possible hybrid with those of the possible parent species, both visually as well as by using limb proportions. "If the individual was from one of the two parent species, all its measurements would be similar to that of one species," Ruppert says. "But that is not the case with this animal."

A photograph of a male proboscis monkey mating with a female silvered leaf monkey, along with anecdotes from boat operators and tour guides about a single male proboscis monkey hanging around a group of female silvered leaf monkeys, has added further weight to the researchers' conclusion.

The mystery monkey is generating a lot of excitement in the area, but Ruppert is concerned for the welfare of both proposed parent species. The International Union for Conservation of Nature classifies proboscis monkeys as endangered and silvered leaf monkeys as vulnerable. "The hybrid is gorgeous, but we don't want to see more of them," Ruppert says. "Both species should have a large enough habitat, dispersal opportunities and enough food to conduct their natural behaviors in the long term," Ruppert argues.

Increasing habitat loss or fragmentation in Borneo and elsewhere as a result of climate change or shifts in land use could lead to more instances of mating — or at least, attempts at mating — between species or even genera, Boonratana says.

The mystery monkey was last photographed in September 2020 with swollen breasts and holding a baby, suggesting that the animal is a fertile female. That would be another surprising development, the researchers say, because many hybrids tend to be sterile. ■

LIFE & EVOLUTION

Tree salamanders glide like skydivers

The amphibians control their descent without webbed limbs

BY JAKE BUEHLER

In one of the tallest trees on Earth, a tan, mottled salamander ventures out on a fern growing high up on the trunk. Reaching the edge, the amphibian leaps like a skydiver exiting a plane.

The salamander's apparent confidence is well-earned. The amphibian can expertly control its descent, gliding while maintaining a skydiver's spread-out posture, researchers report in the May 23 *Current Biology*.

Wandering salamanders (*Aneides vagrans*) are native to a strip of forest in far northwestern California where they climb into the canopies of redwoods. There — as high up as 80 meters or so — the amphibians inhabit mats of ferns that grow in a suspended, miniature ecosystem.

Integrative biologist Christian Brown was studying these canopy crawlers as a graduate student when he noticed they would jump from a hand or branch when perturbed. Brown, now at the University of South Florida in Tampa, and colleagues wondered if the salamanders' arboreal ways and proclivity to leap were related.

The team captured five *A. vagrans* salamanders, plus five each from a slightly less arboreal species and two ground-dwelling species. The team put each salamander in a vertical wind tunnel to simulate falling, filming the falls with a high-speed camera.

Each species was tested in 45 trials. In all trials, the wandering salamanders showed tight control, using their outstretched limbs and tail to maintain a stable position in the air and continuously adjusting as they sailed. These salamanders also slowed their descent speed, what the researchers call parachuting, using their appendages at some point, and in many cases changed course and moved horizontally, or glided.

The slightly less arboreal species had similar aerial dexterity but glided less (16 of 45 trials, or 36 percent of the time, versus 26 of 45 trials, or 58 percent). The two ground huggers mostly flailed ineffectively in the wind.

The wandering salamander, an unexpected aerial ace, can soar from redwood trees.

The wandering salamanders' maneuverable gliding is probably invaluable in the tops of the tall redwoods, Brown says. Rerouting midair to a fern mat or branch during an accidental fall would save the effort spent crawling back up a tree. Gliding might also make jumping to escape a hungry owl or mammal a feasible option.

Brown suspects that the salamanders also use gliding to access better places to live. "Maybe your fern mat's drying out. Maybe there's no bugs. Maybe there are no mates in your fern mat, you look down — there's another fern mat," Brown says. "Why would you take the time to walk down the tree and waste energy, be exposed and [risk] being preyed upon when you could take the gravity elevator?"

Arboreal salamanders also live in the tropics, but those don't live nearly as high as *A. vagrans*, says Erica Baken, a macroevolutionary biologist at Chatham University in Pittsburgh. "It would be interesting to find out if there is a height at which [gliding] evolves."

A. vagrans' relatively flat body, long legs and big feet may allow more control in the air. Brown and colleagues are now using computer simulations to test how body proportions might impact gliding.

Such body tweaks, if they do turn out to be meaningful, wouldn't be as conspicuous as the sprawling, membraned forms seen in other animals know for gliding, such as flying snakes. Many tree-dwelling animals with conventional body plans may be overlooked as gliders, Brown says. "The canopy world is just starting to unfold." ■

C. BROWN

Watch salamanders glide and parachute at **bit.ly/SN_Salamander**

EARTH & ENVIRONMENT

Biocrusts keep the dust settled

The future could be dustier if soil skins aren't protected

BY NIKK OGASA

In the unceasing battle against dust, humans possess a deep arsenal of weaponry, from microfiber cloths and feather dusters to vacuum cleaners. But new research suggests that none of that technology can compare to nature's secret weapon: biological soil crusts.

These biocrusts are thin, cohesive layers of soil, glued together by dirt-dwelling organisms, that often carpet arid landscapes. Though innocuous, these rough soil skins prevent about 700 teragrams (about 30,000 times the mass of the Statue of Liberty) of dust from wafting into the air each year, reducing global dust emissions by roughly 60 percent, researchers report May 16 in *Nature Geoscience*. Unless steps are taken to preserve and restore biocrusts, which are threatened by climate change and shifts in land use, the future will be much dustier, the scientists warn.

Dryland ecosystems, such as savannas, shrublands and deserts, may appear barren, but they provide this important natural service that is often overlooked, says ecologist Bettina Weber of the Max Planck Institute for Chemistry in Mainz, Germany. The findings, she says, "really call for biocrust conservation."

Biocrusts, which cover about 12 percent of Earth's land surface, are constructed by communities of fungi, lichens, cyanobacteria and other microorganisms that live in the topmost millimeters of soil and clump soil particles together using filament-shaped appendages and adhesive substances. In dryland ecosystems, biocrusts play an important role in concentrating nutrients such as carbon and nitrogen and preventing soil erosion.

Since most of the world's dust comes from dry lands, biocrusts are important for keeping dust bound to the ground. Fallen dust can carry nutrients that benefit plants, but it can also reduce water and air quality, hasten glacier melting and reduce river flows. For instance, in the Upper Colorado River Basin, researchers have found that dust not only decreases snow's ability to reflect sunlight, but it also shortens the duration of snow cover by weeks, reducing flows of meltwater into the Colorado River by about 5 percent. That's more water than the city of Las Vegas uses in a year, says Matthew Bowker, a soil ecologist at Northern Arizona University in Flagstaff who wasn't involved in the new study.

Experiments had already shown that biocrusts strengthen soils against erosion, but Weber and colleagues were curious how that effect plays out on a global scale. They pulled data from experimental studies that measured wind velocities needed to erode dust from various soil types and calculated how differences in biocrust coverage would affect dust generation. The wind velocities needed to erode dust from soils completely shielded by biocrusts are on average about five times as high as the wind velocities needed to erode bare soils.

The researchers incorporated these results, along with data on global biocrust coverage, into a global climate simulation to estimate how much dust the world's biocrusts trap each year.

Lichens (whitish-pink) and cyanobacteria (dark brown to blackish) form biocrusts that carpet the ground between succulent plants and shrubs in South Africa's Succulent Karoo ecoregion.

"Nobody has really tried to make that calculation globally before," Bowker says. "Even if their number is off, it shows us that the real number is probably significant."

Using projections of future climate conditions and data on the conditions biocrusts can tolerate, Weber and colleagues estimate that by 2070, climate change and land-use shifts may result in a roughly 25 to 40 percent reduction in area covered by biocrusts globally, which would increase global dust emissions by about 5 to 15 percent.

Preserving and restoring biocrusts will be key to mitigating soil erosion and dust production, Bowker says. Hopefully, these results will help to whip up more discussions on the impacts of land-use changes on biocrust health, he says. "We need to have those conversations." ■

LIFE & EVOLUTION

Headbutts hurt musk ox brains

Punishing headbutts damage the brains of musk oxen. That observation, reported May 17 in *Acta Neuropathologica*, suggests that a life full of bell-ringing clashes is not without consequences, even in animals built to bash.

When charging, a musk ox can reach speeds of up to 60 kilometers an hour before ramming its head directly into an oncoming head. The assumption was that musk ox brains could withstand these forces largely unscathed, says neuroscientist Nicole Ackermans of the Icahn School of Medicine at Mount Sinai in New York City. "No one actually checked."

In fact, the brains of three wild musk oxen (two were female and one was male) showed signs of extensive damage, Ackermans and colleagues found. The damage was similar to what's seen in people with chronic traumatic encephalopathy, a disorder caused by repetitive head hits. In the musk ox brains, a form of a protein called tau had accumulated in patterns that suggested brain bashing was to blame.

In a twist, the brains of the females, which hit heads less frequently than males, were worse off than the male's brain. The male body may cushion blows better with its heavier skull, stronger neck muscles and other protective features.

The results may highlight an evolutionary balancing act: Musk oxen can endure just enough brain damage to allow them to survive and procreate. High-level brainwork may not matter much, Ackermans says. "Their day-to-day life is not super complicated."

—Laura Sanders

FROM TOP: B. WEBER; RAFFI MAGHDESSIAN/AURORA OPEN/GETTY IMAGES PLUS

HUMANS & SOCIETY

Cross-cultural theory falls short in Latin America

Individualist versus collectivist framework is too simplistic

BY SUJATA GUPTA

When Igor de Almeida moved to Japan from Brazil nine years ago, the transition should have been relatively easy. Both Japan and Brazil are collectivist nations, where people tend to value the group's needs over their own. Research shows that immigrants adapt more easily when the home and new countries' cultures match.

But to de Almeida, a cultural psychologist now at Kyoto University, the cultural differences were striking. Japanese people tend to prioritize formal relationships, such as with coworkers or members of the same extracurricular club, for instance, while Brazilian people tend to prioritize friends in their informal social network. "Sometimes I try to find [cultural] similarities, but it's really hard," de Almeida says.

New research helps explain that disconnect. For decades, psychologists have studied how culture shapes the mind, or people's thoughts and behaviors, by comparing Eastern and Western nations. But two research groups working independently in Latin America are finding that a cultural framework that splits the world in two is overly simplistic.

Due to differences in methodology and interpretation, the recent findings are also contradictory. And that raises a larger question: Will overarching cultural theories based on East-West divisions hold up over time, or are new theories needed?

However this debate unfolds, cultural psychologists argue that the field must expand. "If you make most of the cultures of the world … invisible," says Vivian Vignoles, a cultural psychologist at the University of Sussex in England, "you will get all sorts of things wrong."

Such misconceptions can jeopardize political alliances, business relationships, public health initiatives and general

Brazilian Japanese people play Japanese taiko drums. Brazil and Japan are both collectivist nations, but the people think and act in very different ways, making assimilation difficult.

theories for how people find happiness and meaning. "Culture shapes what it means to be a person," says Stanford University behavioral scientist Hazel Rose Markus. "What it means to be a person guides all of our behavior, how we think, how we feel, what motivates us [and] how we respond to other individuals and groups."

Culture and the mind

Most psychologists used to believe that culture had little bearing on the mind. That changed in 1980. Surveys of IBM employees from some 70 countries showed that attitudes about work largely depended on a worker's culture, organizational psychologist Geert Hofstede found.

Later, Markus and Shinobu Kitayama, a cultural psychologist at the University of Michigan in Ann Arbor, fleshed out one of Hofstede's cultural principles: individualism versus collectivism. The pair surmised that living in individualist countries (the West) led people to think independently while living in collectivist countries (the East) led people to think interdependently.

That work, published in 1991, was pioneering, Vignoles says. Psychological research was based mostly in the West, and the Western mind had become the default mind. Now, Vignoles says, "instead of being only one kind of person in the world, there [were] two kinds."

Latin America: a case study

How individualism/collectivism shapes the mind now undergirds the field of cross-cultural psychology. But researchers continue to treat the East and West, chiefly Japan and the United States, as prototypes, Vignoles and colleagues say.

To expand beyond that lens, the team surveyed over 7,000 people in 33 nations and 55 cultures. Participants read such statements as "I prefer to turn to other people for help rather than solely rely on myself" and "I consider my happiness separate from the happiness of my friends and family," and then rated how well those comments reflected their values.

From that survey, the researchers identified seven dimensions of independence/interdependence, including self-reliance versus dependence on others and emphasis on self-expression versus harmony. Strikingly, Latin Americans were as, or more, independent as Westerners in six of the seven dimensions, the team reported in 2016 in the *Journal of Experimental Psychology: General*.

A subsequent analysis of four studies comprising over 17,000 participants from 53 nations largely reaffirmed that finding. For instance, Latin Americans are more expressive than Westerners, Vignoles, de Almeida and colleagues reported in February in *Perspectives in Psychological Science*. That finding violates the common view that people in collectivist societies suppress their emotions to foster harmony, while people in individualistic countries emote as a form of self-expression.

Latin American nations are collectivist, as defined by Hofstede and others, but the people think and behave independently, the team concludes.

A team led by Kitayama has a different take: Latin Americans are interdependent, just not like East Asians. Rather than suppressing emotions, Latin Americans tend to express positive, socially engaging emotions to communicate with others, says cultural psychologist Cristina Salvador of Duke University. That fosters interdependence. Westerners tend to express emotions to show personal feelings, which often have little to do with a person's social surroundings — a sign of independence.

Salvador, Kitayama and colleagues asked more than 1,000 people in Chile, Colombia, Mexico, Japan and the United States to reflect on various social scenarios, instead of having participants respond to explicit statements like Vignoles' team.

For instance, respondents had to imagine winning a prize and then pick what emotions — such as shame, guilt, anger, friendliness or closeness to others — they would express with family and friends.

Respondents in Latin America and the United States expressed strong emotions, Salvador reported in San Francisco in February at a Society for Personality and Social Psychology conference. But while people in the United States expressed egocentric emotions, such as pride, people in Latin America expressed emotions that emphasize connection with others.

Latin America's high ethnic and linguistic diversity made communication with words alone difficult, Kitayama says. "Emotion became a very important means of social communication."

Decentering the West

A shift to a broader framework beyond the East-West binary has begun. But how should that work proceed?

Kitayama's team has mapped how interdependence, which probably preceded the emergence of independence, might have morphed as it spread around the globe. "Self-effacing interdependence" in East Asia, the team says, stemmed from the communal nature of rice farming, "self-assertive interdependence" in Arab regions arose from the nomadic life and "argumentative interdependence" in South Asia came from the area's central role in trade.

Cultural psychology started with a "West and the rest" mentality, Kitayama says. His work with Markus created an "East-West and the rest" mentality. Finally, psychologists are grappling with "the rest," he says.

De Almeida imagines decentering the West further. What if researchers had started off by comparing Japan and Brazil instead of Japan and the United States? Instead of the focus on individualism/collectivism, some other defining facet of culture might have risen to prominence, he says. "I would say emotional expression, that's the most important thing."

He sees a straightforward solution. "We could increase the number of studies not involving the United States," he says. "Then we could develop new paradigms." ■

LIFE & EVOLUTION

Coral rubs may be dolphin self-care

Substances in the coral may keep the mammals' skin healthy

BY ERIN GARCIA DE JESÚS

On scuba dives in the northern Red Sea, wildlife biologist Angela Ziltener often noticed dolphins doing something intriguing. These Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) would line up to take turns brushing their bodies against corals or sea sponges on the seafloor. After more than a decade as an "adopted" member of the pod — a status that let Ziltener get up close without disturbing the animals — she and her team suspect they know why the animals behave this way: They may use corals and sea sponges as their own private pharmacies.

The invertebrates make antibacterial compounds — plus others with antioxidant or hormonal properties — that probably get released into the water when dolphins make contact, Ziltener and colleagues report May 19 in *iScience*. Rubbing could help dolphins maintain healthy skin.

Ziltener, of the University of Zurich, captured video showing dolphins using corals like a bath brush, swimming by to rub various parts of the body. Often it's a peaceful social gathering. "It's not like they're fighting each other for the turn," Ziltener says. "No, they wait and then they go through." Other times, an individual dolphin will arrive at a coral patch on its own.

But the dolphins don't buff their bodies against just any corals, Ziltener says. They're picky, primarily rubbing up against two types of corals and one kind of sea sponge.

Ziltener and colleagues identified 17 compounds in small samples of these corals and sponges, including 10 compounds with antibacterial or antimicrobial activity. It's possible that as the dolphins swim by, the compounds help protect against skin irritations or infections, says study coauthor Gertrud Morlock, an analytical chemist at Justus Liebig University Giessen in Germany.

Other animals, including chimpanzees, are known to self-medicate (*SN: 11/3/90, p. 280*). Marine biologist Jeremy Kiszka of Florida International University in Miami says the new study convinces him that the dolphins use corals and sea sponges for that purpose, but additional experiments are necessary to prove the link. Lab tests, for instance, could identify the types of bacteria that the compounds might work against.

It's also possible that in addition to prevention, dolphins use corals and sea sponges to treat active skin infections, Ziltener says, but the team has yet to see proof of a coral cure. Next up, she says, is figuring out whether dolphins prefer to rub specific body parts on specific corals in this "underwater spa." ■

An Indo-Pacific bottlenose dolphin rubs itself on corals. This behavior may help keep the animal's skin healthy thanks to substances within the corals, researchers say.

A. ZILTENER/DOLPHIN WATCH ALLIANCE

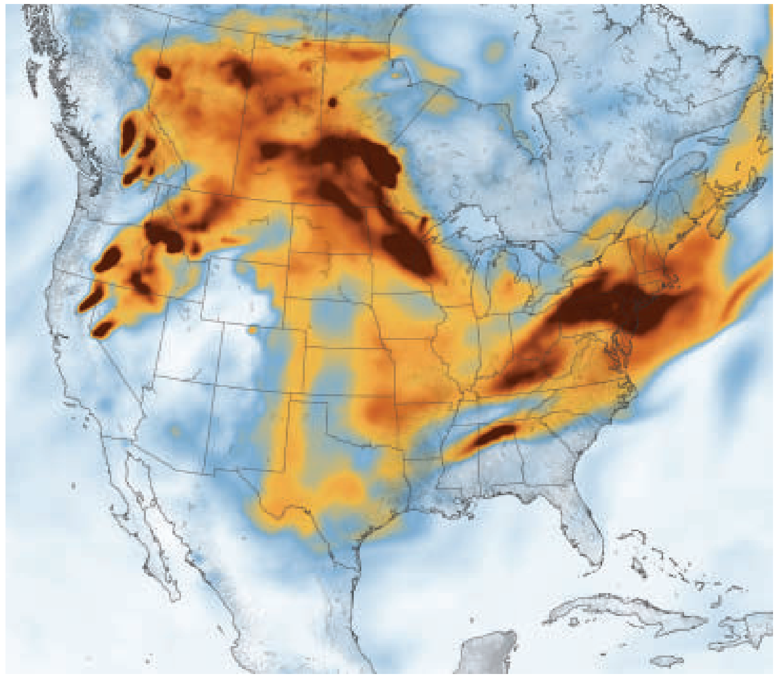
Watch dolphins rub against coral at **bit.ly/SN_DolphinCare**

WILDFIRE SMOKE THREATENS HEALTH FROM AFAR

Western wildfires, like the 2018 Camp Fire in Paradise, Calif., are devastating for local communities. Their smoke also travels to heavily populated areas to the east. Researchers are beginning to study the health effects for people far from the fires.

Bad air in the East, from fires in the West, sends people to emergency rooms

By Megan Sever



Smoke poured into the eastern United States and Canada from wildfires in the West on July 21, 2021 (darker red is denser smoke). Residents of eastern cities received code orange and code red warnings that air quality was unhealthy.

After a relaxing day at the Jersey Shore last July, Jessica Reeder and her son and daughter headed back home to Philadelphia. As they crested a bridge from New Jersey into Pennsylvania, they were greeted with a hazy, yellow-gray sky. It reminded Reeder of the smoky skies she saw growing up in Southern California on days when fires burned in the dry canyons.

Smelling smoke and worried about her asthma and her kids, Reeder flipped the switch to recirculate the air inside the car instead of drawing from the outside. At home, the family closed all the windows and turned their air purifiers on high.

The smoke had traveled from fires raging on the other side of the continent, in the western United States and Canada. Although air quality in Philadelphia didn't come close to the record-bad air quality that some western cities experienced, it was bad enough to trigger air quality warnings—and not just for people with asthma or heart problems.

Most large U.S. wildfires occur in the West. But the smoke doesn't stay there. It travels eastward, affecting communities hundreds to thousands of kilometers away from the fires. In fact, the majority of asthma-related deaths and emergency room visits attributed to fire smoke in the United States occur in eastern cities, according to a study in the September 2021 *GeoHealth*.

The big problem is fine particulate matter, tiny particles also known as $PM_{2.5}$. These bits of ash, gases and other detritus suspended in smoke are no more than 2.5 micrometers wide, small enough to lodge in the lungs and cause permanent damage. $PM_{2.5}$ exacerbates respiratory and cardiovascular problems and can lead to premature death. The particles can also cause asthma and other chronic conditions in otherwise healthy adults and children.

Over the last few decades, U.S. clean air regulations have cut down on particulate matter from industrial pollution, so the air has been getting cleaner, especially in the populous eastern cities. But the regulations don't address particulate matter from wildfire smoke, which recent studies show is chemically different from industrial air pollution, potentially more hazardous to humans and increasing significantly.

With the intensity and frequency of wildfires increasing due to climate change, people across North America need to be concerned about health impacts.

So far, a lot of the research on how wildfire $PM_{2.5}$ can make people sick has been based on people living or working near fires in the West. Now, researchers are turning their attention to how $PM_{2.5}$ from smoke affects the big population centers in the East, far from the wildfires. One thing is clear: With the intensity and frequency of wildfires increasing due to climate change (SN: 12/19/20 & 1/2/21, p. 32), people across North America need to be concerned about the health impacts, says Katelyn O'Dell, an atmospheric scientist at George Washington University in Washington, D.C.

Bad air travels

Air pollution regulations limit $PM_{2.5}$ from exhaust-emitting cars and trucks and fossil fuel–burning factories and power plants. These regulations have done "a really good job" reducing anthropogenic air pollution in the last couple of decades, says Rosana Aguilera, an environmental scientist at the Scripps Institution of Oceanography in La Jolla,

New York City, visible through hazy skies in September 2020, and many places in the East have seen some of the worst air quality in decades due to fires burning in the U.S. West and in Canada. Such fires are increasing in intensity and frequency.

Calif. In the United States, concentrations of six of the most common air pollutants have dropped by 78 percent since the Clean Air Act of 1970, according to the U.S. Environmental Protection Agency. $PM_{2.5}$ concentrations have come down as well—at least until recently.

Western wildfires, which are growing more frequent, more severe and larger, are erasing some of the gains made in reducing industrial pollution, says Rebecca Buchholz, an atmospheric chemist at the National Center for Atmospheric Research in Boulder, Colo.

Fires in the Pacific Northwest are "driving an upward trend" in particulate matter air pollution, Buchholz and colleagues wrote April 19 in *Nature Communications*. Such smoke pollution peaks in August when fires in the region tend to spike and the atmosphere's ability to clean itself through, say, rain, is limited. This spike of late-summer air pollution is new, Buchholz says. It's especially noticeable since 2012.

And, as Reeder and her family experienced last year, transported wildfire pollution is causing substantial particulate matter spikes in the central United States and northeastern North America, Buchholz and colleagues found. Pacific Northwest wildfires thus "have the potential to impact surface air quality, even at large distances downwind of the wildfires," the team wrote, putting some 23 million people in the central United States and 72 million in northeastern North America at increased risk of health impacts from the imported wildfire smoke.

How far and where $PM_{2.5}$ travels depends on weather patterns and how high wildfire smoke reaches—the stronger the fire, the longer it can last and the farther smoke can go, and thus the farther particulate matter can reach. Last year, far-away wildfires created unhealthy air quality conditions in locations from the Great Plains to New York City and Washington, D.C.

New York City saw some of its worst air quality in two decades. Philadelphia had two "code red" days—meaning air quality was unhealthy for all—because of the U.S. West and Canadian fires. In 2019, 2020 and 2021, those fires pushed $PM_{2.5}$ to unhealthy levels in much of Minnesota. In fact, a 2018 study showed that wildfire smoke plumes now waft above Minnesota for eight to 12 days per month between June and September.

Human impacts

Smoke in the West is already having a tangible effect on human health in the East, says O'Dell, lead author of the 2021 *GeoHealth* study.

Reviewing smoke and health data from 2006 to 2018, O'Dell and colleagues found that more people visit emergency rooms and are hospitalized in the East than in the West from asthma problems attributable to smoke $PM_{2.5}$. Asthma-related ER visits and hospitalizations were higher east of the Rockies in 11 of the 13 years.

Over the study period, an average of 74 percent of asthma-related deaths and 75 percent of asthma ER visits and hospitalizations attributable to smoke occurred east of the Rockies. Of the estimated 6,300 excess deaths from asthma complications due to smoke $PM_{2.5}$ that occurred

Air safety yardstick The Air Quality Index, or AQI, ranges from 0 to 500, based on the amount of pollution in the air at a given time. Ground-level ozone, particulate matter (both PM_{10} and $PM_{2.5}$), carbon monoxide, sulfur dioxide and nitrogen dioxide are the primary parameters considered in the index. Code orange (above a score of 100) is unhealthy for people with heart and lung disease, older adults, children and people with diabetes. Code red and above (151–500) is unhealthy for everyone.

Good	Moderate	Unhealthy for sensitive groups	Unhealthy	Very unhealthy	Hazardous
0–5	51–100	101–150	151–200	201–300	301–500

GARY HERSHORN/GETTY IMAGES PLUS; T. TIBBITTS annually over the study period, more than 4,600 were in the East.

Smoke affects so many more people in the East primarily because more people live there, O'Dell notes. Her team defined "West" as west of the Rockies, with a population of 64 million, and "East" as east of the Rockies, home to 226 million people. In the West, smoke $PM_{2.5}$ causes a higher portion of regional asthma deaths. In the East, it's a lower portion of the total population, but a far higher total number of people affected.

"We may be already seeing the consequences of these fires on the health of residents who live hundreds or even thousands of miles downwind," Buchholz said in a press release.

Vulnerable youth

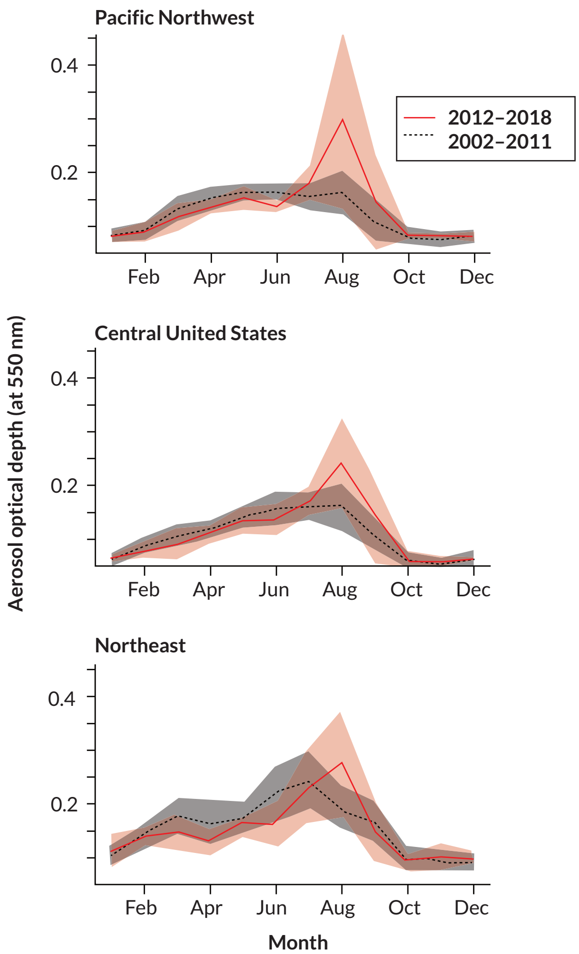
"Asthma is a very widespread, common health condition," says Yang Liu, an environmental scientist at Emory University in Atlanta. In the United States, about 25 million people have asthma, or 8 percent of adults and 7 percent of children, according to the U.S. Centers for Disease Control and Prevention.

Fine particulate matter can spark asthma attacks, but it can also be a danger to people without the condition. Children are especially vulnerable primarily because of physiology. Children breathe faster so they end up taking in more particulate matter, plus their lungs are smaller so more of their lung surface is likely to be damaged when they breathe in particulate matter. And their lungs are still developing, says Jennifer Stowell, an environmental epidemiologist at Boston University School of Public Health.

Stowell led a study, reported in the January *Environmental Research Letters*, estimating how much wildfire smoke will exacerbate asthma attacks in the West. Stowell, Liu and colleagues estimate that, in the 2050s, there will be an additional 155,000 asthma-related ER visits and hospitalizations per wildfire season in the West just from smoke $PM_{2.5}$. The biggest concern, Stowell says, is for children and younger adults.

Aguilera at Scripps and her colleagues found associations between wildfire-specific $PM_{2.5}$ and pediatric respiratory-related ER and urgent care visits. In San Diego County from 2011 to 2017, wildfire-specific $PM_{2.5}$ was 10 times as harmful to respiratory health in children 5 and younger as ambient $PM_{2.5}$, the researchers reported in 2021 in *Pediatrics*. In fact, the same increase in levels of $PM_{2.5}$ from smoke versus ambient sources caused a 26 percent higher rate of ER or urgent care visits. The researchers didn't note whether the children had preexisting asthma.

North American seasonal atmospheric aerosol levels, by region



August peaks Although aerosols, including fine particulate matter, from Pacific Northwest fires have been increasing since 2002, they began a sharp increase in 2012, spiking in the warm, dry summer months. As smoke from the Northwest wafted eastward, similar smaller spikes were seen in the Central United States and northeastern North America.

And even when a wildfire increased $PM_{2.5}$ by a small amount, respiratory ER and urgent care visits in kids 12 and under increased, Aguilera and colleagues reported in 2020 in the *Annals of the American Thoracic Society*. "Even relatively smaller wildfires can still generate quite an impact on the pediatric population," Aguilera says. "And really, any amount of PM or air pollution is harmful."

Studies of nonhuman primates have also shown permanent effects of smoke on the young—results researchers expect would also apply to humans, given genetic similarities. In 2008, a group of infant rhesus macaques at the California National Primate Research Center at the University of California, Davis was exposed to high $PM_{2.5}$ levels

At the California National Primate Research Center, rhesus macaques that were exposed to wildfire smoke early in life have immune disorders, nervous system changes and weakened lungs.

"Early life smoke exposure [in macaques]... changed the trajectory of lung development," and it doesn't appear to be reversible.

HONG JI

from a series of devastating wildfires in Northern California. Researchers have been comparing those monkeys with macaques born a year later that weren't exposed to smoke.

At around age 3, macaques exposed to smoke displayed immune disorders and reduced lung capacity, lung function and lung volume, says Hong Ji, a molecular biologist at UC Davis and the primate center who wasn't involved with this study. The lungs look like they had fibrosis, Ji says. "Early life smoke exposure... changed the trajectory of lung development," and it doesn't appear to be reversible, she says.

The monkeys exposed to wildfire $PM_{2.5}$ also have important changes to how their DNA works, Ji and colleagues reported in the January *Environment International*. Exposure to wildfire smoke in infancy can cause life-altering, long-term changes to the monkeys' nervous and immune systems, as well as brain development, Ji says. Even worse, she says, the DNA changes are the type that can be passed down and may result in generational damage.

Even macaques born after in utero exposure to wildfire smoke can suffer cognitive, immune and hormone problems, primate center researchers reported April 1 in *Nature Communications*.

Now, Ji and colleagues have teamed with Rebecca Schmidt, a molecular epidemiologist at UC Davis who's leading a study on the effects of wildfire smoke exposure on pregnant women and young children. This research group, as well as other teams, is also looking into whether $PM_{2.5}$ is causing genetic changes to babies exposed to smoke in utero, Ji says. The more results gathered on the effects of wildfire $PM_{2.5}$ on babies and children — and even in pregnancy — the more dangerous we realize it is, Ji says.

Chemical differences

Particulate matter changes as it travels through the atmosphere, both in volume and in chemistry. Some $PM_{2.5}$ is emitted directly from fires, and some is born from chemicals and trace gases emitted from fires that get chemically processed in the atmosphere, Buchholz says. Reactions that happen in the smoke plume, combined with sunlight, can create even more $PM_{2.5}$ downwind of the fires. How these particulates change chemically — through interactions between the atmosphere and the particulate matter, and between fire pollution and human pollution — and what that means for human health "is a really active area of research right now," she says. "It's super complicated."

Epidemiological and atmospheric chemistry studies indicate that wildfire $PM_{2.5}$ is more hazardous to human health than ambient $PM_{2.5}$, says Stowell, the Boston epidemiologist. One such study compared particulate matter from Amazonian fires with urban sources such as vehicle exhaust in Atlanta. Nga Lee Ng, an atmospheric chemist at Georgia Tech, and colleagues found that smoke particulate matter is more toxic than urban particulate matter, "inducing about five times higher cellular oxidative stress," Ng says. Oxidative stress damages cells and DNA in the body.

In addition, as smoke travels through the atmosphere and ages, it seems to become even more toxic, Ng says. Reactions between the particulate matter and sunlight and atmospheric gases change the particulate matter's chemical and physical properties, rendering it even more potentially harmful. So, even though particulate matter dissipates over time and distance, "the health effects per gram are greater," says Daniel Jaffe, an atmospheric chemist at the University of Washington Bothell.

That means that the studies of health effects near wildfires in the West may not represent the full story of how smoke from distant fires affects people in the East.

Liu, at Emory, hopes to see the U.S. government revisit policies related to what $PM_{2.5}$ levels are dangerous, since they're based on ambient and not wildfire-related $PM_{2.5}$. In March, an EPA advisory panel recommended just that. In a letter to the agency, the Clean Air Scientific Advisory Committee wrote: "Regarding the annual $PM_{2.5}$ standard, all CASAC members agree that the current level of the annual standard is not sufficiently protective of public health and should be lowered." They added, "There is substantial epidemiologic evidence from both morbidity and mortality studies that the current standard is not adequately protective."

Local communities throughout the country need to determine when to close schools or at least keep kids inside, Liu says, as well as when to advise people to close windows and turn on air purifiers. Good masks — N95 and KN95 — can help too (yes, masks that block viruses can also block particulate matter).

City, county and state governments also need to prepare the health care system to respond to increased asthma issues, Liu says. Some states are starting to respond. In 2017, for example, the Minnesota Pollution Control Agency increased its air quality monitoring stations around the state from two to 18. The agency is also working with the National Weather Service, the Minnesota Department of Health and the Minnesota Department of Transportation to better communicate air quality warnings.

In the meantime, much more research is needed into the human health implications of increasing wildfire smoke, Buchholz says, as well as the chemical interactions in the atmosphere, how climate is changing fires, how fires change year after year, and how they impact the atmosphere, not to mention how different trees, buildings and other fuels affect particulate matter.

"Wildfires are perhaps one of the most visible ways that [climate change] is linked to health," Stowell says. And the reality is, she says, "we're going to see it remain as bad or worse for a while." ■

Explore more

- Katelyn O'Dell *et al*. "Estimated mortality and morbidity attributable to smoke plumes in the United States: Not just a western US problem." *GeoHealth*. September 2021.

Megan Sever is a freelance science editor and writer based in Portland, Ore.

MINNESOTA POLLUTION CONTROL AGENCY

Minnesota, after experiencing a rise in smoky summer days, has added extra air quality monitoring stations to improve local forecasts.

Smoke gets on the brain

Health impact studies of air pollution, including wildfire smoke, have mostly focused on the lungs. But toxicologist Matthew Campen of the University of New Mexico in Albuquerque is looking at the brain.

In a study of the inflammatory effects of smoke $PM_{2.5}$ on the brains of mice, Campen and colleagues found that inflammation in the lungs was modest compared with the "profound" inflammation in the brain, Campen says. Given what's known about how damaging smoke can be in the lungs, to find even greater effects on the brain is troubling, he says.

The inflammatory effect on the mice's brains was almost immediate, within 24 hours of exposure, the researchers reported in the March *Toxicological Sciences*. The particulates enter the body through the respiratory system, get in the blood, and are small enough to cross the blood-brain barrier and start affecting the brain. Inflammation has been linked with dementia in older people and neurodevelopmental issues in younger people, plus mood disorders like anxiety and depression, Campen says.

"I'm hoping that our study with mice spurs … epidemiologists to take a look," he says. "The effects we see are much stronger and more worrisome than what we see in the lungs," he says, but we don't know yet at what $PM_{2.5}$ levels the danger begins. "We need to explore this more rigorously."
— Megan Sever

Ancient Smellscapes

A carved relief of an ancient Egyptian queen smelling a lotus flower represents the fragrant world that pharaohs and their families inhabited.

ALAIN GUILLEUX/ALAMY STOCK PHOTO

Identifying odor molecules and brewing Cleopatra's perfume yield new findings on past scents

By Bruce Bower

Ramses VI faced a smelly challenge when he became Egypt's king in 1145 B.C. The new pharaoh's first job was to rid the land of the stench of fish and birds, denizens of the Nile Delta's fetid swamps.

That, at any rate, was the instruction in a hymn written to Ramses VI upon his ascension to the throne. Some smells, it seems, were considered far worse than others in the land of the pharaohs.

Surviving written accounts indicate that, perhaps unsurprisingly, residents of ancient Egyptian cities encountered a wide array of nice and nasty odors. Depending on the neighborhood, citizens inhaled smells of sweat, disease, cooking meat, incense, trees and flowers. Egypt's hot weather heightened demand for perfumed oils and ointments that cloaked bodies in pleasant smells.

"The written sources demonstrate that ancient Egyptians lived in a rich olfactory world," says Egyptologist Dora Goldsmith of Freie Universität Berlin. A full grasp of ancient Egyptian culture requires a comprehensive examination of how pharaohs and their subjects made sense of their lives through smell, she contends. No such study has been conducted.

Archaeologists have traditionally studied visible objects. Investigations have reconstructed what ancient buildings looked like based on excavated remains and determined how people lived by analyzing their tools, personal ornaments and other tangible finds.

Rare projects have re-created what people may have heard thousands of years ago at sites such as Stonehenge (SN: 9/26/20, *p.* 14). Piecing together, much less re-creating, the olfactory landscapes, or smellscapes, of long-ago places has attracted even less scholarly curiosity. Ancient cities in Egypt and elsewhere have been presented as "colorful and monumental, but odorless and sterile," Goldsmith says.

Changes are in the air, though. Some archaeologists are sniffing out odor molecules from artifacts found at dig sites and held in museums. Others are poring over ancient texts for references to perfume recipes and have even cooked up a scent much like one presumably favored by Cleopatra. In studying and reviving scents of the past, these researchers aim to understand how ancient people experienced, and interpreted, their worlds through smell.

Molecular odors

A growing array of biomolecular techniques is enabling the identification of molecules from ancient aromatic substances preserved in cooking pots and other containers, in debris from city garbage pits, in tartar caked on human teeth and even in mummified remains.

Ingredients of a re-created ancient fragrance called the Mendesian perfume consist of pine resin, cassia cinnamon, true cinnamon, myrrh and moringa oil. Cleopatra herself may have worn this scent.

D. GOLDSMITH, S. COUGHLIN

Take the incense burner. Finding an ancient incense burner indicates only that a substance of some kind was burned. Unraveling the molecular makeup of residue clinging to such a find "can determine what exactly was burned and reconstruct whether it was the scent of frankincense, myrrh, scented woods or blends of different aromatics," says archaeologist Barbara Huber.

That sort of detective work is exactly what Huber, of the Max Planck Institute for the Science of Human History in Jena, Germany, and colleagues did in research on the walled oasis settlement of Tayma in what's now Saudi Arabia.

Researchers generally assume that Tayma was a pit stop on an ancient network of trade routes, known as the Incense Route, that carried frankincense and myrrh from southern Arabia to Mediterranean destinations around 2,300 to 1,900 years ago. Frankincense and myrrh are both spicy-smelling resins extracted from shrubs and trees that grow on the Arabian Peninsula and in northeastern Africa and India. But Tayma was more than just a refueling oasis for trade caravans.

The desert outpost's residents purchased aromatic plants for their own uses during much of the settlement's history, a team led by Huber found. Chemical and molecular analyses of charred resins identified frankincense in cube-shaped incense burners previously unearthed in Tayma's residential quarter, myrrh in cone-shaped incense burners that had been placed in graves outside the town

Researchers used a portable mass spectrometer to measure chemical traces of aromatic substances inside ancient Egyptian vessels now held at an Italian museum. Some artifacts yielded signs of oils, fats or beeswax, all of which could have been neutral-smelling base ingredients for perfumes or ointments.

wall, and an aromatic substance from Mediterranean mastic trees in small goblets used as incense burners in a large public building.

Fragrances of various kinds that most likely had special meanings permeated a range of daily activities at ancient Tayma, Huber's group reported in 2018 in Munich at the 11th International Congress on the Archaeology of the Ancient Near East.

In a more recent study, published in May in *Nature Human Behaviour*, Huber and colleagues outlined ways to detect chemical and genetic traces of ancient scents. For example, they described techniques to find scent-related proteins in tooth tartar.

Other researchers have gone searching for molecular scent clues in museum-held artifacts. Analytical chemist Jacopo La Nasa of the University of Pisa in Italy and his colleagues used a portable version of a mass spectrometer to study 46 vessels, jars, cups and lumps of organic material.

These artifacts were found more than a century ago in the underground tomb of Kha and his wife Merit, prominent nonroyals who lived during Egypt's 18th dynasty from about 1450 B.C. to 1400 B.C. The spectrometer can detect the signature chemical makeup of invisible gases emitted during the decay of different fragrant plants and other substances that had been placed inside vessels.

Analyses of residue from inside seven open vessels and of one lump of unidentified organic material detected oil or fat, beeswax or both, the scientists report in May in the *Journal of Archaeological Science*. One open vessel yielded possible chemical markers of dried fish and of a possible aromatic resin that could not be specified. The remaining containers were sealed and had to stay that way due to museum policy. Measurements taken in the necks of those vessels also picked up signs of oils or fats and beeswax in some cases. Evidence of a barley flour appeared in one vessel's neck.

Museum-based studies such as La Nasa's have great potential to unlock ancient scents. But that's true only if researchers can open sealed vessels and, with a bit of luck, find enough surviving chemical components of whatever was inside to identify the substance, Goldsmith says.

Luck did not favor La Nasa's group, she says. "Their analyses did not detect any [specific] scents."

If the vessels held aromatics, then oils, fats and beeswax would have provided a base for adding scented ingredients. This was a common practice, Goldsmith says. Starting with mixtures of those substances, Egyptian perfume makers added a host of fragrant ingredients that included myrrh, juniper berries, frankincense, nut grass, and resin and bark from styrax and pine trees. The heating of these concoctions produced strongly scented ointments.

Cleopatra's perfume

A tradition of fragrant remedies and perfumes began as the first Egyptian royal dynasties assumed power around 5,100 years ago, Goldsmith's research suggests. Ancient Egyptian hieroglyphic and cursive documents describe recipes for several perfumes. But the precise ingredients and amounts remain unknown.

That didn't stop Goldsmith and historian of Greco-Roman philosophy and science Sean Coughlin of the Czech Academy of Sciences in Prague from trying to re-create a celebrated Egyptian fragrance known as the Mendesian perfume. Cleopatra, a perfume devotee during her reign as queen from 51 B.C. to 30 B.C., may have doused herself with this scented potion. The perfume took its name from the city where it was made, Mendes.

Excavations conducted since 2009 at Thmouis, a city founded as an extension of Mendes, have uncovered the roughly 2,300-year-old remains of what was probably a fragrance factory, including kilns and clay perfume containers. Archaeologist Robert Littman of the University of Hawaii at Manoa and anthropological archaeologist Jay Silverstein of the University of Tyumen in Russia, who direct the Thmouis dig, asked Goldsmith and Coughlin to crack the Mendesian perfume code by consulting ancient writings.

After experimenting with ingredients including moringa and desert date oils, myrrh, cinnamon and pine resin, Goldsmith and Coughlin produced a scent that they suspect approximates what Cleopatra probably wore. It's a strong but pleasant, long-lasting blend of spiciness and sweetness, they say.

A description of the Thmouis discoveries and efforts to revive the Mendesian scent — dubbed Eau de Cleopatra by the researchers — appeared in

J. LA NASA ET AL/J. ARCHAEOL. SCI. 2022

the September 2021 *Near Eastern Archaeology*.

Goldsmith has re-created several more ancient Egyptian perfumes from written recipes for fragrances that were used in everyday life, for temple rituals and in the mummification process.

An elite perspective

Odor molecules unearthed in archaeological digs and reconstituted perfumes from the past, however, offer only a partial view of the scents of thousands of years ago. To get a more complete picture of an ancient place's range of smells — its smellscape — some archaeologists are combing ancient written texts for references to smell.

That's what Goldsmith did to come up with what she thinks is a smellscape typical of ancient Egyptian cities. Here's what a "smellwalk" through one of these cities would entail, she says.

In the royal palace, for instance, the perfumed smell of rulers and their family members would have overpowered that of court officials and servants. The pleasant smells would perhaps have denoted special ties to the gods among those in charge, Goldsmith wrote in a chapter of *The Routledge Handbook of the Senses in the Ancient Near East*, published last September.

In temples, priests anointed images of gods with what was called the 10 sacred oils. Though the ingredients are mostly unknown, each substance apparently had its own pleasing scent and ritual function. Temples mixed smells of perfumes, flowers and incense with roasted meat. Written sources describe the smell of fatty meat being grilled as especially pleasing and a sign of peace as well as authority over enemies.

In other parts of an ancient Egyptian city, Goldsmith says, scribal students lived in a special building where they learned Egyptian script. Achieving such knowledge required total devotion and the avoidance of perfume or other pleasant scents. One ancient source described aspiring scribes as "stinking bulls." That name speaks, and reeks, for itself.

Meanwhile, in workshops, sandal makers mixing tan to soften hides and smiths making metal weapons at the mouths of furnaces probably developed their own distinctive foul smells, Goldsmith says.

Stinky odors get far fewer mentions than sweet aromas in many of the written accounts from ancient Egypt that Goldsmith reviewed. Goats and other domestic animals, butchered carcasses, open latrines and garbage in the streets, for example, get no mention in these surviving texts.

An awareness that such texts may represent only an elite perspective, and thus not reveal the entire smellscape of the time or how it was perceived by everyday folks, is crucial when compiling the scents of ancient history, Goldsmith says.

The smell of civilization

Once researchers come up with a reasonable reconstruction of an ancient city's smellscape — the pleasant and the foul — the challenge shifts to figuring out how the ancients interpreted those smells.

Scent is a powerful part of the human experience. Today, scientists know that smells, which humans can discriminate surprisingly well, can instantly trigger memories of past experiences (SN: 4/19/14, *p.* 6). And social and ritual meanings also get attached to specific odors — there's nothing like the smell of freshly mowed grass and grilled hot dogs to evoke memories of summer days at the ballpark.

People in modern settings probably perceive the same smells as nice or nasty as folks in ancient Egypt or other past societies did, says psychologist Asifa Majid of the University of Oxford. In line with that possibility, members of nine non-Western cultures, including hunter-gatherers in Thailand and farming villagers in Ecuador, closely agreed with Western city dwellers when ranking the pleasantness of 10 odors, Majid and her colleagues report in the May 9 *Current Biology*.

Smells of vanilla, citrus and floral sweetness — dispensed by pen-sized devices — got high marks. Odors of rancid oiliness and a fermented scent like that of ripe cheese or human sweat evoked frequent "yech" responses.

A collective "yech" in response to the Nile Delta's moist, stinky emissions may have inspired the hymn that instructed Ramses VI to rid the land of its swampy fish and fowl smell. But Goldsmith argues

A wall carving at the Karnak Temple Complex near Luxor, Egypt, shows the pharaoh Ramses II holding an incense burner. Smells of aromatic substances lit in incense burners probably held deep meaning for ancient Egyptians.

PRISMA ARCHIVO/ALAMY STOCK PHOTO

Pompeii residents eating at small taverns such as this one around 2,000 years ago may have whiffed a range of nice and nasty odors that the residents experienced as familiar and comforting.

GREGORIO BORGIA/AP PHOTO

that the hymn's meaning is deeper and hinges on what ancient Egyptians saw as a conflict between sweet and evil smells.

In a 2019 review of texts written during the reigns of various ancient Egyptian kings, Goldsmith was struck by frequent references to this odiferous opposition. She concluded that ancient Egyptians' largely unexplored views about what exemplified good and bad smells could provide insights into their world view. Researchers have long noted that concepts known as *isfet* and *ma'at* helped ancient Egyptians determine what was good or bad in the world. *Isfet* referred to a natural state of chaos and evil. *Ma'at* denoted a world of order and justice.

Signature odors were associated with *isfet* and *ma'at*, Goldsmith proposed in a chapter in the 2019 book *Sounding Sensory Profiles in the Ancient Near East*. In Nile societies, the smelly fish and birds best represented *isfet*'s nasal assault. Fish, in particular, signified not only stench but also the danger of unfamiliar places outside the pharaoh's command, she concludes. Meanwhile, the ancient documents equated scented ointments and perfumes with the *ma'at* of civilized, pharaoh-ruled cities, she says.

Thus, an Egyptian pharaoh's first duty was to replace the social and physical stink of *isfet* with the sweet smell of *ma'at*, Goldsmith contends. In his welcoming hymn, Ramses VI got a friendly reminder to make Egypt politically strong and olfactorily fresh.

Explicit beliefs connecting *isfet* with evil smells and *ma'at* with sweet smells throughout ancient Egyptian history haven't yet been established but deserve closer scrutiny, says UCLA Egyptologist Robyn Price.

Price thinks that, rather than being fixed, values that were applied to scents fluctuated over time. For instance, some ancient texts describe the "marsh," where fish and fowl flourished, as a place of divine creation, she says. But documents from southern Egypt often spoke negatively about northern Egyptians, perhaps influencing claims that northern marshes stunk of *isfet* during periods when the two regions were under separate rule.

So, even if the ancients tagged the same odors as pleasurable or offensive as people do today, culture and context probably profoundly shaped responses to those smells.

Working-class Romans living in Pompeii around 2,000 years ago — before Mount Vesuvius' catastrophic eruption in A.D. 79 — provide one example. Archaeological evidence and written sources indicate that patrons of small taverns throughout the city were bombarded with strong smells, says archaeologist Erica Rowan of Royal Holloway, University of London. Diners standing or sitting in small rooms and at outdoor counters whiffed smoky, greasy food being cooked, body odors of other customers who had been toiling all day and pungent aromas wafting out of nearby latrines.

The smells and noises that filled Pompeii's taverns provided a familiar and comforting experience for everyday Romans who made these establishments successful, Rowan suspects. Excavations have uncovered 158 of these informal eating and drinking spots throughout Pompeii.

Roman cities generally smelled of human waste, decaying animal carcasses, garbage, smoke, incense, cooked meat and boiled cabbage, Classical historian Neville Morley of the University of Exeter in England wrote in 2015 in a chapter of *Smell and the Ancient Senses*. That potent mix "must have been the smell of home to its inhabitants and perhaps even the smell of civilization," he concluded.

Ramses VI undoubtedly regarded the perfumed world of his palace as the epitome of civilized life. But at the end of a long day, Egyptian sandal makers and smiths, like Pompeii's working stiffs, may well have smelled home as the air of city streets filled their nostrils. ■

Explore more

- Barbara Huber *et al*. "How to use modern science to reconstruct ancient scents." *Nature Human Behaviour*. May 2022.

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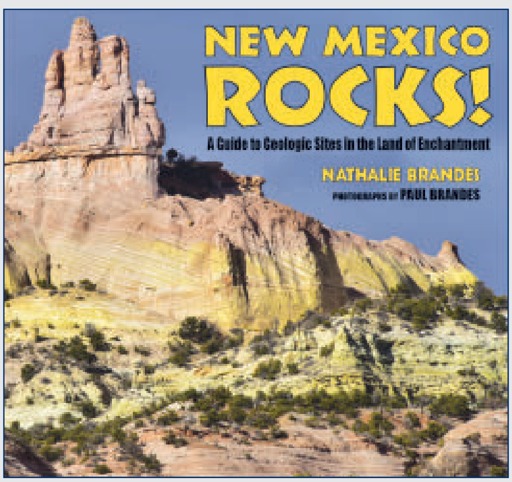

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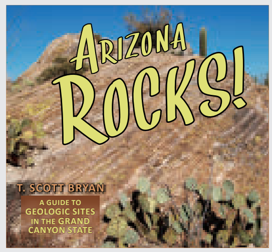

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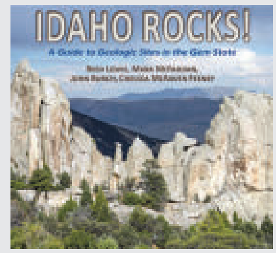

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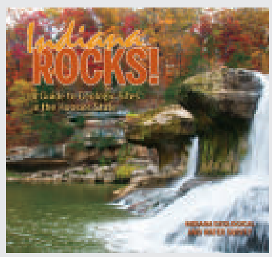

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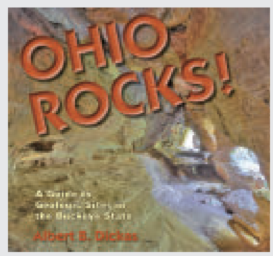

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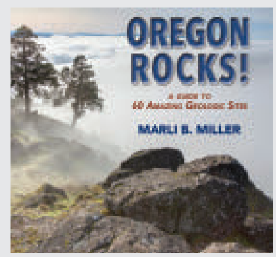

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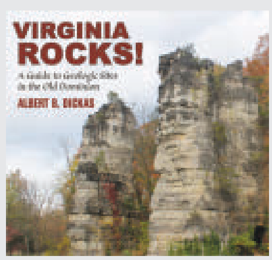

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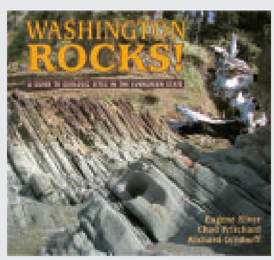

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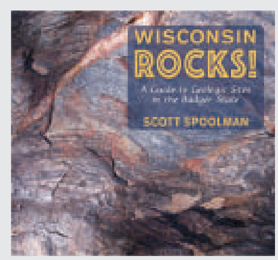

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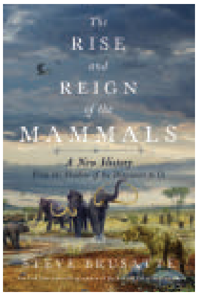

The Rise and Reign of the Mammals
Steve Brusatte
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BOOKSHELF

The story of mammals is a tale of innovation

In my opinion, the most satisfying science documentary TV series ever made was a 1970s British production called *Connections*. Hosted by impish historian James Burke, wearing bell-bottoms and thick-framed tortoiseshell glasses, each episode revealed how one small innovation from earlier human civilizations led to another and then another and another, culminating in the invention of some ultramodern (for the 1970s) technology.

Watching these pieces of the past come together was deeply gratifying, if not a little dizzying. The present is so familiar that it feels inevitable. But it was striking to see modern civilization, even modern humans, in context, to recognize how all that we are now actually hinges on countless moments of invention, improvement and experimentation in the deep past.

I had a similar reaction to *The Rise and Reign of the Mammals*, paleontologist Steve Brusatte's sweeping history of the animals that have, for the moment, inherited the Earth. Moving generally forward in time, the book describes how the mammalian line progressively acquired a range of features that have come to define what a mammal is.

Some of the moments of evolutionary invention that led to what we now think of as a mammal are remarkably subtle. There's the hard roof of the mouth that created a dedicated airway to the lungs, allowing mammal ancestors to eat and breathe at the same time. There's the change from a spine that bends from left to right (which produces the classically reptilian side-to-side gait) to one that enables bending up and down, which ultimately allowed mammals to take in more oxygen as they moved, helping them run faster. And there's the variety of tooth shapes — incisors, canines, premolars and molars — that made it possible for mammals to eat many kinds of food. A reptile, by contrast, tends to have just one tooth type.

Some mammalian characteristics are very familiar: milk production, warm-bloodedness, hair. But there's one less-well-known evolutionary advance that was in its humble way quite profound, setting "us apart from amphibians, reptiles, and birds," Brusatte writes. It's a joint in the jaw that makes chewing possible (SN: 8/17/19, p. 8). The ability to chew was "a major evolutionary turning point," he writes. "It triggered a domino chain of changes to mammalian feeding, intelligence, and reproduction."

Brusatte also describes a second small, curious adaptation: the transformation of two bones in the reptile jaw, which migrated to the inner ear to become two members of a famous trio, the hammer and anvil (the third is the stirrup). These inner ear bones are the basis for yet another key mammalian feature: the ability to hear a wide range of frequencies, particularly in the upper register.

The story of the Age of Mammals is often told as the flip side to the dinosaurs' demise. But the fossil record reveals that mammals were hardly newcomers: They arose around the same time as the dinosaurs, over 200 million years ago. Even during the Age of Dinosaurs, "in the smaller and hidden niches, it was already the Age of Mammals," Brusatte writes. "Mammals were *better* than the dinosaurs at being small."

Within just a few hundred thousand years of the asteroid impact that wiped out all nonbird dinos some 66 million years ago, mammals moved in to fill the vacancy, rapidly getting a lot bigger, ballooning from, say, mouse-sized to beaver-sized (SN: 12/7/19, p. 32). Pretty soon, they got a lot smarter too. In a geologic blink — a scant 10 million years — mammals' brains caught up with their brawn, and then the Age of Mammals was off to the races (SN: 5/7/22 & 5/21/22, p. 18).

Paleontology narratives often require refocusing a story's lens in a way that can be jarring, zooming out to encompass Earth-wide climate cataclysms and mass extinctions and then in again to describe tiny bones and obscure species. Brusatte, though, is a nimble storyteller and he's chosen an engrossing story to tell.

As a science writer, I often find myself focusing on minute advances, studying tiny threads. So it's satisfying to sit back and admire the full tapestry as presented in *The Rise and Reign of the Mammals*. Reading this book reminded me what I most enjoy about geology, paleontology and the evolution of life on Earth: This planet has got some epic stories. — *Carolyn Gramling*

The beaverlike mammal *Kimbetopsalis simmonsae* lived about 65.5 million years ago, in the wake of the die-off of non-bird dinosaurs.

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SOCIETY UPDATE

STEM TALENT STARTS WITH TEACHERS

The Society for Science is dedicated to supporting the educators developing the next generation of STEM leaders and innovators. Through our STEM Research Grants Program, we are proud to provide grants to middle and high school teachers engaging their students in scientific research. Educators receive kits containing equipment to support research interests across a wide variety of topics, from computer programming to wildlife observation. Or they can request up to $5,000 to purchase specialized materials of their choosing, with priority consideration given to schools that support students from low-income communities and demographics underrepresented in STEM fields.

Since the COVID-19 pandemic began, the Society has provided more than 9,000 kits, valued at over $560,000, to educators in all 50 states, Washington, D.C., American Samoa, Puerto Rico, Mexico, Peru and Uruguay.

> “When you provide students with opportunities, you open up a whole new world for them. The students might not choose to pursue a STEM field, but it is important that they learn the value of perseverance and cooperation and the hunger for learning—values that doing research can teach them.”
>
> **EILEEN POSERIO**
> STEM Research Grant recipient; Educator at Wolf Point Junior/Senior High School in Wolf Point, Montana

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SOCIETY FOR SCIENCE

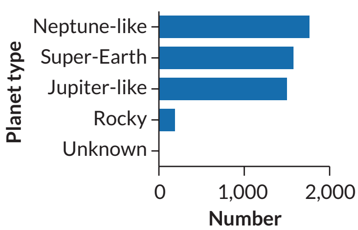
APRIL 23, 2022

SOCIAL MEDIA

Above and beyond

NASA's tally of known planets beyond our solar system reached a new milestone, **Liz Kruesi** reported in "NASA's exoplanet count tops 5,000" (*SN: 4/23/22, p. 5*). Of the confirmed exoplanets as of March 31, those the size of Neptune are the most common (see graph below). Twitter user **@Steve9thCircle** quipped: "Sounds like classic Nep(o)tunism to me."

Breakdown of confirmed exoplanets by type



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Particle perspectives

Scientists are tracking the movements of subatomic particles called muons to reveal the inner worlds of pyramids, volcanoes and more, ***Emily Conover*** *reported in "Muons open doors"* (SN: 4/23/22, p. 22).

Reader and longtime subscriber **John Ewald** praised **Conover's** "enjoyable and detailed" reporting. "She alerted us to concepts and investigations that are honestly new to me," **Ewald** wrote. "She carried us through those things with a pace that let me emerge [at the end] to say, 'No particle like it.'"

Ewald also appreciated that the issue's editor's note gave an inside look into how the idea for **Conover's** feature bloomed (SN: 4/23/22, p. 2). Editor in chief **Nancy Shute** wrote that physicists sometimes consider muons a nuisance because they get in the way of many experiments. But **Conover** noticed an exciting trend: scientists reimagining the pesky particles as useful tools for discovery. **Shute** "added information, so I learned from her writing too," **Ewald** wrote.

A dynamic brain

A study linked COVID-19 with reduced gray matter in parts of the brain associated with the sense of smell, but it's still unclear if the changes are harmful or permanent, ***Laura Sanders*** *reported in "COVID-19 can change a person's brain"* (SN: 4/23/22, p. 8).

News coverage of the study, with headlines about brain damage and shrinkage, concerned many in the public, **Sanders** reported. But the brain typically transforms throughout life — including during adolescence and pregnancy — and those changes are not necessarily a cause for alarm. Some readers were relieved to learn that the brain is not so static. "The fact that the brain is constantly changing shape due to various stimuli makes me feel less worried about COVID changes," Facebook user **Bel Vedere** wrote. "It would certainly be interesting to see the long-term follow-up to these studies."

The story also eased the mind of reader **Lynne Mullins**. After seeing some alarming coverage of the study's results, "it is reassuring that answers won't be available for a while," **Mullins** wrote.

Online corner

As part of Science News' *centennial celebration, we created a quiz to test our readers' knowledge of 100 years of science stories. The quiz, posted on our website in late April, asked people to guess when in the last century 15 headlines were published.*

An article featured in the quiz, "The Earth is a soup-kettle," was published in (spoiler alert!) 1932 and reported on geologist Arthur Holmes' idea for how continents could float atop "boiling" rock (SN: 9/10/32, p. 162). At the time, the theory of plate tectonics did not yet exist. Reader **Martin Kappeyne** asked why the piece didn't reference meteorologist Alfred Wegener's continental drift theory, which dates back to 1912.

That story, written by Frank Thone, "focused primarily on the question of Earth losing heat — and not the idea of continental drift," says special projects editor **Elizabeth Quill**.

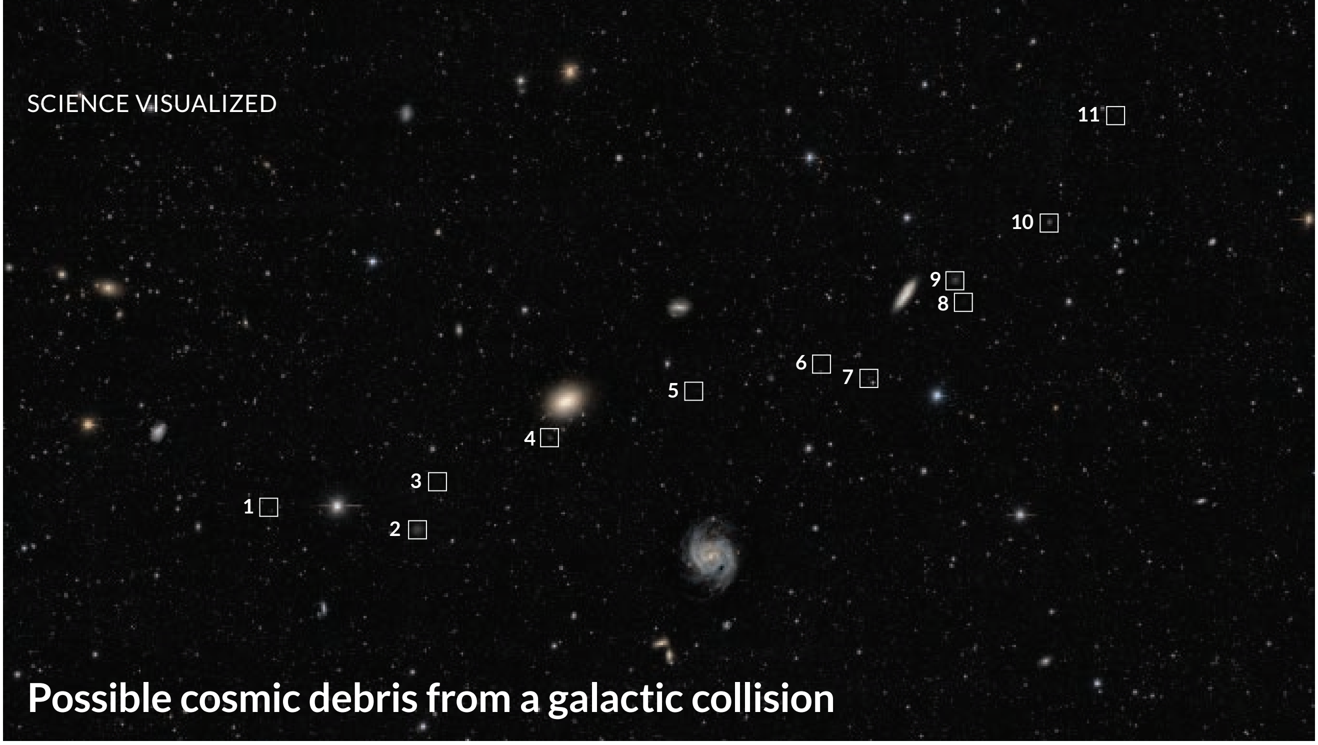
But Thone *did* slip in a mention of the theory: "Thus are mountain folds thrown up on the edge of continents, Prof. Holmes thinks; for he is one of those geologists who believe in the theory of shifting and migrating continents, most notably advocated by the great German scientist, von Wegener."

Quill doesn't claim to know what was going on in Thone's mind, "and his coverage choices probably had a lot to do with what was occupying the attention of scientists in his circle at that snapshot in time," she says. "But the lack of emphasis on continental drift might have something to do with how contentious the idea was." In a look back at the emergence of plate tectonics as a unifying theory, **Carolyn Gramling** reported that debates between "mobilists" who supported continental drift and "fixists" who opposed it were raging in the 1920s. In the next decades, many geologists turned their attention to other matters until interest in the idea rekindled in the 1950s, when new data surfaced from the bottom of the oceans (SN: 1/16/21, p. 16).

Online readers scored an average of 7.8 out of 15 on the headline quiz. Think you'll get more? Test yourself at **bit.ly/SN_HeadlineQuiz**

E. OTWELL

SCIENCE VISUALIZED



Possible cosmic debris from a galactic collision

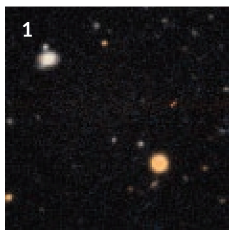
In a patch of sky in the constellation Cetus, an apparent row of dwarf galaxies seems to span more than 6 million light-years. This lineup (shown above) may have formed in the aftermath of a long-ago galactic crash. And that crash may explain why these and certain other galaxies are surprisingly devoid of dark matter.

In 2018 and 2019, astronomer Pieter van Dokkum of Yale University and colleagues reported on two dwarf galaxies lacking dark matter (*SN Online*: 3/28/18). Dark matter is thought to be the foundation of all galaxies, gravitationally attracting gas that eventually forms stars. So some process must have separated these galaxies from their dark matter long ago.

It turns out those two galaxies, NGC1052-DF2 and NGC1052-DF4 (numbers 2 and 9 in close-ups at right), are racing away from each other as if they had come from the same spot, van Dokkum and colleagues report in the May 19 *Nature*. What's more, the duo is part of a chain of 11 galaxies, a structure that could have formed in the aftermath of a collision of two ancient dwarf galaxies, the team says.

That smashup could have split dark matter from normal matter. In such a crash, the dark matter would have continued on its path, because it doesn't interact with other matter. But the gas would have slammed together, forming clumps that each became their own galaxy free of dark matter. The newfound string of galaxies might have formed from such clumps.

Some scientists are skeptical. "I just don't think the bar has been met," says astronomer Michelle Collins of the University of Surrey in Guildford, England. More measurements would help. She's awaiting estimates on how far each galaxy is from Earth, which would reveal whether the lineup is real or just a chance overlap seen from our viewpoint. —*Emily Conover*



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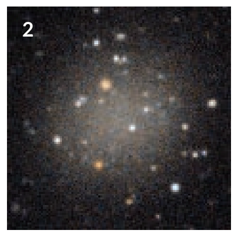
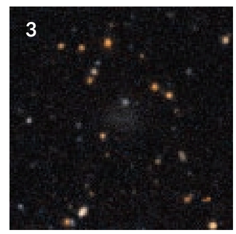


NGC1052-DF2



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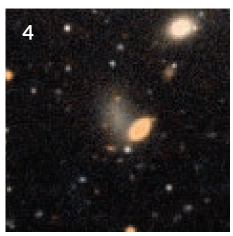

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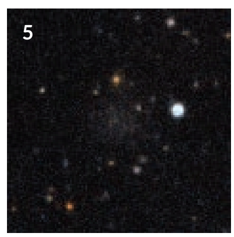

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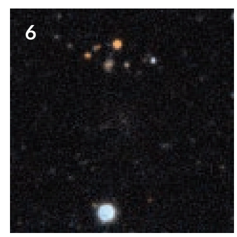

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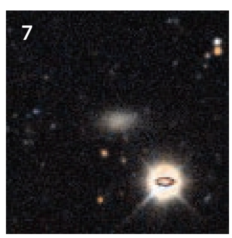

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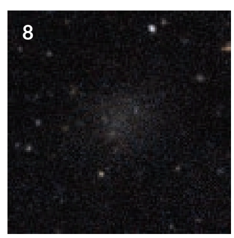

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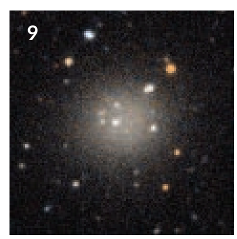

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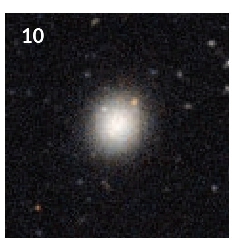

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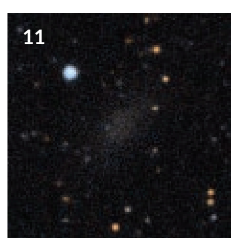

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