Embryos Reset the Clock | Overlooked Insect Invaders

Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ JULY 31, 2021

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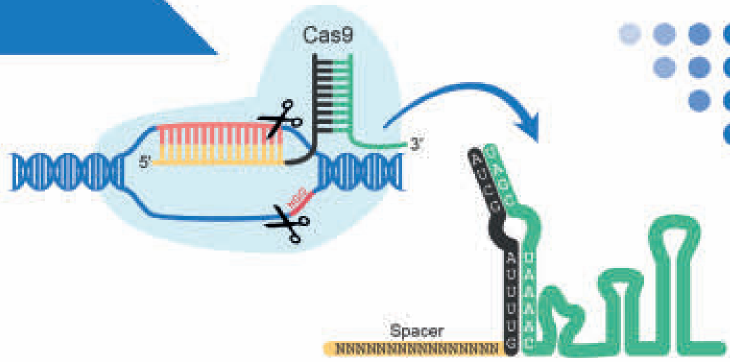

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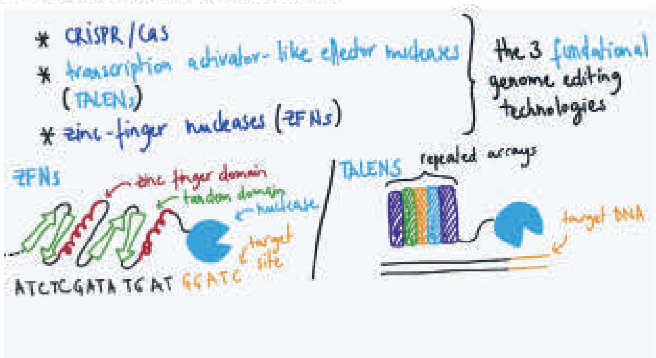

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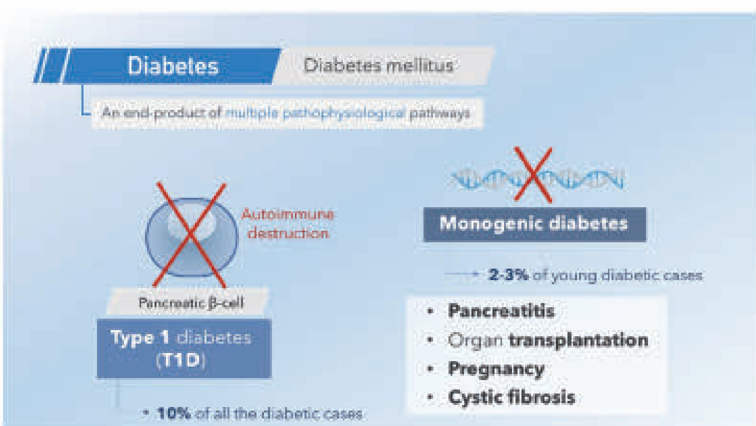

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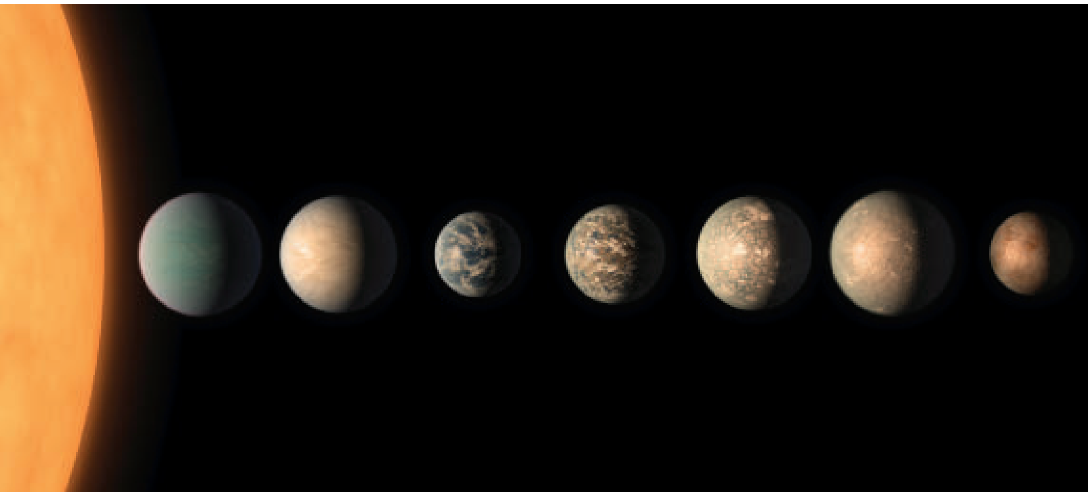

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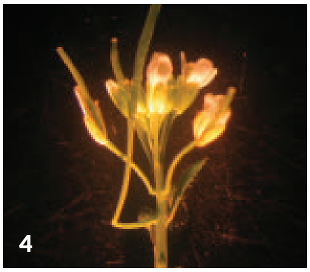

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Departments

COVER A bridge of material connects a pair of galaxies called Arp 273 across tens of thousands of light-years. *NASA, ESA, the Hubble Heritage Team/ STScI and AURA*

FROM TOP: JPL-CALTECH/NASA; T. GOOKIN; AURELIEN GUICHARD/FLICKR (CC BY-SA 2.0)

A century of exploring the endless final frontier

People have long speculated on the existence of worlds beyond our Earth. In the 17th century's *Paradise Lost,* John Milton's angel suggested to Adam that there was not just life on the moon, but on "other Suns, perhaps/With their attendant Moons." Alien realms and the captivating — or terrifying — beings that might live there have become a staple of the imagination, from H.G. Wells' Martian invaders in 1897's *The War of the Worlds* to the more benevolent strangers drawing smoky rings to communicate with the linguist portrayed by Amy Adams in the 2016 film *Arrival*.

But it has taken science a bit longer to match our imaginations. As early as the 1850s, astronomers declared that they had discovered planets beyond our solar system, but the claims didn't hold up.

In this issue, astronomy writer Lisa Grossman tells the story of scientists' search for other worlds, and the decades of struggle it took to confirm their existence (Page 18). It wasn't until the 1990s that researchers confirmed that planets exist outside our solar system.

Why the long wait? There were many technological challenges to surmount, as well as a long-held supposition that other solar systems would work just like ours. And if you're not on the lookout for something completely different, how would you find it?

Grossman is an ideal teller of this tale. She studied planetary science while an undergraduate student at Cornell University, and started her career as a science journalist covering the discoveries of the Kepler space telescope, which searched for exoplanets in our galaxy. Writing this issue's story, which is part of our Century of Science project, also gave her the opportunity to revisit earlier explorations, including the extraordinary journeys of the Voyager space probes, which were launched in 1977 to study Jupiter and Saturn. Those boxes checked, the probes just kept on going, with Voyager 1 becoming the first craft to enter interstellar space.

Part of the great fun of reporting a story like this is being able to talk with legends in the field like Candice Hansen, who worked on Voyager and was one of the first women involved in planetary missions. "She's seen everything," Grossman says. "She had so many great stories; she was so generous with her time."

Grossman also got to dial up Jim Bell, a planetary scientist who was her adviser at Cornell. She had worked in his lab calibrating images from the Spirit and Opportunity Mars rovers. Her task: to try to figure out if the dark stuff in one image was the same as the dark stuff in another.

Does she ever wish she'd become a researcher, so she could be one of those folks high-fiving when a rover touches down on Mars? "Rarely," she says, laughing. Her professional life is still focused on discovering and exploring distant worlds, with the added perk of being able to explain the science to the rest of us. We're glad she's on the beat, and have devoted the entire feature section to her story, as well as a gallery of some of our favorite galaxies. Enjoy!

— Nancy Shute, Editor in Chief

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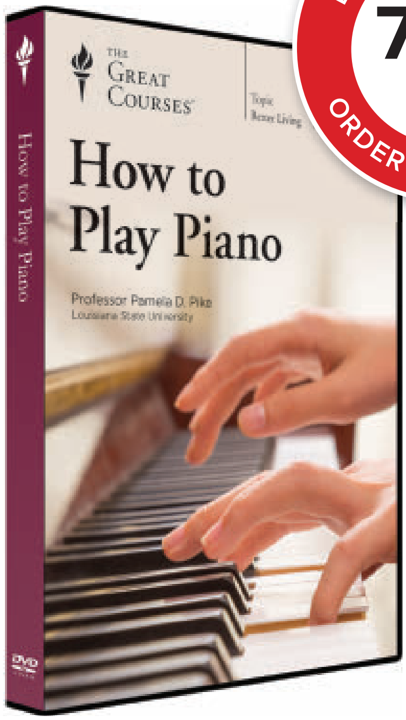

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Have you always wanted to take up the piano, but never knew where to start? The piano is one of the most gratifying instruments to play, and an excellent introduction to the theory and practice of music. Yet, too many people who want to play believe it requires too much work, so they miss out on the joys that playing even a simple melody can bring.

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Excerpt from the August 7, 1971 issue of *Science News*

50 YEARS AGO

This plastic will self-destruct

Public indignation over litter and garbage has caused industry to ask chemists whether self-destroying, or quickly degradable, plastics might be devised to replace indestructible ... glass, aluminum and plastics, which comprise the largest segment of consumer waste.... [Chemist James] Guillet and his team ... devised a self-destroying plastic that is about ready for marketing — a wrapping paper that disintegrates in about a month.

UPDATE: Guillet's work on polymers that degrade via light helped pave the way for their wider commercial use. But these materials may have created more problems than they solved. Most plastics wind up in landfills where the materials don't get enough light to degrade as intended (*SN: 1/30/21, p. 20*). Plastics that do break down turn into microscopic pieces that can wind up in ecosystems and harm animals. Scientists are trying to make more eco-friendly plastics, such as compostable plastics that can be totally broken down with enzymes (*SN: 6/5/21, p. 5*).

River sounds played near gentle Idaho streams (one shown) affected bird and bat foraging, suggesting that natural noises shape ecosystems.

THE SCIENCE LIFE

'Phantom rivers' shape bird and bat hunting habits

For two summers in a rugged area of the Pioneer Mountains in Idaho, the roar of rushing white water filled the air. Yet only gentle streams flowed.

These "phantom rivers" were part of an experiment led by ecologist Dylan Gomes of Boise State University. He and colleagues were testing a hypothesis that the sounds of nature influence where and how animals forage.

"There's a lot of research suggesting that [human] noise negatively affects [animals], from communication to foraging to reproduction, and even survival," Gomes says. For example, the sounds of highway traffic can drive migrating birds away from their regular rest stops (*SN: 2/21/15, p. 22*).

But the natural soundscape is "one component of the niche that we've been ignoring," says ecologist Gail Patricelli of

RETHINK

For some dinosaurs, the Arctic was family-friendly

Dinosaurs didn't just summer in the high Arctic; they may have lived there year-round, new fossil evidence suggests. Hundreds of bones and teeth found along the Colville River in northern Alaska belonged to dino hatchlings, researchers say. The remains, from the Prince Creek geologic formation, represent seven dinosaur families — including tyrannosaurs, hadrosaurs and ceratopsids — that lived about 80 million to 62 million years ago.

"These are the northernmost [nonavian] dinosaurs that we know of," says paleontologist Patrick Druckenmiller of the University of Alaska Museum of the North in Fairbanks. It's now clear they did not just migrate seasonally to polar latitudes, he says. "They're actually nesting and laying and incubating eggs ... practically at the North Pole."

Some dinosaurs may have incubated eggs for up to six months (*SN: 2/4/17, p. 4*), which would have left little time for dinos nesting in the Arctic to migrate south before winter, Druckenmiller and colleagues report June 24 in *Current Biology*. Though the Arctic was warmer during the dinos' lifetime than it is today, overwintering dinosaurs would have endured months of darkness and snowfall. The dinos may have fought the cold with some degree of warm-bloodedness, Druckenmiller speculates. These baby dino fossils unearthed more questions than answers, he says. "We've opened a whole can of worms." *— Nikk Ogasa*

19 mm

A baby tyrannosaur tooth (top, far left) and a baby theropod bone (middle row, far right) are among the remains that hint some dinosaurs nested in the Arctic.

FROM TOP: CORY TOTH; P. DRUCKENMILLER

the University of California, Davis. The phantom rivers experiment suggests we shouldn't, she says.

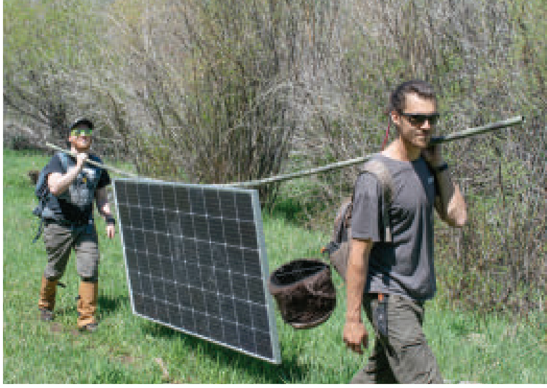
Gomes and his team hauled about 3.5 metric tons of speakers, solar panels and other equipment into the countryside in 2017 and 2018. Though they carried most of this gear on their backs, the researchers had to call on a mule train when an access road flooded during the first summer. At 60 study sites near streams, the team broadcast white water noise at different volumes and frequencies, or pitches, creating the auditory illusion of rushing rivers.

As the phantom rivers played, the researchers surveyed two prevalent, sound-dependent animal groups — birds and bats. Bats echolocate and listen for their prey, and birds communicate through song, Gomes explains. "They're such sound specialists that it makes sense to focus on them."

For each 12-decibel increase in white water noise volume, bird abundance decreased by about 7 percent, and bat activity decreased by about 8 percent, the researchers report May 24 in *Nature Communications*. Birds were especially deterred by white water noise pitches that overlapped with birdsong. And for each 2,000-hertz increase in pitch, the overall activity of bats decreased by about 20 percent.

Amid all the noise, Gomes and his team deployed 720 fake clay caterpillars among willow trees often visited by birds. Overall, birds foraged less as noise volume increased, even though the creatures rely on vision to forage. The birds may find the noise distracting, similar to how a person would struggle to solve a crossword puzzle at a rock concert, Gomes says.

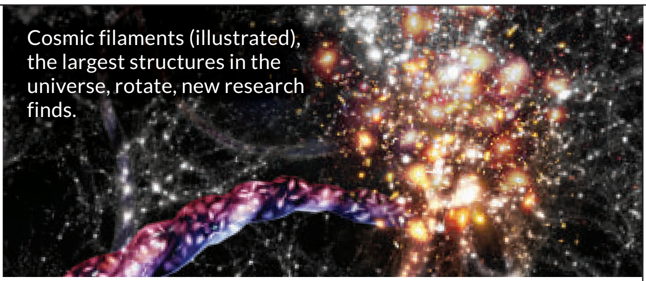
The researchers similarly tested the effect of white water noise on bat foraging. They set up small speakers that played insect sounds to attract passive-listening, or "gleaning," bats. Fluttering



Ecologist Dylan Gomes (right) and colleague Nic Carlson carry solar panels for a study gauging how natural sounds affect animal behavior.

mechanical devices that mimicked flapping insect wings attracted active echolocating, or "hawking," bats. In bat species that could both glean and hawk, gleaning behavior decreased and hawking increased when the researchers increased white water noise volume and pitch.

If changes in natural noises can so readily influence where and how animals forage, Gomes says, then it's even more crucial to manage and mitigate the rapidly encroaching noises of people (*SN: 6/10/17, p. 14*). — *Nikk Ogasa*



Cosmic filaments (illustrated), the largest structures in the universe, rotate, new research finds.

THE –EST

Cosmic filaments go for a spin

Moons do it, stars do it, even whole galaxies do it. Now scientists say, the universe's largest known structures do it too. Tendrils called cosmic filaments, made of dark matter and galaxies, twirl like giant corkscrews. Until now, galaxy clusters were the largest structures known to rotate. Cosmic filaments, which contain most of the universe's mass and stretch hundreds of millions of light-years, spin at a scale that makes galaxies look like dust specks. Measuring galaxies' velocities perpendicular to cosmic filaments' axes revealed that the structures rotate, scientists report June 14 in *Nature Astronomy*. Simulations of dark matter clumps moving around a filament also detected rotation, a second team reports July 1 in the *Monthly Notices of the Royal Astronomical Society*. Next, scientists want to tackle what makes cosmic filaments spin. — *Jaime Chambers*

HOW BIZARRE

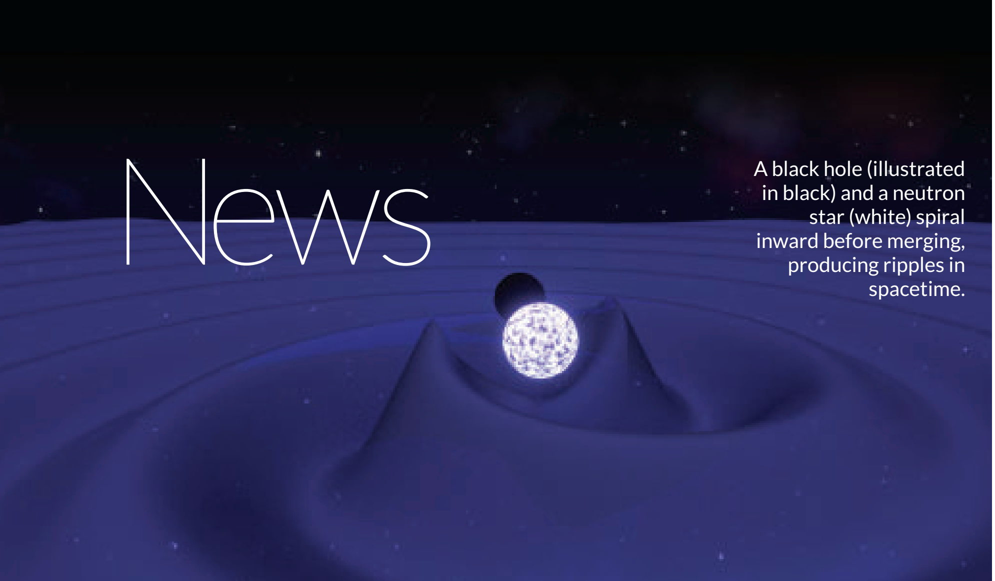
Popular lab plant reveals a new organ

A plant that has been put under microscopes for decades may seem unlikely to be able to keep secrets. But in the widely studied *Arabidopsis thaliana*, scientists have identified the cantil — a newly reported plant organ named for its cantilever-like way of branching off of the main stem. The structure appears in some wild and lab varieties of *A. thaliana* under only certain conditions in captivity, molecular biologist Timothy Gookin and colleagues report in the June *Development*.

Short days prompt *A. thaliana* to shore up resources; long days tell it to churn out flowers. Cantils form when the switch from stockpiling to blooming is delayed, as the plant grows while waiting for the flowering signal, the team found. Scientists' preference for long growing days and fast-flowering conditions kept cantils hidden, says Gookin, formerly of Penn State. It's unclear if the plants use the organs. So far, cantils are known to occur only in *A. thaliana*. But the discovery is a reminder to keep observing closely. — *Jaime Chambers*

The widely studied plant *Arabidopsis thaliana* recently gave up a secret: It has a cantilever-like organ (arrow). The newfound part develops in only some plant varieties and only when flowering is delayed.

FROM TOP: CORY TOTH; A. KHALATYAN AND J. FOHLMEISTER/AIP; T. GOOKIN



A black hole (illustrated in black) and a neutron star (white) spiral inward before merging, producing ripples in spacetime.

MARK MYERS/OZGRAV/SWINBURNE UNIV.

ATOM & COSMOS

Black holes devour dead stars

An elusive source of gravitational waves has been found

BY EMILY CONOVER

Caught in a fatal inward spiral, a neutron star met its end when a black hole swallowed it whole. Gravitational ripples from that collision spread outward through the cosmos, eventually reaching Earth. The detection of those waves marks the first reported sighting of a black hole engulfing a dense remnant of a dead star. And in a surprise twist, scientists spotted a second such merger just days after the first.

Until now, all gravitational wave sources with confirmed identities were twos of a kind: either two black holes or two neutron stars colliding and coalescing (*SN: 1/30/21, p. 30*). The violent cosmic collisions create waves that stretch and squeeze the fabric of spacetime, undulations that sensitive detectors can suss out.

The mismatched pairing of a black hole and neutron star was the final type of merger that scientists expected to find with current gravitational wave observatories. By coincidence, researchers spotted two of these events within 10 days of one another, the LIGO, Virgo and KAGRA collaborations report in the July 1 *Astrophysical Journal Letters*.

Unions between black holes and neutron stars had never been seen before by any means. "This is an absolute first look," says theoretical physicist Susan Scott of the Australian National University in Canberra, a LIGO collaboration member.

Signs of the black hole–neutron star collisions registered in the LIGO and Virgo gravitational wave observatories in 2020, on January 5 and January 15. The first merger consisted of a black hole about 8.9 times the mass of the sun and a neutron star about 1.9 times the sun's mass. The second merger had a 5.7–solar mass black hole and a 1.5–solar mass neutron star. Both collisions occurred more than 900 million light-years from Earth, scientists estimate.

To form detectable gravitational waves, the objects that coalesce must be extremely dense. Scientists can typically identify these objects by their mass. Anything with a mass above five solar masses could only be a black hole, scientists think. Anything less than about 2.5 solar masses must be a neutron star.

One earlier gravitational wave detection involved a black hole merging with an object that couldn't be identified, as its mass fell in between the cutoffs believed to separate black holes and neutron stars (*SN: 8/1/20, p. 8*). Another previous detection may have resulted from a black hole melding with a neutron star, but the signal from that event wasn't strong enough for scientists to be certain that the detection was the real deal. The two new detections clinch the case for black hole and neutron star meetups.

One of the new events is more convincing than the other. The January 5 merger was seen in just one of LIGO's two gravitational wave detectors, and the signal has a relatively high probability of being a false alarm, says astrophysicist Cole Miller of the University of Maryland in College Park. "If this were the only event, then you would not be as confident." But the January 15 event "seems pretty solid," he says.

Epic rendezvous between neutron stars and black holes happen regularly throughout the cosmos, the detections suggest. Based on the pace of detections, researchers estimate that such events within 1 billion light-years of Earth take place about once a month.

Scientists don't yet know how neutron stars and black holes come to meet up. They might form together, as two stars that orbit one another until both run out of fuel and one collapses into a black hole and the other forms a neutron star. Or the objects might form separately and meet up in a region packed with neutron stars and black holes.

Scientists had expected that as a black hole and neutron star spiral inward and merge, the black hole could rip the neutron star to shreds, producing a light show that could be observed with telescopes. But astronomers found no fireworks in the aftermath of the two newly reported encounters, nor any evidence that the black holes deformed the neutron stars along the way.

That could be because the black holes were much larger than the neutron stars, suggesting that the black holes gulped down the stars whole in a meal worthy of Pac-Man, Scott says. If scientists spot a black hole shredding a neutron star in the future, that could help pin down the properties of the neutron-rich material that makes up the dead stars (*SN: 6/5/21, p. 8*).

In past gravitational wave detections, LIGO, based in the United States, teamed up with Virgo, in Italy. The new observations are the first to include researchers from a third observatory, KAGRA, in Japan. LIGO, Virgo and KAGRA are now offline while scientists tinker with the detectors and will resume their communal search for cosmic collisions in 2022. ■

Embryos may reset the biological clock

In mice, a 'rejuvenation event' wipes out genetic signs of aging

BY ERIN GARCIA DE JESÚS

As a person ages, so do all of the body's cells, which accumulate damage over time. But why offspring don't inherit those changes — effectively aging a child even before birth — has been a mystery. "When you are born, you don't inherit your parents' age," says Yukiko Yamashita, a developmental biologist at MIT who studies the immortality of germline cells such as eggs or sperm. "For some reason, you are at zero."

Experts once thought that germline cells might be ageless — somehow protected from the passage of time. But studies have shown signs of aging in eggs and sperm, dispelling that idea. So researchers have hypothesized that germline cells might instead reset their age after conception, reversing any damage.

In a new study, scientists describe evidence that supports that rejuvenation hypothesis. Both mouse and human germline cells appear to reset their biological age in the early stages of an embryo's development. A rejuvenation period that takes place after an embryo has attached to the uterus sets the growing embryo at its youngest biological age, dubbed "ground zero," researchers report June 25 in *Science Advances*.

Understanding how germline cells reverse aging could help researchers develop treatments for age-related diseases, such as arthritis or Parkinson's, says Vittorio Sebastiano, a developmental biologist at Stanford University School of Medicine who was not involved in the work. In such diseases, certain cells might stop working properly due to age-related damage. Resetting the age of those cells could prevent them from causing problems.

It's possible that this rejuvenation period "can be leveraged and hijacked somehow to basically try to promote similar processes of rejuvenation in normal cells," Sebastiano says.

Vadim Gladyshev, a biochemist and geneticist who studies aging at Harvard Medical School and Brigham and Women's Hospital in Boston, and colleagues used molecular clocks to predict the approximate ages of mouse embryos in the early stages of development. The clocks measure epigenetic changes, chemical tags on DNA that can accrue as cells age or are exposed to things like pollution. Such tags can change a gene's activity but not the information that the gene contains.

The scientists were studying the embryos' biological ages, which are determined by the function and health of cells, in contrast with chronological ages, which mark time in years (*SN: 7/23/16, p. 16*). By tracking epigenetic changes, the team found that the age of the mouse embryos stayed constant during the first stages of cell division immediately following fertilization. But by around 6.5 to 7.5 days into development, after an embryo attached to the uterus, the average biological age of embryos had dipped — a sign that cells were undergoing some type of rejuvenation event. A mouse embryo's "back to zero" may be somewhere between 4.5 to 10.5 days after fertilization, the researchers say. At some point during development, though the exact point is still unclear, a mouse embryo's biological age then begins to climb.

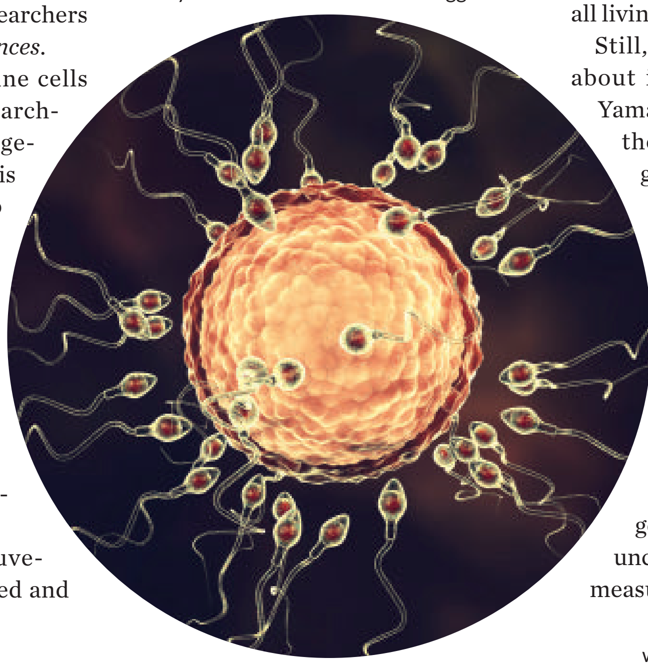
Understanding how germline cells reverse aging could help researchers develop treatments for age-related diseases.

Studying human embryos at the earliest stages of development is prohibited. Therefore, similar data for humans are unavailable, Gladyshev says. But genetic data from human embryos that were slightly further along in development than the mouse embryos showed no signs of immediate aging, a hint that a similar process happens in people.

The study is a first step that "poses more questions than answers," says Sebastiano, "which is great." Some of those questions: What mechanism pushes cells to reset their age? Are there specific genes that drive the process? Do all living things rejuvenate in this way?

Still, there's reason to be cautious about interpreting the results, says Yamashita, who was not involved in the study. It's possible that epigenetic changes are only part of the story, so relying solely on them could lead to miscalculations. Other factors linked to a cell's biological age, for instance, include whether a cell has multiple copies of specific genes. As a result, the clocks that measure epigenetic changes might not pinpoint the precise "ground zero" for germline cells. Future work might uncover other phenomena that help measure cells' age, Yamashita says. ■

Eggs and sperm (illustrated) age, but these germline cells reset their biological age during the early stages of an embryo's development, a study of mouse and human cells suggests.



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LIFE & EVOLUTION

‘Murder hornet’ frenzy distorts reality

Unlike Asian giant hornets, most insect invaders don’t go viral

BY SUSAN MILIUS

Already, 2021 has been a weird year in Asian giant hornet news, and the season of checking North America for signs of invasion still has months to go.

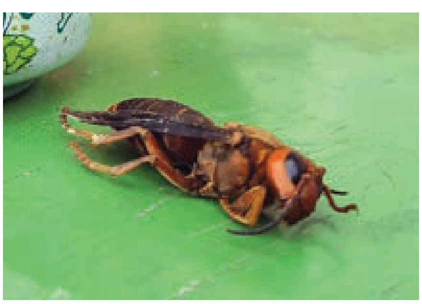
The first of these invasive hornets found on the continent this year, in June, doesn’t indicate how well, or if, any of last year’s hornets survived the winter, scientists say. Yet that hornet shows quite well the relentless risk of newly arriving insects.

That specimen, a dead male insect lying on a lawn in Marysville, Wash., belongs to the hefty species *Vespa mandarinia*. The Asian giant hornets, nicknamed murder hornets, were first detected outdoors in Canada and the United States in 2019 (*SN: 7/4/20 & 7/18/20, p. 14*). Yet the “dry, crispy” male is not part of known hornet invasions, entomologist Sven Spichiger said at a June 16 news conference.

Tests show the male “is definitely not the same genetic line as the ones we have found,” said Spichiger, of the Washington State Department of Agriculture in Olympia. Neither the U.S. finds, all from Washington, nor British Columbia’s over the border are closely related to the new-found hornet. It’s a separate incursion no one had noticed until now.

This oddball new specimen may help correct the skewed impression that sneaky invasive arrivals are rare. The hornets’ appearance in North America may have been a shock to some, but in reality, worrisome insects show up often, and will probably keep doing so. Fortunately, making a permanent home is harder than getting here, scientists say.

The first Asian giant hornet identified in North America in 2021, this dead male, was from a previously unknown incursion.



When news of the Asian giant hornets’ arrival first broke in 2019, entomologist Doug Yanega was not at all surprised. “It is very fair to say that there are many invasive species,” says Yanega, of the University of California, Riverside. “We just got a new African mantis species in California this past year in LA, and the expectation is that it is likely to spread.”

But even alarming pest arrivals rarely kick up the fuss prompted by Asian giant hornets. At a peak in hornet news during May 2020, Yanega contrasted the new intruders with the South American palm weevil (*Rhynchophorus palmarum*). The weevil had reached Southern California and could “wipe out every palm tree in the state,” according to Yanega. Yet, “there have been ZERO [national] mainstream media reports about this, an insect that seriously threatens to have a VASTLY greater negative impact on the economy and our way of life than those hornets ever will,” he fumed in an e-mail.

The relentless influx of invading insects may be one reason so few make it into the general news. For instance, U.S. Customs and Border Protection reported 31,785 incidents of detecting some pest in fiscal year 2020. Among the more alarming finds were larvae of crop-damaging khapra beetles (*Trogoderma granarium*), in a commercial shipment from China, at International Falls, Minn.

Passenger luggage can pose substantial risks too. In 2018, inspectors at Washington Dulles International Airport in Virginia and later at Baltimore/Washington International Airport in Maryland noticed the beetles in basmati rice and then in dried cowpeas that travelers brought with them from abroad.

The Dulles luggage had the most living insects: 12 larvae and four adults. Even that tiny number was unacceptable.

Tiny invasive khapra beetles (one shown from the front and side) could cause massive economic damage if they settle in North America.

This is the only insect species that U.S. customs officials act upon even when all specimens are found dead. The beetles nibble stored seeds but will also soil the goods with stray body parts and hairs that can make babies fed dirty grain sick and adults uncomfortable. Starting in 1953, a major effort in the Southwestern United States eliminated invasions and eventually preserved crop marketability. But the 16-year undertaking was expensive, costing the equivalent of more than $100 million in today’s economy.

For 2021, to pick just one example of interlopers that have not gone viral, consider red palm mites (*Raoiella indica*). Inspectors at one of Houston’s airports discovered the pests, which threaten palms and bananas, in a shipment of fresh rosemary from Mexico.

Beetles and mites aside, menacing hornets of other species have shown up before the latest Asian giant hornets, says Paul van Westendorp. An apiculture specialist, he strategizes British Columbia’s fight against *V. mandarinia*. In May 2019, just months before the discovery of an Asian giant hornet’s arrival, a *V. soror* hornet appeared in Canada. It was “alive, but not for long,” van Westendorp says. Not a frail beast, this species hunts other insects and has been reported to catch prey as large as a gecko. *V. soror* looks very much like *V. mandarinia*, he says.

Even Asian giant hornets have turned up at least once in the United States before 2019. An inspector in 2016 flagged a package holding a papery insect nest coming into the San Francisco airport. The nest held Asian giant hornet larvae and pupae, and some were still alive. These and other species of hornets accounted for about half of the 50 interceptions of hornets and yellow jackets flagged from 2010 to 2018 at U.S. ports of entry, researchers reported in 2020 in *Insect Systematics and Diversity*.

Only some invaders will manage to make permanent homes in new territory. Of these, the real troublemakers seem to be a minority. For instance, out of 455 nonnative plant-attacking insect species that have settled into forests in the continental United States, 62 cause noticeable damage, researchers reported in 2011 in *PLOS ONE*. But even a few rampaging invasive pests can get expensive.

Relentless as the onslaught of unwanted arrivals is, there's hope for stamping out the more noticeable invasions if caught early. *Vespa* hornets are "large-bodied and obvious, so people will see them," says entomologist Lynn Kimsey of the University of California, Davis. A *V. affinis* nest showed up in San Pedro, in Southern California, at least a decade ago. However, she says, "it was killed and there's been no sighting of the species since, as far as I've heard."

Catching such intrusions early isn't always easy. The Port of Oakland in California receives about 1 million overseas shipping containers each year. At best, U.S. Department of Agriculture inspectors can check maybe 10 percent of those containers for stowaway insects, Kimsey says. Add to this all the cargo arriving at Long Beach, San Diego and the other West Coast ports, plus all the cargo jets. "What's amazing is that we don't see more invasives," she says. "I think this tells you how hard it is for exotic species to get established."

They'll keep arriving though. All the more reason to keep an eye out for something funny on the lawn, even if it's just a withered nugget. ■

A protein found in the eyes of European robins responds to magnetic fields, an ability that could help the birds tell north from south.

LIFE & EVOLUTION

Case builds for bird 'quantum compass'

Tests confirm a protein in robin eyes can sense magnetic fields

BY EMILY CONOVER

Scientists could be a step closer to understanding how some birds might exploit quantum physics to navigate.

Researchers suspect that some songbirds use a "quantum compass" that senses the Earth's magnetic field, helping them tell north from south during annual migrations (*SN: 7/23/16, p. 8*). New measurements support the idea that a protein in birds' eyes called cryptochrome 4, or CRY4, could serve as a magnetic sensor.

CRY4's magnetic sensitivity is thought to rely on quantum mechanics, the math that describes physical processes on the scale of atoms and electrons. If the idea pans out, it would be a step forward for biophysicists who want to understand when quantum principles become important in biological processes.

In lab experiments, CRY4 from retinas of European robins (*Erithacus rubecula*) responded to magnetic fields, scientists report in the June 24 *Nature*. That's a crucial property for the protein to serve as a compass.

The study is the first to show "that birds' cryptochrome 4 is magnetically sensitive," says sensory biologist Rachel Muheim of Lund University in Sweden. Blue light hitting CRY4 initiates the protein's magnetic-sensing ability. The light sets off reactions that result in two unpaired electrons in different parts of the protein. Those lone electrons behave like tiny magnets, pointing either parallel to one another or in opposite directions.

But quantum physics dictates that the electrons do not settle on either arrangement. Rather, they exist in a limbo called a quantum superposition, which describes only the probability of finding the electrons in either configuration. Magnetic fields change those probabilities. In turn, that affects how likely the protein is to form an altered version. Birds may be able to tell their orientation in a magnetic field based on the amount of altered protein.

Biochemist Jingjing Xu of the University of Oldenburg in Germany and colleagues hit isolated protein with blue laser light. They then measured how much light the sample absorbed. Exposing robin CRY4 to a magnetic field changed the protein's absorbance, a sign that the magnetic field affected how much altered protein was produced. Meanwhile, exposing CRY4 from nonmigratory chickens (*Gallus gallus*) and pigeons (*Columba livia*) to the magnetic field had little effect.

Other lab tests have shown that those birds can sense magnetic fields, says biophysicist Thorsten Ritz of the University of California, Irvine. Whether the CRY4 magnetic-sensing differences are a result of evolutionary pressure for migratory birds to have a stronger sensor is unclear.

Experiments on isolated proteins don't match conditions in birds' eyes, Xu says. Future tests on retinas should give the team a literal bird's-eye view. ■

When Japan's Sakurajima volcano erupts, it produces lightning and smaller, invisible surges of electrical activity.

EARTH & ENVIRONMENT

Volcano vents odd electrical bursts

Mysterious surges could help warn of dangerous eruptions

BY ALKA TRIPATHY-LANG

As one of Japan's most active volcanoes, Sakurajima often dazzles with spectacular displays of volcanic lightning set against an ash-filled sky. But the volcano can also produce much smaller, invisible bursts of electrical activity that mystify and intrigue scientists.

Now, an analysis of 97 explosions at Sakurajima from June 2015 is helping to show when eruptions produce visible lightning bolts versus when they produce the mysterious, unseen surges of electrical activity, researchers report in the June 16 *Geophysical Research Letters*.

These invisible bursts, called vent discharges, happen early in eruptions, so scientists might be able to find a way to use the surges to warn of dangerous explosions.

Volcanic lightning can form by silicate charging, which happens both when rocks break apart during an eruption and when rocks and other material flung from the volcano jostle each other in the turbulent plume. Tiny ash particles rub together, gaining and losing electrons, which creates positive and negative charges that tend to clump together in pockets of like charge. Lightning zigzags between the charged clusters, neutralizing the unstable electrical field, says volcanologist Cassandra Smith of the Alaska Volcano Observatory in Anchorage.

Experiments have shown that volcanic lightning can't form without some amount of ash in the plume, Smith says. "So if you're seeing volcanic lightning, you can be pretty confident in saying that the eruption has ash."

Vent discharges, on the other hand, are bursts of electrical activity that produce a continuous, high-frequency signal for seconds — an eternity compared with lightning.

Focusing on Sakurajima's explosions

ATOM & COSMOS

Jupiter may have had a shadowy birth

Cold nursery could explain the planet's peculiar atmosphere

BY KEN CROSWELL

Jupiter may have formed in a shadow that kept the planet's birthplace colder than Pluto. The frigid temperature could explain the giant world's unusual abundance of certain gases, a new study suggests.

Jupiter consists mostly of hydrogen and helium, which were the most common elements in the planet-spawning disk that spun around the newborn sun. Other elements that were gases near Jupiter's birthplace became part of the planet too, in the same proportions as they existed in the protoplanetary disk (*SN: 7/8/17 & 7/22/17, p. 18*). Astronomers think the sun's composition of elements largely reflects that of the protoplanetary disk, so Jupiter's gases should resemble that solar makeup. But nitrogen, argon, krypton and xenon are about three times as common on Jupiter, relative to hydrogen, as they are on the sun.

Where those extra elements came from is "the main puzzle of Jupiter's atmosphere," says planetary scientist Kazumasa Ohno of the University of California, Santa Cruz.

If Jupiter was born at its current distance from the sun, the temperature of the planet's birthplace would have been around –213° Celsius. In the protoplanetary disk, those elements should be gases at that temperature. But they would freeze solid below about –243° C. It's easier for a planet to accrete solids than gases. So if Jupiter arose in a much colder environment than its current home, the planet could have acquired solid objects laden with those extra elements as ice.

For this reason, in 2019, two different research teams suggested that Jupiter had originated in the deep freeze beyond the current orbits of Neptune and Pluto, then spiraled toward the sun.

Now Ohno and astronomer Takahiro Ueda of the National Astronomical Observatory of Japan propose a new idea: Jupiter formed where it is, but a pileup of dust in between the planet's orbit and the sun cast a long shadow that cooled Jupiter's birthplace. The frosty temperature made nitrogen, argon, krypton and xenon freeze and become a greater part of the planet, the duo proposes in the July *Astronomy & Astrophysics*.

"It's a clever fix of something that might have been difficult to rectify otherwise," says astrophysicist Alex Cridland of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany. Cridland was among the scientists who had sug-

MIKE LYVERS/MOMENT/GETTY IMAGES

with plume heights of three kilometers or less and lasting less than five minutes, Smith and colleagues examined silicate charging, plume dynamics and the relationship between volcanic lightning and vent discharges.

As expected, lightning occurred in plumes full of ash, the team found. Vent discharges, however, occurred only when ash-rich plumes with volcanic lightning rocketed skyward at velocities greater than about 55 meters per second.

Monitoring vent discharges, which provide a measure of an eruption's intensity, could cover gaps left by other volcano monitoring methods and may eventually be helpful for quickly spotting ash-laden eruptions, says research meteorologist Chris Schultz of NASA's Marshall Space Flight Center in Huntsville, Ala. For example, infrasound is used to indicate when an explosion has occurred, but the technique doesn't differentiate between ash versus gas.

Tracking ash is vital, Smith says, "because that's what's dangerous for aviation and local communities." ■

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gested that Jupiter formed beyond the orbits of Neptune and Pluto. The new scenario avoids the complication of having to explain how or why Jupiter moved much closer to the sun after birth, he says.

The dust that cast the shadow came from rocky objects closer to the sun that collided and shattered, Ohno and Ueda suggest. In contrast, farther from the sun, where the protoplanetary disk was colder than in Earth's vicinity, water froze, forming snowball-like objects. When those snowballs collided, they tended to stick together and thus didn't cast much of a shadow, the team says.

Future missions to Saturn could test the new idea, Ohno says. The dust shadow barely reached that planet's birthplace, the team calculates. If so, then Saturn arose in a warmer region and so should not have acquired nitrogen, argon, krypton or xenon ice. But if Saturn and Jupiter formed beyond Neptune and Pluto, then they should have lots of those elements. ■

J. DEPASQUALE, LAS CUMBRES OBSERVATORY, NASA, STSCI

ATOM & COSMOS

Scientists spy a new type of supernova

The blast occurs in stars too small to explode the typical way

BY EMILY CONOVER

A long-predicted type of cosmic explosion has finally burst onto the scene.

Researchers have found convincing evidence for an electron-capture supernova, a stellar explosion ignited when atomic nuclei sop up electrons within a star's core. Scientists first predicted the phenomenon in 1980, but had never definitively seen one. A flare that appeared in the sky in 2018, called supernova 2018zd, matches several expected hallmarks of the blasts, scientists report June 28 in *Nature Astronomy*.

"These have been theorized for so long, and it's really nice that we've actually seen one now," says astrophysicist Carolyn Doherty of Konkoly Observatory in Budapest.

Electron-capture supernovas result from stars with masses that put them on the precipice of being able to explode. Stars with more than 10 times the sun's mass go supernova after fusion reactions in the core cease, and the star can no longer withstand gravity. The core collapses inward and rebounds, causing the star's outer layers to explode. Smaller stars, with less than about eight solar masses, resist collapse and form dense objects called white dwarfs. But between about eight and 10 solar masses, there's a poorly understood middle ground. For some stars that fall in this range, scientists have long suspected that electron-capture supernovas should occur.

During this type of explosion, neon and magnesium nuclei within a star's core capture electrons. An electron vanishes as a proton converts to a neutron, and the nucleus morphs into another element.

Electron capture is bad news for the star's war against gravity, since electrons help the star fight collapse. According to quantum physics, the closer that electrons are packed together, the faster they move. Those zippy electrons exert a pressure that opposes the inward pull of gravity. But if reactions within a star chip away at the number of electrons, that support weakens. If the star's core gives way — boom — that sets off an electron-capture supernova.

But without a direct observation, such a blast remained theoretical. "The big question here was does this kind of supernova even exist?" says astrophysicist Daichi Hiramatsu of the University of California, Santa Barbara and Las Cumbres Observatory in Goleta, Calif.

Hiramatsu and colleagues created a list of six criteria that an electron-capture supernova should meet. For example, the explosions should be less energetic, and should forge different varieties of chemical elements, than typical supernovas. Supernova 2018zd checked all the boxes.

Luck helped the team clinch the case. Usually, when scientists spot a supernova, the star that produced it has already been blown to bits. In this case, the star — about 70 million light-years from Earth on the edge of galaxy NGC2146 — showed up in previous images taken by space telescopes. Its properties matched those expected for the type of star that would produce an electron-capture supernova.

Finding more of these supernovas could help unveil their progenitors, misfit stars in that odd mass middle ground. ■

On the outskirts of galaxy NGC2146 (left in this composite image), scientists found the first clear example of an electron-capture supernova (large dot, below).

EARTH & ENVIRONMENT

Yeast turns corn leftovers into fuel

Tweaked microbe could tap underused source of energy

BY NIKK OGASA

When corn farmers harvest their crop, they often leave the stalks, leaves and spent cobs to rot in the fields. Now, engineers have fashioned a new strain of yeast that can convert this inedible debris into ethanol, a biofuel. If the process can be scaled up, this largely untapped renewable energy source could help reduce reliance on fossil fuels.

The leaves, stalks and spent cobs left behind after a corn harvest could one day become a source of sustainable energy, a new study suggests.

Previous efforts to convert this fibrous material, called corn stover, into fuel met with limited success. Before yeast can do its job, corn stover must be broken down, but this process often generates by-products that kill the yeast. By tweaking a gene in common baker's yeast, researchers have engineered a strain that can defuse those deadly by-products and get on with the job of making ethanol.

The new yeast was able to produce more than 100 grams of ethanol for every liter of treated corn stover, an efficiency comparable to the standard process that uses corn kernels, which are easier to break down, to make the biofuel, researchers report June 25 in *Science Advances*.

"They've produced a more resilient yeast," says Venkatesh Balan, a chemical engineer at the University of Houston who was not involved in the research.

In the United States, most ethanol is made from corn, the country's largest crop, and is mixed into most of the gasoline sold at gas stations. Corn ethanol is a renewable energy source, but it has limitations. Diverting corn to make ethanol can detract from the food supply, and expanding cropland just to plant corn for biofuel clears natural habitats. Converting inedible corn stover into ethanol could increase the biofuel supply without having to plant more crops.

"Corn can't really displace petroleum as a raw material for fuels," says metabolic engineer Felix Lam of MIT. "But we have an alternative."

Lam and colleagues started with *Saccharomyces cerevisiae*, or common baker's yeast. Like bakers and brewers, biofuel producers already use yeast to convert sugars in corn kernels into ethanol (*SN: 9/30/17, p. 4*).

The sugars in corn kernels are easy for yeast to access, whereas corn stover contains sugars bound in lignocellulose, a plant compound that yeast can't break down. Applying harsh acids can free these sugars, but the process generates toxic by-products called aldehydes that can kill yeast.

> "Corn can't really displace petroleum as a raw material for fuels. But we have an alternative."
> FELIX LAM

Lam's team had an idea — convert the aldehydes into something tolerable to yeast. The researchers already knew that by adjusting the chemistry of the yeast's growing environment, they could improve its tolerance to alcohol, which is also harmful at high concentrations. With that in mind, Lam and colleagues homed in on a yeast gene called *GRE2*, which helps convert aldehydes into alcohol. The team randomly generated about 20,000 yeast variants, each with a different, genetically modified version of *GRE2*. Then, the team placed the horde of variants inside a flask that also contained toxic aldehydes to see which yeast variants would survive.

Multiple variants survived the gauntlet, but one dominated. With this battle-tested version, the researchers found that the modified baker's yeast could produce ethanol from treated corn stover almost as efficiently as from corn kernels. What's more, the yeast could generate ethanol from other woody materials, including wheat straw and switchgrass.

"We have a single strain that can accomplish all this," Lam says.

This strain resolves a key challenge in producing ethanol from fibrous materials like corn stover, Balan says. But "there are many more improvements that will have to happen to make this technology commercially viable," he adds, such as overcoming logistical challenges in harvesting, transporting and storing large volumes of corn stover.

"There are so many moving parts to this problem," Lam acknowledges. But he thinks his team's findings could help kick-start a "renewable pipeline" that harnesses underused, sustainable fuel sources. The vision, he says, is to challenge the reign of fossil fuels. ■

LIFE & EVOLUTION

Beetle walks on water upside down

Video footage of scurrying insect sheds light on the rare ability

BY JAKE BUEHLER

Being quite small, insects can have a very different relationship with the water-air interface than larger animals do. Surface tension allows for insects like water striders to skate along the top of still waters, for example. But new research describes an unusual way to tread along this boundary: from the underside.

A water-dwelling beetle can scuttle upside down along the underside of the water's surface, as if the water were a solid pane of glass, researchers report in the August *Ethology*. It's the first detailed documentation of a beetle moving in this manner, which is known only in precious few animal groups.

Behavioral ecologist John Gould of the University of Newcastle in Callaghan, Australia, hadn't set out to look for beetles one night in the country's Watagan Mountains. Gould had instead been searching for tadpoles in ephemeral pools. In one of these pools, he spotted a black object smaller than a pinky nail.

"At first, I just assumed it must have been a bug that had fallen into the water and was swimming across the surface," Gould says, "but then realized the bug was upside-down and below the water's surface."

As Gould quickly filmed the scene, the beetle — later identified as a water scavenger beetle belonging to the family Hydrophilidae — walked under the water's surface just as it would on a flat, solid surface, periodically resting and changing direction.

Later, Gould mentioned the encounter to his colleague Jose Valdez, a wildlife ecologist at the German Centre for Integrative Biodiversity Research in Leipzig. Valdez thought the observations were interesting, but he'd seen insects walk upright underwater before.

"I didn't fully grasp what he was describing until he showed me the video," Valdez says. "Then I was floored."

Searching the scientific literature, the researchers found that some snails could slide along the underside of the water's surface on a layer of mucus, but little documentation of beetles walking this way existed.

It's a publication gap that surprises entomologist Martin Fikáček of the National Sun Yat-sen University in Kaohsiung, Taiwan. The undersurface walking ability is known to aquatic beetle specialists, who exploit the behavior when collecting beetles. For instance, researchers will unsettle a pond bottom, causing beetles to float to the surface where they skitter around upside down, he says. But no one had looked closely at the phenomenon.

"It's actually cool that somebody started to think about [beetles' abilities], because we always see it and we never even thought about it," Fikáček says.

How the Hydrophilidae beetle physically manages this feat is still unclear, but the researchers have an idea. Gould's recording of the beetle showed an air bubble trapped along the creature's upturned belly. The bubble's buoyancy may flip and pin the beetle to the underside of the water's surface, the team suspects. That would allow the insect to put pressure on the water-air boundary with every step, creating what Gould observed as tiny hills of water sprouting from the beetle's feet.

It would have been interesting to know which parts of this species "are [water-repellent] and which are not, as well as information on feet anatomy," says movement physiologist Tom Weihmann of the University of Cologne in Germany. For the beetle to push off against the water like the researchers describe, perhaps the beetle's feet are attracted to water while its body repels water, he says.

Gould and Valdez think the beetle might use this water-walking superpower to stay far away from ambush predators that lurk along the bottom of these pools. But this must be sussed out with additional research.

Future research might reveal if the beetle can switch to the opposite side of the water-air interface. Additional studies on the physics of the beetle's upside-down water-walking prowess could also inspire advancements in robotics, as has been accomplished with water striders, the team notes.

The findings highlight how often we ignore or miss the amazing things the smallest animals are doing every day, Gould says. "Describing the natural history of the small is just as important as describing the natural history of any large mammal or bird." ■

Water scavenger beetles (one shown) can reportedly walk along the underside of the water's surface, a rare ability in the animal kingdom.

Watch a beetle walk on the underside of water at **bit.ly/SN_BeetleWalk**

Protesters in New York City in March drew attention to escalating hate directed at Asian Americans. In research, Asian Americans are often omitted or treated as a uniform group.

TAYFUN COSKUN/ANADOLU AGENCY VIA GETTY IMAGES

HUMANS & SOCIETY

Science overlooks Asian Americans

The pandemic has put a spotlight on this understudied population

BY SUJATA GUPTA

For years, sociologist ChangHwan Kim has sought to characterize the lives and experiences of Asian Americans. Gatekeepers in the research community, though, have often scoffed at his focus on a demographic group that looks like the picture of success in terms of education, earnings, health and other variables (*SN: 5/8/21 & 5/22/21, p. 20*).

"In my experience, if I have a study with only Asian Americans, journals are reluctant to publish that work," says Kim, of the University of Kansas in Lawrence.

An apparent lack of interest in studying Asian Americans isn't limited to sociology; it even appears in medical research. At about 23 million people, Asian Americans, an ethnically diverse group, represent about 7 percent of the U.S. population and are the fastest-growing demographic group in the country. Yet just 0.17 percent of the National Institutes of Health's roughly $451 billion research funding between 1992 and 2018 went to clinical studies that included a focus on Asian Americans, researchers reported in 2019 in *JAMA Network Open*.

Over the last year, politicians' use of racial epithets, such as "China virus" and "kung flu," to refer to COVID-19, alongside a surge in violence against Asian Americans, has thrust this population into the media spotlight. This attention is "a new phenomenon," Kim says. That media gaze has revealed just how little is known about the health and well-being of Asian Americans.

Asian Americans' invisibility in public and scientific discourse stems from the majority-minority paradigm, Kim says. This sociological paradigm frames white Americans, the majority, as better off than minority groups across several metrics, including educational outcomes, wages and family stability. So studies of minorities often focus on issues related to marginalization and inequality. Asian Americans do not appear to fit the paradigm.

"Minorities are doing worse than whites. That's what people want to talk about," Kim says. "Studies on Asian Americans make things complicated."

Nuanced success

Because of their apparent success, Asian Americans are often excluded from research, lumped together with white people or placed in the catchall category of "other."

But studying success is itself important, says sociologist Arthur Sakamoto of Texas A&M University in College Station. For instance, researchers study both struggling and successful white Americans to understand the full range of outcomes within the group, he says. Yet, with minority groups, researchers largely focus on those who are struggling, thereby excluding Asian Americans. "If you really want to understand the ultimate nature of social problems, you also have to study the contrast," says Sakamoto. "You can't just study one end of the distribution."

Moreover, Asian Americans do face challenges. For instance, they are less likely to utilize mental health services than other demographic groups, and not necessarily because Asian Americans have fewer mental health issues. In the January 2020 *Psychiatric Services*, researchers reported that among a U.S. sample of 10,494 white people and 451 Asian Americans diagnosed with major depressive disorder, 70 percent of the white people received mental health treatment compared with just 35 percent of the Asian Americans.

And though their education levels and earnings are on par with or even higher than white Americans, Asian Americans are underrepresented in managerial and supervisory positions.

Even when Asian Americans are studied, researchers rarely break down this extremely heterogeneous group into distinct populations. Members hail from at least 19 countries, each with different cultures and languages, and no one population dominates. Thus, treating Asian Americans as a monolithic group can hide struggling subgroups. The overall Asian American poverty rate is 10 percent, for example, but jumps to 25 percent for Mongolian and Burmese populations in the United States, according to an April report from the nonpartisan Pew Research Center.

Understanding this group and its complexities is becoming increasingly important as the population grows, Kim says. Asians are projected to surpass Hispanic people as the largest immigrant group by 2055, according to Pew. By then, Asians are expected to comprise 36 percent of all U.S. immigrants, while Hispanic people will make up 34 percent.

Gaps in the data

The datasets that researchers use to study U.S. demographic groups reflect this long-standing disinterest in studying Asian Americans, Kim says. Few surveys include enough Asian Americans to study subgroups within the category in detail. That's true, he says, even of the U.S. Census Bureau's annual surveys, which provide snapshots of demographic and labor trends.

Meanwhile, few popular longitudinal surveys that follow people across long stretches of time, such as the National Longitudinal Surveys and Panel Study of Income Dynamics, include enough Asian American people to even study them as a bloc. "We cannot study how Asian Americans move across their lives or how Asian Americans move from the parents' generation to the second generation," Kim says.

Community psychologist Nellie Tran ran into that problem several years ago. As a graduate student, she wanted to understand the educational outcomes of U.S.-born Asian Americans and scoured the scientific literature. "I only came up with 45 articles in history," says Tran, now at San Diego State University.

Most of those articles relied on a single dataset, the National Educational Longitudinal Study of 1988, which ran from 1988 to 2000 and followed individuals from eighth grade to young adulthood. Sociologists "were studying many different questions off one group of students," Tran says. That group wasn't even relevant to Tran's work, as the Asian Americans in the survey were predominantly foreign-born.

Kim and other researchers have developed work-arounds to overcome some of those gaps. Studying well-educated Asian Americans is feasible, for instance, thanks to the National Survey of College Graduates. That survey, conducted by the Census Bureau, takes place every two to three years and tracks outcomes for U.S. bachelor's degree holders. Because of their strong presence in higher education, Asian Americans are well-represented in this survey. The survey also includes data on where first-generation Asian Americans originated. "That means you can actually divide Asian Americans by ethnic group. So for well-educated Asian Americans, we have a dataset," Kim says.

Kim's research using that data has revealed inequalities even among this select group. College-educated Asian American men born in the United States earn 8 percent less than white men with the same level of education and college major, Kim and Sakamoto reported in 2010 in *American Sociological Review*. Similarly, Asian American women are less likely to reach managerial positions than white women with the same qualifications, Kim noted in 2014 in *Social Forces*. For both men and women, these disadvantages are evident across most Asian ethnic groups.

Similar datasets do not exist for less-educated Asian Americans. For example, six of the eight victims in the mass shooting at three Atlanta-area spas in March were Asian American women and probably poor, Kim says. Working-class Asian Americans are the most invisible members of an already invisible group. "We need to know who are they, what they need," Kim says. For instance, little is known about what access such workers have to relevant social programs or if those programs are culturally appropriate.

Recently, Kim and colleagues zoomed in on employment changes brought on by the pandemic. He used short-term census data and looked for changes in individual employment from January to August 2020. When Kim dove into the data, he says, he was startled to find that Asian Americans lacking a bachelor's degree were more likely to have lost their job during the initial COVID-19 lockdown in April and May 2020 than any other demographic group. That finding appeared in the February *Research in Social Stratification and Mobility*. Kim could not break the data down further to see which Asian American ethnic groups suffered the most.

Overcoming publication bias

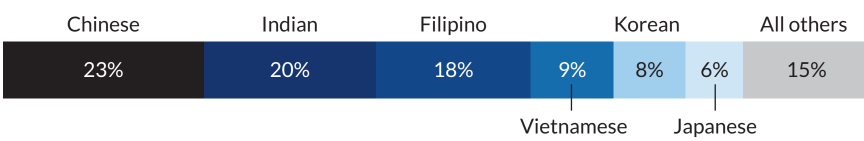
Absent a targeted effort to study Asian Americans, progress in understanding this demographic group will remain limited, Kim says.

Right now, when he submits studies focused on Asian Americans to journals, he includes a lengthy explanation of the need for such work. He includes the statistics showing how fast the Asian American population is growing. And he argues that Asian Americans' experiences can help elucidate how immigrants assimilate — or not — in the United States. He is particularly interested in understanding how that assimilation process differs by socioeconomic status, gender and country of birth. For instance, how does the life trajectory of a working-class Asian immigrant differ from that of a U.S.-born, middle-class third-generation Asian American?

Asian Americans, with all their successes and struggles, merit their own analysis, Kim says. "Look at all the other studies that focus on African Americans only, Hispanics only, white Americans only. Why is studying Asian Americans only not legitimate?" he asks. "Asian Americans are Americans. We need to understand them." ■

Diverse origins As of 2019, six origin groups account for about 85 percent of the Asian American population, with Chinese being the single largest group. At least 13 other origin groups make up the other 15 percent of the population. SOURCE: PEW RESEARCH CENTER

Asian Americans, by origin group



C. CHANG

LIFE & EVOLUTION

How spiraling fractals form in Romanesco cauliflower

The swirling green cones that make up the head of Romanesco cauliflower also form a fractal pattern, which repeats itself on multiple scales. The genes that underlie this stunning structure have been identified, and the fractal pattern has been replicated in the common lab plant *Arabidopsis thaliana*, researchers report in the July 9 *Science*.

"Romanesco is one of the most conspicuous fractal shapes that you can find in nature," says Christophe Godin, a computer scientist with the National Institute for Research in Digital Science and Technology who is based at École Normale Supérieure de Lyon in France. "The question is, why is that so?"

Godin and colleagues knew an *Arabidopsis* variant could produce small cauliflower-like structures. So the team manipulated the genes of *A. thaliana* in both computer simulations and experiments in the lab. By altering three genes, the team grew a Romanesco-like head on *A. thaliana*. Two of those genetic tweaks hampered flower growth. In place of a flower, the plant grows a shoot, and on that shoot, it grows another shoot, and so on, says plant biologist François Parcy at CNRS in Grenoble. "It's a chain reaction."

Altering the third gene increased the growing area at the end of each shoot and provided space for spiraling conical fractals to form. The team's next step, Parcy says, "will be to manipulate these genes in cauliflower." *— Nikk Ogasa*

Romanesco cauliflower exhibits one of nature's most stunning fractal displays.

GENES & CELLS

Your DNA may affect how susceptible you are to COVID-19

Some people can blame their DNA for making them more likely to get COVID-19 or become severely ill.

A study of almost 50,000 people with COVID-19 has uncovered 13 genetic variants linked to an increased risk of infection or of developing severe illness, an international research team reports online July 8 in *Nature*.

Some of the variants had been uncovered before. For instance, the researchers confirmed a link between blood type and the likelihood of getting infected, but don't know why people with type O blood may be slightly protected.

But at least one association was unknown: A variant in a gene called *FOXP4* is associated with more severe COVID-19, the team found. That variant boosts the gene's activity and has been linked to lung cancer and interstitial lung disease, which causes scarring and stiffness of the lungs. Yet-to-be-developed drugs that inhibit activity of *FOXP4*'s protein might help people recover from COVID-19 or prevent severe illness.

The disease-associated version of the gene is more common in Latino populations in the Americas and in East Asians. Only 2 to 3 percent of people with European ancestry have the variant, compared with 7 percent of people in the Middle East, 20 percent of Latinos and 32 percent of East Asians. *— Tina Hesman Saey*

MATTER & ENERGY

A portable atomic clock could revolutionize space travel

An atomic clock that could transform deep-space travel has successfully completed its first test run in space.

NASA's Deep Space Atomic Clock, which launched on a satellite in 2019, outperformed all other clocks in space during its first year in orbit around Earth. The clock, DSAC for short, was at least 10 times as stable as clocks on GPS satellites, researchers report in the July 1 *Nature*.

To navigate, space probes listen for signals from antennas on Earth and then bounce those signals back. Refrigerator-sized atomic clocks on the ground measure that round trip time, which can take hours, to pinpoint a spacecraft's location.

A future spacecraft carrying a toaster oven–sized DSAC could simply measure how long it takes a signal from Earth to arrive and calculate its own position. Untethering navigation from Earth could someday enable self-driving spaceships.

DSAC keeps time using electrically charged atoms, or ions, rather than neutral atoms. Bottling ions within electric fields prevents those atoms from bumping into the walls of their container. Such interactions cause the neutral atoms in GPS satellite clocks to lose their rhythm.

By comparing DSAC with the U.S. Naval Observatory's atomic clock on the ground, the team found that the space clock drifted by about 26 picoseconds, or trillionths of a second, over the course of a day. That's comparable to the ground-based atomic clocks used for deep-space navigation. *— Maria Temming*

ATOM & COSMOS

Any aliens near these stars could spot Earth crossing the sun

Astronomers look for distant planets by watching for the shadow the worlds cast when passing between their star and Earth. If any aliens are searching for other intelligent life, they could spot us using the same trick.

Scientists have identified 1,715 star systems whose hypothetical inhabitants could have seen Earth cross in front of the sun sometime in the last 5,000 years. Another 319 stars will come into the right positions for spotting Earth in the next 5,000 years, astrophysicists report in the June 23 *Nature*. Seventy-five of the stars are close enough that human-made radio waves have already reached them; seven stars have potentially habitable planets.

The team used maps of over a billion stars from the European Space Agency's Gaia spacecraft, which measures star movements and distances from Earth. The team identified the region of space from which stars can see Earth cross the sun and then ran the clock backward and forward to see stars move in and out of that zone. *— Lisa Grossman*

Clusters of stars like this one helped show that the Milky Way is enormous and just one of many galaxies. The glittering young stars in this Hubble Space Telescope image are about 20,000 light-years away in the constellation Carina.

ScienceNews 100

To celebrate our upcoming 100th anniversary, we've launched a series that highlights some of the biggest advances in science over the last century. To see more from the series, visit the Century of Science site at **www.sciencenews.org/century**

NASA, ESA, THE HUBBLE HERITAGE TEAM/STSCI AND AURA, A. NOTA/ESA AND STSCI, AND THE WESTERLUND 2 SCIENCE TEAM

A Century of New Worlds

A series of revolutions in astronomy have bumped us from the center of the universe

By Lisa Grossman

A century ago, the Milky Way galaxy was the entirety of the known universe. We had no idea what made the stars shine, and only one star — our own sun — was known to harbor any planets. Of those planets, humans had explored only one: Earth.

"The stellar universe, as we know it ... is a flattened, watch-shaped organization of stars and nebulae," astronomer Harlow Shapley wrote in *Science News Bulletin*, the earliest version of *Science News*, in August 1921 (*SN: 8/8/1921, p. 3*). That sparkling pocket watch was the Milky Way, and at the time Shapley wrote this, astronomers were just beginning to conceive that anything at all might lie beyond it.

Today, spacecraft have flown by every one of the solar system's planets, taking close-ups of their wildly alien faces. The solar system, it turns out, contains a cornucopia of small rocky and icy bodies that have challenged the very definition of a planet. Thousands of planets have been spotted orbiting other stars, some of which may have the right conditions for life to thrive. And the Milky Way, we now know, is just one of billions of galaxies.

The last 100 years have brought a series of revolutions in astronomy, each one kicking Earth a bit farther from the center of things. Along the way, people have not exactly been receptive to these blows to our home planet's centrality. In 1920, the question of whether there could be other "island universes" — galaxies — was the subject of the Great Debate between two astronomers. In the 1970s, when Mars was shown to have a pink sky, not blue, reporters booed. Their reaction "reflects our wish for Mars to be just like the Earth," said astronomer Carl Sagan afterward. And in the 1990s, astronomers almost missed extrasolar planets hiding in their data because they had tailored their search techniques to find planets more like those in our own solar system.

But turning our focus from Earth has opened our minds to new possibilities, new universes, new places where life might exist. The next century of astronomy could bring better views of our cosmic origins and new strategies for finding worlds that other creatures call home.

The misperceptions of decades past suggest scientists should be careful when predicting just what we'll find in the future.

"You learn a lot of humility in this business," says planetary scientist Candice Hansen of the Planetary Science Institute, based in Tucson. "You always learn a lot more when you're wrong than when you're right."

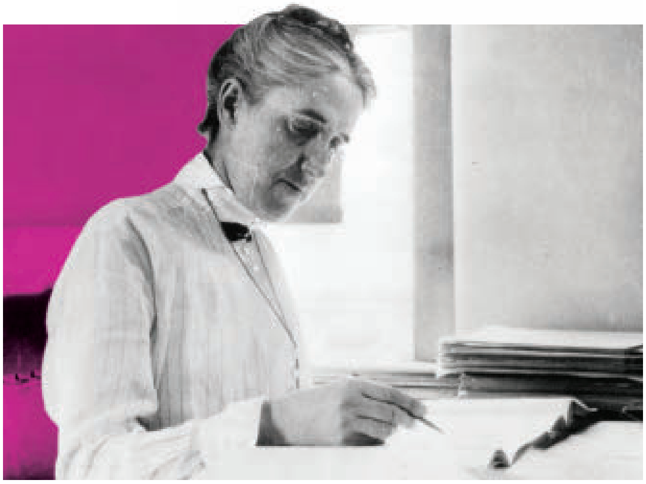
More than the Milky Way

At the turn of the 20th century, conventional wisdom held that the Milky Way stood alone. It contained stars, sometimes organized in clusters, and fuzzy patches of light known as nebulae. That was about it.

Some nebulae had spiral structures, "appearing in the telescope like vast Fourth-of-July pinwheels," as *Science News Letter*, the predecessor of *Science News*, described them in 1924. In the 18th century, German philosopher Immanuel Kant had described nebulae as "higher universes," or, "so to speak, Milky Ways." But by the early 1900s, most astronomers thought that drawing that parallel was ridiculous.

"No competent thinker," wrote historian of astronomy Agnes Clerke in 1890, can "maintain any single nebula to be a star system of coordinate rank with the Milky Way."

By the 1920s, though, that view was already being challenged. As early as 1914, astronomer Heber Curtis of Lick Observatory in California argued that spiral nebulae are not



In the early 1900s, astronomer Henrietta Leavitt discovered a feature of certain stars, called Cepheid variables, that helped other astronomers measure cosmic distances. Those stars ultimately helped prove that the Milky Way is just one of many galaxies.

part of the Milky Way, but rather "inconceivably distant galaxies of stars or separate stellar universes so remote that an entire galaxy becomes but an unresolved haze of light."

Around the same time, Shapley, of Mount Wilson Observatory in California, began to prove that the Milky Way itself was inconceivably vast.

Shapley built on work by Henrietta Leavitt, one of a group of women "computers" at Harvard University who pored over photographic plates capturing the night sky. In studying photographs of the Magellanic Clouds, which we now know are two small galaxies that orbit the Milky Way, Leavitt noticed that certain stars varied in brightness over time, some of them in a peculiar way. "It is worthy of notice," she wrote in 1908, that "the brighter variables have the longer periods." In other words, brighter stars twinkled more slowly.

That meant that these variable stars, called Cepheids, could be used to estimate cosmic distances. It's hard to tell how far away a cosmic object truly is — bright-looking stars could be intrinsically dim but close, while faint-looking stars could be intrinsically bright but distant. But all the Cepheids within the same cloud should be roughly the same distance from Earth. That meant "their periods are apparently associated with their actual emission of light," Leavitt wrote in 1912. To figure out any Cepheid's true brightness, all an astronomer had to do was measure its twinkling speed. It was a short step from there to figuring out its distance.

Shapley put this fact to use just a few years later, measuring distances to Cepheids within globular clusters of stars to figure out the sun's position in the Milky Way. To his surprise, the sun was not in the center of the galaxy but off to one side. The Milky Way's starry disk was also about 10 times wider than previous astronomers had assumed: about 300,000 light-years across, according to his calculations. (He overshot a bit; modern astronomers think it's somewhere between 120,000 and 200,000 light-years.)

He and Curtis took their opposing views to the public at a meeting of the National Academy of Sciences in Washington, D.C., in April 1920, in an event that became known as the Great Debate. Each had 40 minutes to present their views on whether there is only one or several universes — what we now think of as galaxies.

Shapley, who was in his 30s and considered a rising star in the field, went first. A former journalist who reportedly was uncomfortable speaking to crowds, he read his argument from a typewritten script. He barely touched on the question of other universes, focusing instead on his new measurements of the Milky Way's size. The implication was that the Milky Way was too large for other galaxies to make sense.

Curtis was an older, well-respected authority on spiral nebulae, as well as a gifted speaker. He argued for the then-standard view that the Milky Way was much smaller than Shapley supposed. But even a large Milky Way shouldn't negate the possibility of other, equally large galaxies, he argued. The spectra of light coming from spiral nebulae was similar enough to that of the Milky Way that they could be similar objects, he maintained.

Both astronomers were partly right, and partly wrong.

Galaxies come into view

The Great Debate was resolved by a young astronomer named Edwin Hubble working at Mount Wilson. Hubble also used Leavitt's Cepheid variable technique to measure cosmic distances, this time by finding the variable stars in the spiral nebulae themselves.

Hubble started observing the Andromeda nebula, one of the brightest nebulae on the sky, in the fall of 1923. He used Mount Wilson's 60-inch telescope and its 100-inch telescope, then the world's largest. Over the next year or so, he studied 35 Cepheids in Andromeda and a different nebula called Triangulum. Their periods were long enough that the nebulae had to be on the order of a million light-years away for the stars to appear so faint. (We now know it's more like 2.5 million light-years to Andromeda and 2.7 million to Triangulum.)

"Measuring the distance to Andromeda was a big deal because it was the first evidence that there are galaxies beyond our own," says astronomer Emily Levesque of the University of Washington in Seattle. "It changed what we thought of as the shape of our universe."

A few hints that the Milky Way was not alone had cropped up before that, but Hubble's finding clinched it. Even if the Milky Way was as big as Shapley claimed, Andromeda lay outside its borders. When Shapley received Hubble's paper, he reportedly said, "Here is the letter that destroyed my universe."

Science News Letter reported Hubble's finding under the headline "Sky Pinwheels Are Stellar Universes 6,000,000,000,000,000,000 Miles Away" in December 1924 (*SN: 12/6/24, p. 2*).

"It seems probable that many of the smaller spiral nebulae are still more remote and appear smaller on this account," the story quotes Hubble as saying. "The portion of the universe within the range of our investigation consists of vast numbers of stellar galaxies comparable to our own, scattered about through nearly empty space and separated from one another by distances of inconceivable magnitude." Here at last was the modern view of the universe.

By the end of the decade, Hubble had not only shown that the spiral nebulae were "island universes," he also had begun to classify different galaxy types and think about how they evolved over time. What's more, he showed that galaxies were flying away from each other at speeds proportional to their distance. In other words, the universe was expanding.

By the end of the century, astronomers knew that the universe was dotted with billions of galaxies of all shapes and sizes. In April 1990, NASA launched the first optical space telescope into Earth's orbit, giving the world a new perspective on space.

"Instead of these blurry blobs from even the best mountaintop observatories on our planet," says planetary scientist Jim Bell of Arizona State University in Tempe, "all of a sudden the entire realm of solar system, galaxy, extragalactic ... was opened up by getting above the atmosphere."

NASA named the telescope after the scientist who opened astronomers' minds to the existence of such a universe: the Hubble Space Telescope.

The images it has captured over 30 years of operations — star clusters, galaxies and nebulae — are so iconic they are printed on everything from socks and coffee mugs to high fashion runway designs. The telescope itself was recently immortalized in Lego form.

"It's the one that literally everyone has heard of," says Levesque. Most people today think Hubble was "the guy who built the telescope."

One image from early on in the space telescope's tenure stands out. In December 1995, the telescope's director, Robert Williams, decided to train the observatory on a tiny, dark patch of sky near the handle of the Big Dipper for 10 consecutive days. The resulting portrait of this featureless bit of sky revealed thousands of previously unknown galaxies sending their light from farther away than astronomers had ever seen before (*SN: 1/20/96, p. 36*). The universe as Edwin Hubble had imagined it, chock-full of island universes, was captured in one hard look.

As for Henrietta Leavitt, she missed out on the recognition she deserved for helping knock the Milky Way from its central perch. A Swedish mathematician wrote to her in 1925 saying that her work "has impressed me so deeply that I feel seriously inclined to nominate you to the Nobel Prize in physics for 1926." He received a reply from Shapley, by then director of the Harvard College Observatory: Leavitt had died four years earlier.

Astronomer Edwin Hubble, shown here holding a drawing of a galaxy, proved that there are other galaxies outside of the Milky Way.

HUBBLE: HALE OBSERVATORIES, COURTESY OF AIP EMILIO SEGRÈ VISUAL ARCHIVES

Steps to Mars

The first liquid-fueled rockets, precursors to the ones that later carried robots and people into space, launched in the 1920s. A century later, robots have flown past, orbited or landed on every planetary body that was known in 1920, and a few that weren't. People have walked on the moon and have lived in space for more than a year at a time. And serious talks about sending people to Mars are in the works.

NASA used to explore other worlds in a clear order, first observing with telescopes and then carrying out increasingly complex missions: flybys, orbiters, landers, rovers, then people and sample returns. "We've taken that entire progression on the moon, in [the last] century," Bell says. "Sometime in this new century, we'll add Mars to that list. All the rest of the solar system, we've got large chunks of that matrix checked off."

After the Soviet Union launched the first artificial satellite, Sputnik 1, in 1957, space launches came fast and furious. Many were demonstrations of political and military might. But a lot of them had scientific merit, too. The Soviet Luna 3 spacecraft photographed the farside of the moon in 1959 — shortly after NASA's founding. Spacecraft flew past Venus and Mars in the 1960s, sending back the first closeup data on their alien atmospheres and surfaces.

Before NASA's Viking 1 spacecraft landed on Mars in July 1976, *Science News* and others envisioned the Red Planet with a blue sky. Mars' sky is actually a dusty yellowish-pink.

That same decade, humans landed on the moon and brought back rocks, opening a wide and detailed window into the history of the solar system. The lunar samples from the Apollo missions gave scientists a way to figure out how old planetary surfaces are around the solar system, taught us that the entire inner solar system was bombarded with impacts in its youth and gave us an origin story for the moon (*SN: 7/6/19 & 7/20/19, p. 18*).

"Until we started the space program, we really had no idea what the geology was on other places," says Hansen of the Planetary Science Institute. "Early in the century, they were still debating whether the craters on the moon were impact craters or volcanic calderas. Even right there in our own backyard, we didn't know what was going on."

And extraterrestrial geology was surprising. Without meaning to, planetary scientists had based a lot of their expectations for other worlds on the Earth. The cover of *Science News* from June 1976, the month before NASA's Viking 1 lander became the first long-lived spacecraft to land softly on Mars, showed Mars with a Cheez Whiz–colored desert under a clear blue sky. In the sleep-deprived rush to release the first color images sent back by Viking 1, scientists processed the image to produce a blue sky there, too.

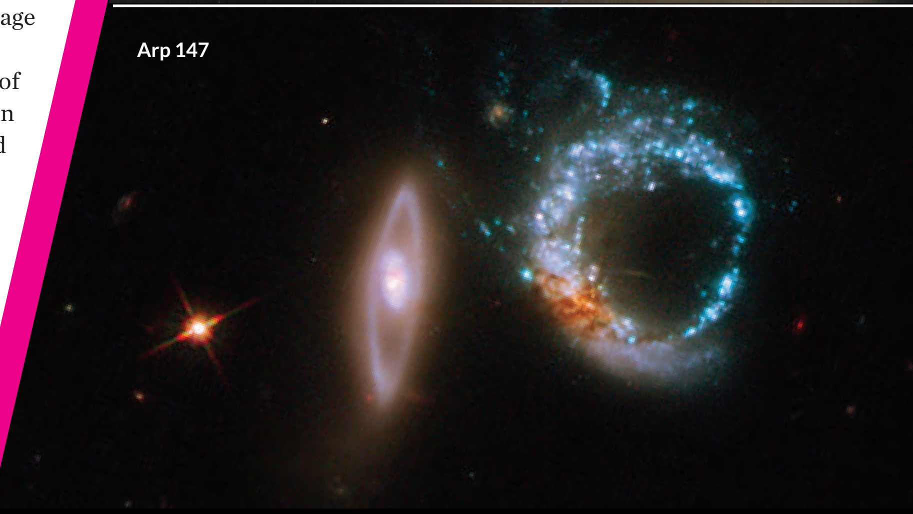
But the day after the landing, James Pollack of the imaging team told reporters that the Martian sky was actually pink, probably thanks to scattered light from dust particles suspended in the air.

"When we found the sky of Mars to be a kind of pinkish-yellow rather than the blue which had erroneously first been reported, the announcement was greeted by a chorus of good-natured boos from the assembled reporters," Sagan later wrote in the introduction to his popular book *Cosmos*. "They wanted Mars to be, even in this respect, like the Earth."

Still, the Viking 1 and 2 landings brought Mars down to Earth, so to speak. "Mars had become a place," Viking project scientist Gerald Soffen said in an interview for a NASA historical project published in 1984. "It went from a word, an abstract thought, to a real place."

In some ways, the Viking landers' views of Mars were disappointing. The mission's central goal was explicitly to search for microbial life. It was "a long shot," journalist Janet L. Hopson wrote in *Science News* in June 1976 (*SN: 6/5/76, p. 374*). But "even if no signs of life appear, [biologists] stand to gain their first real perspective on terrestrial biochemistry, life origins and evolution."

Arp 244



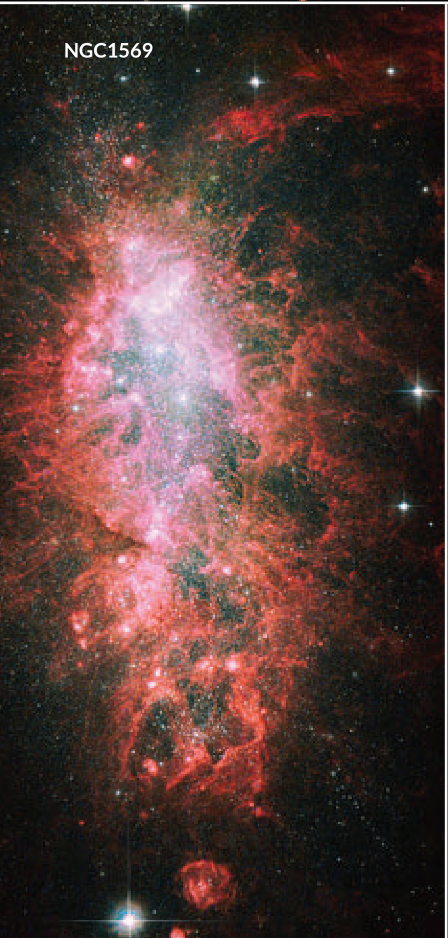
Arp 147

Bizarre beauties

In the 1960s, astronomer Halton Arp proposed that researchers use the weirdest-looking galaxies as natural experiments to learn what gives a galaxy its shape. To help researchers figure out what makes a galaxy spiral, blobby or some other shape, Arp published the 1966 *Atlas of Peculiar Galaxies*, a compilation of 338 galaxies sorted by appearance.

Arp's categories were spiral, elliptical, neither spiral nor elliptical, double and none of the above. At the time, some of the galaxies had no names or designations, and are still best known by their Arp numbers, like Arp 273 and Arp 147 (a pair of interacting ring galaxies).

Despite their diversity, most of the peculiar galaxies are now thought to be going through a merger or interacting with another galaxy. But Arp never bought that explanation. He claimed for years that galaxies' shapes come from material ejected from their luminous cores. Here are five of the most beautiful and bizarre galaxies, as seen by the Hubble Space Telescope and others, which offer much greater detail than Arp had access to half a century ago. *— Lisa Grossman*



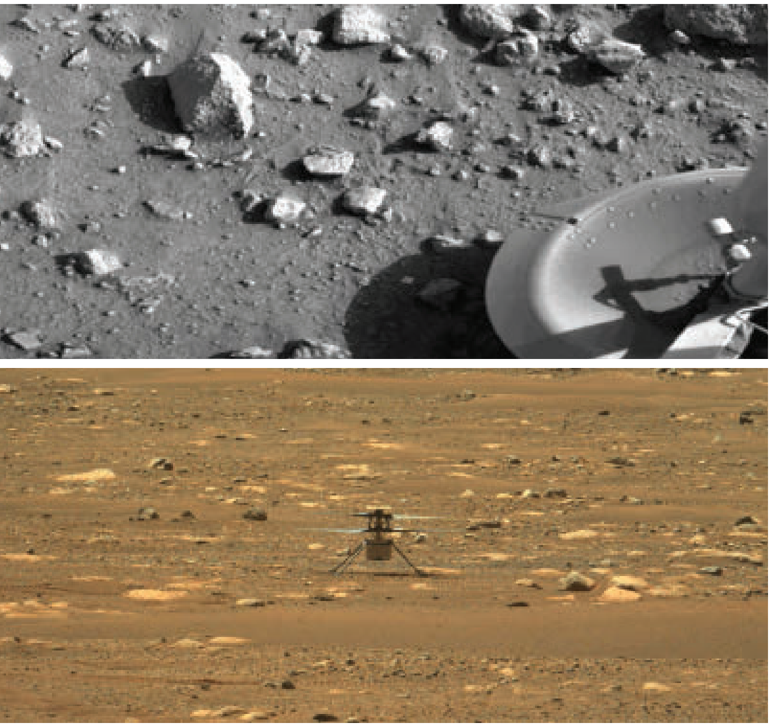
Arp 244 (the Antennae galaxies)
Looking like a backward comma, Arp 244 is a pair of colliding galaxies in the constellation Corvus that began interacting a few hundred million years ago. The yellowish blobs at the top and bottom of the image are the cores of the original galaxies, blue marks star-forming regions and pink is glowing hydrogen gas.
HUBBLE/ESA AND NASA

Arp 147
The blue ring galaxy on the right of this image probably became ring-shaped after the galaxy on the left passed through it. The collision created a density wave that propagated outward, like ripples through a pond. The pileup of gas produced by the wave helped spark the blue ring of star formation. The reddish knot at the bottom left of the ring may mark the galaxy's original core.
NASA, ESA, M. LIVIO/STSCI

NGC2276
The spiral galaxy NGC2276 is forming bright new stars along its upper left edge. That starburst could have been triggered by a previous collision, or by the galaxy's motion through the hot gas that lies within galaxy clusters.
NASA, ESA, STSCI, PAUL SELL/UNIV. OF FLORIDA

NGC1569
This galaxy is a dwarf galaxy in the constellation Camelopardalis that is undergoing a burst of star formation. Over the last 100 million years, it has formed stars at a rate 100 times that of the Milky Way. All that star formation eventually produced supernovas, whose strong stellar winds also sculpted the galaxy.
NASA, ESA, THE HUBBLE HERITAGE TEAM/STSCI AND AURA

M51 (the Whirlpool galaxy)
M51 is a classic spiral, with two curving arms of young blue stars reaching out from a yellowish central core of older stars. Some astronomers think the Whirlpool's arms are so prominent because of the small galaxy at the tip of one of the arms, NGC5195 (yellow blob at top of image). Despite how close the galaxies look, NGC5195 has actually been passing behind the Whirlpool for hundreds of millions of years. Shock waves from the smaller galaxy's passage may help sculpt the larger's distinctive shape.
NASA, ESA, S. BECKWITH/STSCI, THE HUBBLE HERITAGE TEAM/STSCI AND AURA



The first image taken on the surface of Mars (top), in July 1976, shows the footpad of NASA's Viking 1 lander and the rocks of a basin called Chryse Planitia. Almost 45 years later, the small helicopter Ingenuity (bottom) landed with the Perseverance rover and became the first robot to fly in the thin Martian atmosphere. Its blades span 1.2 meters.

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

The results of the Viking mission's life-detection experiments were inconclusive, a finding almost worse than a true negative.

NASA subsequently pulled back from seeking life directly. The next 45 years of Mars missions searched for signs of past water, potentially habitable environments and organic molecules, instead of living organisms. All of those features turned up in data from the Spirit, Opportunity and Curiosity rovers in the 2000s and 2010s.

Now, NASA's Perseverance rover, which landed in February 2021, is hunting for signs of ancient microbial life. The rover will cache rock samples that a future mission will bring back to Earth. And the joint Russian and European space agencies' ExoMars rover — named Rosalind Franklin, after the chemist whose work was central to discovering DNA's structure — aims to seek molecular signatures of life on Mars and just below the surface after it launches in 2022.

Sagan predicted in 1973 that if he had been born 50 years in the future, the search for life on Mars would have already been completed. Today, 48 years later, we're still looking.

Exotic moons

The year after the Vikings landed on Mars, another pair of spacecraft launched to check almost the entire rest of the solar system off scientists' must-see list. Astronomers realized that in 1977, the planets would line up in such a way that a spacecraft launched that year could reach Jupiter, Saturn, Uranus and Neptune one by one, stealing a little angular momentum from each world as it went along. The mission was dubbed Voyager (*SN: 8/27/77, p. 132*).

"There's never been anything like it, and there never will be again," says Bell, of Arizona State. "It was comparable to the voyages of Magellan or Darwin or Lewis and Clark. Just an absolutely profound mission of discovery that completely changed the landscape of planetary science in this century."

Voyager's views of the outer solar system forced scientists to think outside of the "Earth box," says Hansen, who worked on the mission. "The Voyager imaging team, bless their hearts, they would make predictions and then they'd be wrong," she says. "And we would learn something."

Hansen recalls chatting with a member of the imaging team when the spacecraft was approaching Jupiter and its dozens of moons. "He said, 'Candy, we will see craters on [moons] Io and Europa, because we know from the density that those are rocky worlds. But not on Ganymede and Callisto, because those are ice,' " she recalls. Instead, the images showed Ganymede and Callisto were covered in craters. "That was an aha moment — ice is going to act like rock at those temperatures." Meanwhile, ocean-swathed Europa and molten Io had almost no craters.

The moons of Jupiter presented "a whole, previously unimagined family of exotic worlds, each radically different not only from its companions, but also from everything else in the planet-watcher's experience," journalist Jonathan Eberhart wrote in *Science News* in April 1980 (*SN: 4/19/80, p. 251*).

Before 1979, Earth was the only geologically active, rocky world scientists knew about. But Voyager changed that view, too. A member of Voyager's optical navigation team, Linda Morabito, spotted an odd, mushroom-shaped feature extending off the edge of Io while she was trying to plot the spacecraft's position on March 9, 1979. She consulted with the science team, and they soon realized they were looking at a gigantic volcanic plume. Io was erupting in real time.

Three planetary scientists had predicted Io's fire before the plumes were discovered. The three suggested the moon was heated by a gravitational tug-of-war between Jupiter and one or two of its other moons, Europa and Ganymede.

But most of the planetary science community was stunned. "We take gravity for granted here. It keeps our feet on the ground," Hansen says. "But gravity molds and shapes so many things in so many unexpected ways."

Voyager and subsequent missions to the outer planets, like Galileo at Jupiter in the 1990s and Cassini at Saturn in the 2000s, transformed our view of the solar system in another profound way. They revealed several surprising parts of the solar system where life might exist today.

Voyager hinted that Europa might have a liquid water ocean beneath an icy shell. Galileo strengthened that idea, and suggested the ocean might be salty and have contact with the moon's rocky core, which could provide chemical nutrients for microbial life. NASA is now developing a mission to fly past Europa. "I will not be surprised if life is somehow discovered on Europa in my lifetime, or in this century," Bell says.

Shortly after the Cassini spacecraft arrived at Saturn in 2004, scientists realized that the tiny moon Enceladus vents dramatic plumes of water vapor, dust and ice crystals into space from a hidden subsurface sea. That moon also looks like a good place for life.

If the last century of exploring the solar system was about coming to grips with alien geology, Hansen says, this coming century is going to be about oceanography — getting a grip on the strange seas in our own solar system.

"I think that's going to shape a lot of the research going forward," Hansen says. Now that it's clear these moons have oceans, researchers will ask if they are habitable, and eventually, if they are inhabited.

Exoplanets detected

The first planet spotted outside our solar system — an exoplanet — was so different from anything in our solar system that astronomers weren't hunting for anything like it.

"Knowing that there are actually planets around other stars now seems so trivial to say," says exoplanet observer Debra Fischer of Yale University. "But we had arguments in 1995 about whether other stars have planets."

So when astronomer Michel Mayor of the Geneva Observatory turned his spectrograph on the sky in April 1994, he kept quiet about his hopes of finding true exoplanets. He was more likely to find brown dwarfs, failed stars that never grew massive enough to burn hydrogen.

His instrument used a clever new way to hunt for other worlds, called the radial velocity technique. Previous exoplanet hunters had looked directly for a star's motion in response to the gravity of an orbiting planet, watching to see if the star would move back and forth in the sky. That technique had led to several planetary claims, even dating back to 1855, but none of them had held up. Those motions are tiny; Jupiter's influence moves the sun by just 12 meters per second.

Instead, Mayor and others studied a shift in the wavelength of starlight as a star moved to and fro. As a star approaches us, the light shifts to shorter, or bluer, wavelengths; as it moves away, the light grows redder. Calculating the velocity of a star's back-and-forth motion, astronomers could figure out the minimum mass and length of the year of whatever was tugging that star.

The shifts Mayor was looking for were still minuscule. The search was considered futile, and fringe — like looking for little green men. So astronomers who explicitly claimed to be searching for planets had a hard time scheduling observations at telescopes. Brown dwarfs, on the other hand, were considered legitimate science, and would be easier to detect.

So the world was astounded when, in October 1995, Mayor and his student Didier Queloz reported strong evidence not of a brown dwarf, but of a true planet orbiting the sunlike star 51 Pegasi, about 50 light-years from our solar system.

The new planet was weird. It seemed to be about half the mass of Jupiter, too puny to be a brown dwarf. But it orbited the star once every 4.23 Earth days, putting it incredibly close to its star. There's nothing like that in our solar system, and astronomers had no idea how it could exist.

"The news flashed through the astronomical community like a lightning bolt," wrote journalist Ron Cowen in *Science News*, in the first of three stories on the new planet he would write within a month (*SN: 10/21/95, p. 260*).

51 Peg b, as it came to be known, launched a new era. "It means planets exist around other sunlike stars, we can find them, and they might be the exciting ones," says Yale anthropologist Lisa Messeri, who has studied how astronomers create worlds out of pixels and spectra. "Firsts are exciting because they promise there will be seconds and thirds and fourths."

Spacecraft have revealed that some moons let their insides out. Jupiter's moon Io (left) spurts plumes of magma as high as 390 kilometers into the air. Jupiter's moon Europa (center) and Saturn's moon Enceladus (right) both host subsurface seas and may vent water into space.

FROM LEFT: JPL-CALTECH/NASA, UNIV. OF ARIZONA; JPL-CALTECH/NASA, SETI INSTITUTE; JPL-CALTECH/NASA, SPACE SCIENCE INSTITUTE

The search was on. A group from San Francisco quickly found two more planets hiding in data the researchers hadn't finished analyzing yet. Those next two planets, 70 Vir b and 47 UMa b, were also more massive and closer to their stars than expected.

The existence of these three worlds, which were named hot Jupiters because their close-in orbits should make them sizzle, upended the paradigm for what a planet could be like. Clearly, our solar system was not the template for the universe.

Yet for a few years after 51 Peg b was announced, astronomers debated whether the planet was really there. Maybe the star's apparent back-and-forth was just its outer atmosphere breathing in and out. Those debates waned as more planets were discovered, but it took a new technique to really convince everyone.

Astronomers had predicted at least back to the 1850s that some planets would pass in front of their stars from the perspective of Earth. As it crossed, or transited, the face of its star, a planet could reveal its presence by blocking a little bit of the star's light.

But if other solar systems are like ours, transits would be incredibly difficult to detect. Our planets are too small and too far from the sun to cast a large shadow. Hot Jupiters, on the other hand, should block way more of a star's light than any planets in our solar system. With the discovery of 51 Peg b, transits seemed not only possible to detect, but almost easy.

The first transiting extrasolar planet revealed itself in 1999, when then-Harvard graduate student David Charbonneau drove to Colorado to do his thesis work with astronomer Tim Brown. Brown had built a tiny telescope on a friend's farm north of Boulder, setting up the computers in a repurposed turkey coop, to search for transiting planets. By the time Charbonneau arrived, however, the farm had been sold and the telescope relocated to a lab site.

To practice the technique, Charbonneau aimed Brown's telescope at a star, called HD 209458, that already had a suspected planet. The star's light dimmed by about 1 percent, and then it shone bright again. That was a clear sign of a planet about 32 percent wider than Jupiter.

That discovery ended all doubts about the existence of exoplanets, says Fischer, who had worked with the exoplanet-hunting group in San Francisco. "It happened like that," Fischer says, with a finger snap. The combined size and mass of the planet unambiguously ruled out brown dwarfs or other exotic explanations. "It walks like a Jupiter, talks like a Jupiter, it's a Jupiter."

There was another advantage to the transit method: It can show the composition of a planet's atmosphere. Planets detected by the wobble technique were "little more than phantoms," Cowen wrote in *Science News* in 2007. They were too small to be seen, and too close to the star to be photographed directly.

"Everyone had assumed that if you wanted to [detect] the atmosphere of an extrasolar planet, you'd have to image it," Charbonneau told *Science News*. But starlight filtering through a transiting planet's sky could reveal what gases surround the alien world without the need for a snapshot.

Hunt for habitable planets

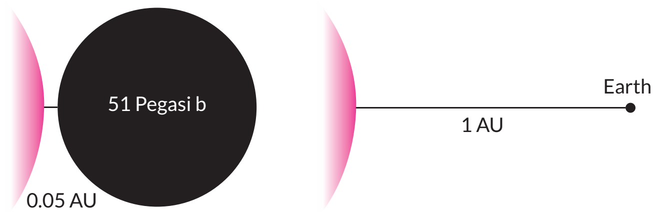
Transits soon overtook wobbles as the most fruitful planet-finding strategy. That was mostly thanks to the launch of NASA's Kepler space telescope in March 2009.

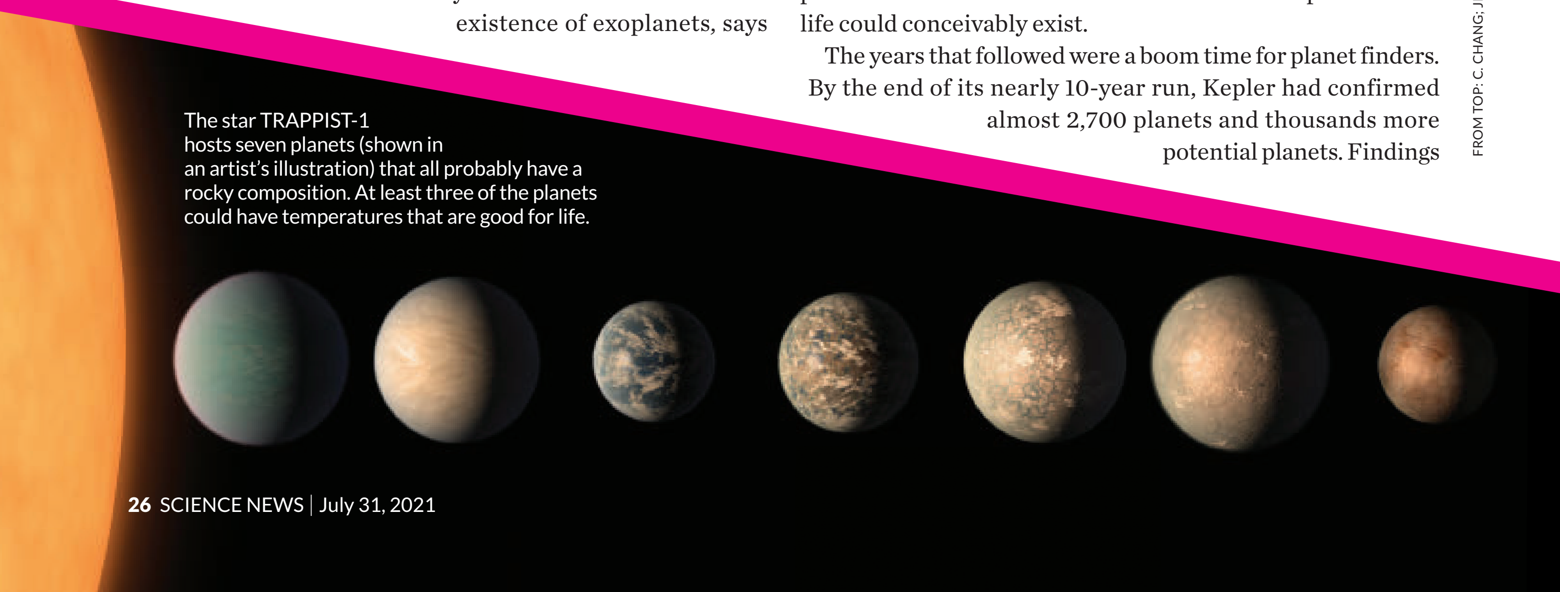
Kepler's mission was explicitly about finding other Earths. For nearly four years, the telescope stared at 170,000 stars in a single patch of sky to catch as many transiting planets as it could. In particular, its operators were hoping for Earth-sized planets in Earthlike orbits around sunlike stars — places where life could conceivably exist.

The years that followed were a boom time for planet finders. By the end of its nearly 10-year run, Kepler had confirmed almost 2,700 planets and thousands more potential planets. Findings

Big surprise The first planet found orbiting a star similar to our sun fit nobody's mold. Dubbed a "hot Jupiter," 51 Pegasi b is bigger than Jupiter, but 20 times closer to its star than Earth is to the sun (Earth is one astronomical unit, AU, or 150 million kilometers from the sun). 51 Pegasi b circles its star in four days; Earth's orbit is a lengthier 365 days. SOURCE: M. MAYOR AND D. QUELOZ/*NATURE* 1995

A tight orbit for a large planet





The star TRAPPIST-1 hosts seven planets (shown in an artist's illustration) that all probably have a rocky composition. At least three of the planets could have temperatures that are good for life.

FROM TOP: C. CHANG; JPL-CALTECH/NASA

went beyond the hot Jupiters to worlds the size of Earth and planets in the "habitable zone," where temperatures could be right for liquid water.

Discoveries came so quickly that a single new world stopped being a news story. Kepler's data shifted from revealing new worlds one by one to taking an exoplanet census. It showed that hot Jupiters are not actually the most common type of planet; they were just the easiest ones to spot. The most common type makes no appearance in our solar system: worlds between the size of Earth and Neptune, which may be rocky super-Earths or gaseous mini-Neptunes.

And Kepler revealed that there are more planets in the galaxy than stars. Every one of the billions and billions of stars in the Milky Way should have at least one world in its orbit.

But the telescope never really achieved the goal of finding another Earth. Kepler required three transits to confirm a world's existence. That means the telescope had to stare for at least three years to find a planet orbiting at Earth's exact distance.

By 2013, after four years of observing, half of Kepler's stabilizing reaction wheels had failed. The telescope couldn't maintain its unblinking view of the same part of the sky. Mission scientists cleverly reprogrammed the telescope to look at other stars for shorter spans of time. But most of the planets found there orbited closer to their stars than Earth does, meaning they couldn't be Earth twins.

Finally, Kepler ran out of fuel in 2018, with no true Earth analog in sight.

Messeri recalls an exoplanet conference at MIT in 2011 where a lot of the conversation was about finding a twin of Earth.

"It was a peak of excitement — maybe we're going to find this planet in the next three years, or five years. It felt close," she says. "What's interesting is, in the 10 years since then, it still feels that close."

But astronomers had already realized they might not need a true Earth analog to find a planet where life could exist. Rocky worlds orbiting smaller, dimmer stars than the sun are easier to find, and might be just as friendly to life.

Charbonneau again was ahead of the curve, having started a program called MEarth in 2008 to hunt for habitable planets around puny M dwarf stars using eight small telescopes in Arizona (plus another eight in Chile that were added in 2014). Within six months, Charbonneau and colleagues had found a super-Earth dubbed GJ 1214b that is probably a water world — maybe a bit too wet for life.

The European Southern Observatory started the TRAPPIST, for TRAnsiting Planets and PlanetesImals Small Telescope, survey from La Silla, Chile, in 2010. Another telescope, at Oukaïmeden Observatory in Morocco, came online to search for planets orbiting Northern Hemisphere stars in 2016. Among that survey's discoveries is the TRAPPIST-1 system of seven Earth-sized planets orbiting a single M dwarf star, three of which might be in the habitable zone (*SN: 3/18/17, p. 6*).

NASA's successor to Kepler, TESS, or Transiting Exoplanet Survey Satellite, has been scanning the entire sky since April 2018 for small planets orbiting bright nearby stars, including M dwarfs. It spotted more than 2,200 potential planets in its first full-sky scan, scientists announced in March 2021.

These days, astronomers are joining up with scientists across disciplines, from planetary scientists who study hypothetical exoplanet geology to microbiologists and chemists who think about what kinds of aliens could live on those planets and how to detect those life-forms. That's a big shift from even 10 years ago, Messeri says. In the early 2010s, no one was talking about life.

"You weren't allowed to say that," she says. "Astronomers would whisper it to me during fieldwork, but this was not a search for aliens."

Exoplanet astronomy is on firmer ground now. Its leading figures have won MacArthur "genius" grants. Pioneer planet finders Mayor and Queloz won the 2019 Nobel Prize in physics. The work is no longer hidden away in conferences that are actually about stars. "It doesn't have to legitimize itself anymore," Messeri says. "It's a real science."

The promise that transiting planets can reveal the contents of their alien atmospheres may soon be fulfilled. NASA's James Webb Space Telescope may launch this year, after many years of delays. One of its first tasks will be to probe the atmospheres of transiting planets, including those of TRAPPIST-1.

If anything is alive on those absolutely alien, unearthly worlds, maybe the next century will bring it to light. ■

Exoplanet detections Astronomers have hunted exoplanets with several techniques, some better than others. The earliest claimed exoplanet detections used the astrometry method, but almost none of them held up. Success came with the radial velocity method in the 1990s. But the transit method has proved most prolific. SOURCE: NASA

Method	Description	Planets discovered
Transit	When a planet passes directly between its star and an observer, it dims the star's light by a measurable amount.	3,343
Radial velocity	Orbiting planets cause stars to wobble in space, leading to an observable shift in the color of the star's light.	866
Gravitational microlensing	Light from a distant star is bent and focused by a planet's gravity as the planet passes between the star and Earth.	108
Direct imaging	Astronomers can take pictures of an exoplanet by removing the overwhelming glare of the star it orbits.	53
Astrometry	The orbit of a planet can cause a star to move visibly on the sky.	1

Explore more

- Hans J. Deeg and Juan Antonio Belmonte (eds). *Handbook of Exoplanets*. Springer, 2018.
- "Transcripts of the 'Great Debate.'" *Bulletin of the National Research Council*. May 1921. bit.ly/GD1921

Wild Souls
Emma Marris
BLOOMSBURY, $28

BOOKSHELF

What are animals owed in a human-run world?

On the Arctic Ocean's fringe, polar bears stand on ice thinning from human-caused climate change. Without thick ice from which to powerfully pounce on seals, many polar bears can't eat. Should we feed them to right our wrongs? Or should we leave them alone, even if that means they starve to extinction?

Emma Marris' *Wild Souls* prompts readers to grapple with this question and more. An absorbing and nuanced blend of philosophy and science, the book explores what we owe the nonhuman world, questioning the very concepts of wildness and nature. The result may change how readers view nonhuman animals, from caged creatures to polar bears in the north.

Marris guides readers through a series of case studies, from Indigenous hunting practices to municipal zoos, all brought to life through attentive on-the-ground reporting. Running through these examples is a central ethical tension: How do we weigh the tangible moral value of an individual sentient creature against the more abstract value of species or ecosystems, which are of course unfeeling but rouse such depths of emotion in us when they are threatened or lost?

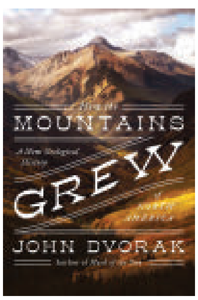
Islands are a front line of this conflict, where life that's blossomed in isolation is threatened by species we've introduced. Marris examines efforts, from the Galápagos to New Zealand, to kill millions of individual mice, rats and other creatures in the name of preserving species deemed more important.

Marris takes a stand on certain issues, arguing, for example, that zoos are immoral. She also asks whether it's ever right to save a species like the California condor — which once soared above most of North America but dwindled to just a handful of individuals in the 1980s — by caging the remaining birds for captive breeding.

The book makes a clear case for the moral value of individual sentient creatures, providing a rundown of the latest science that dissolves the distinct line often drawn between humans and nonhumans. These include studies that suggest fish feel pain and that rats help fellow rats in need because they experience emotions (*SN: 2/13/21, p. 9*).

Defining the objective, inherent value of species proves tricker. "There's something precious in what we call 'nature,' in the flow of energy, in the will to survive," Marris writes. "But I cannot present overwhelming arguments that this is true. I can only passionately assert it."

She finds no set formula for making ethical choices about animals' fates. Instead, readers may realize something profound: There are no perfect ways to act ethically when incommensurable values collide. As we try to mend the mess we've made of nature, all we can do is act with thoughtful humility. *— Jonathan Lambert*



How the Mountains Grew
John Dvorak
PEGASUS BOOKS, $29.95

BOOKSHELF

North America's rocks whisper tales of past life

Imagine a world where pigeon-sized dragonflies soar above spiders with half-meter-long legs, where 2-meter-long millipedes slither and 20-kilogram scorpions hunt. About 300 million years ago, such surreal creatures thrived; today, rocks hint at how these and other creatures in the deep past lived. These clues allow geologist and writer John Dvorak to vividly re-create ancient landscapes in *How the Mountains Grew: A New Geological History of North America*.

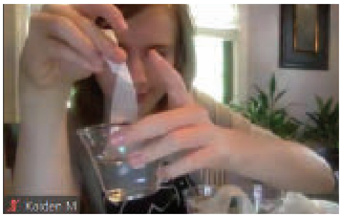
Far from a dusty tome plodding through plate tectonics, the book teems with life as Dvorak establishes inextricable links between geology and biology. Take the oversize dragonflies and millipedes now preserved as fossils. Rocks of a similar age hold evidence of a rise in atmospheric oxygen that helps explain how these animals grew so large.

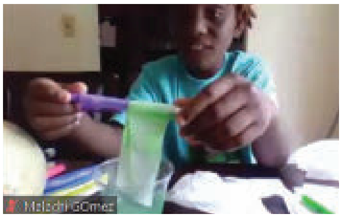
The book zigzags from place to place on a chronological, continental-scale field trip. To avoid dizzying readers, Dvorak revisits certain sites that preserve multiple threads of geologic history. For instance, at Mount Rushmore in South Dakota's Black Hills, he describes how, about 2 billion years ago, molten rock rose and lodged itself into sedimentary rocks deposited on the seafloor of bygone oceans. Today, presidents' faces stare out from this now-solidified magma, those ancient oceanic sediments sitting just below the visage of George Washington. The book later returns to glimpse younger seas that came and went, depositing sediments now replete with fossils. All these rocks, Dvorak explains, whisper stories of how this particular mountain grew.

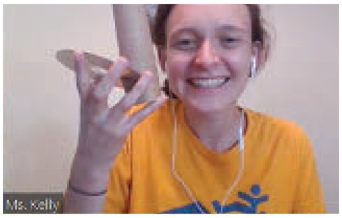
Dvorak also ponders Earth's future, envisioning an ice sheet grinding down Mount Rushmore's carefully carved profiles more than 100,000 years from now. And he considers humankind's future, arguing that we must determine how our dependence on fossil fuels — the result of another interplay between biology and geology — will end.

But it's a different end, the asteroid impact that marked the demise of the nonbird dinosaurs, where Dvorak's storytelling shines brightest. He imagines the final days of the last *Tyrannosaurus rex*, describing its desperate search for food somewhere well north of Mount Rushmore. In the hours to months after the impact, we share this behemoth's last steps, its final gasps.

"No degree of evolutionary perfection could have guaranteed survival," Dvorak writes. As that lone *T. rex* dies on the page, we can't help but realize that we, too, are brief biological moments in geologic time. *— Alka Tripathy-Lang*







VENTURING OUTDOORS, INDOORS

There are many activities we have learned to do indoors since the COVID-19 pandemic began. Pittsburgh-based Venture Outdoors, an organization dedicated to introducing people to the benefits of outdoor recreation, including kayaking, had to pivot to identify indoor activities to drive home this message. By connecting youth to outdoor exploration through environmentally focused STEM learning, the nonprofit aims to build a community of environmental stewards who work to protect local green spaces.

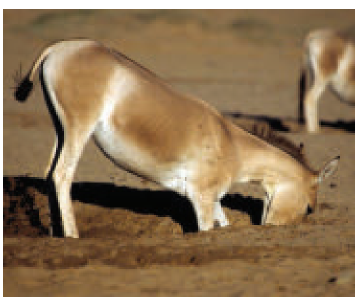
Thanks to a $2,000 STEM Action Grant from the Society for Science, Venture Outdoors distributed 20 STEM kits (right), and experiments to go along with them, to local students in fourth and fifth grade, such as the students pictured above being led through a chromatography water experiment. The grant also funded 30 "explorer kits" for younger students. The STEM Action Grant program supports community-driven nonprofit organizations working to enhance the public's understanding of science and increase participation of underrepresented populations in STEM fields.

JUNE 5, 2021

SOCIAL MEDIA

Burrowing beasts

Wild donkeys and horses dig water holes that benefit other desert animals, **Jonathan Lambert** reported in "Equids supply water to thirsty wildlife" (*SN: 6/5/21, p. 14*). On Twitter, reader **@JohnHenryDonner**, who describes himself as a walking dad joke, quipped: "It's called a burro for a reason."



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How 'bout them nuts?

*X-ray CT scans reveal that jostling a box of mixed nuts nudges oblong Brazil nuts to point more vertically, allowing the bulky nuts to rest on top as smaller ones sink to the bottom, **Maria Temming** reported in "How physics helps Brazil nuts come out on top"* (SN: 6/5/21, p. 4).

Reader **Charvak Kant** asked if this phenomenon, called the Brazil nut effect, applies to objects of all shapes — including spheres whose orientations wouldn't change.

Shape affects the Brazil nut effect, but exactly how is still unclear, says imaging scientist **Parmesh Gajjar** of the University of Manchester in England. It is very difficult to experimentally examine mixtures of objects, **Gajjar** says, but size does strongly influence how particles segregate. Even spheres of different sizes in a mixture will separate. In fact, the very first study to use the phrase "Brazil nut effect," published in *Physical Review Letters* in 1987, was done on spherical objects, he says.

Chaotic clocks

*As a clock becomes more accurate, it generates more disorder, **Emily Conover** reported in "Strict timekeeping creates entropy"* (SN: 6/5/21, p. 13).

Reader **Steve Comins** wondered why an accurate clock would emit more disorder than an inaccurate clock that ticks too fast.

In short, consistency is key, **Conover** says. In the context of the story, an inaccurate clock refers to one whose ticks are unevenly spaced, she says. Some ticks may come faster and some slower than they should, so you can't predictably tell time. But a clock that ticks consistently faster or consistently slower than normal could still be accurate, as long as you figure out the rate at which it's ticking.

For example, a clock that consistently ticks twice in one second could still accurately tell time; you'd just have to count each tick as a half-second. Such a fast-ticking clock would likely emit more entropy than a normal clock, but it would also be more precise, in accordance with the researchers' results, **Conover** says.

Fluid definitions

*A wave in one of Saturn's rings shows that the planet's core is spread out and bloated with hydrogen and helium, **Ken Croswell** reported in "Saturn's heart is fuzzy and diffuse"* (SN: 6/5/21, p. 9).

Saturn's immense gravity squeezes most of the planet's hydrogen and helium, which exist as gases on Earth, into a fluid, **Croswell** reported. Reader **Ken Koutz** questioned the use of the term "fluid," given that gases are already considered fluids.

While a fluid can be a gas or a liquid, physicists often use the term to refer to supercritical states, in which distinct gas and liquid phases are blurred, story editor **Chris Crockett** says. "That is exactly what is thought to happen deep inside giant planets such as Saturn," he says. "The fluid there is neither gas nor liquid, strictly speaking, but it still has fluid properties."

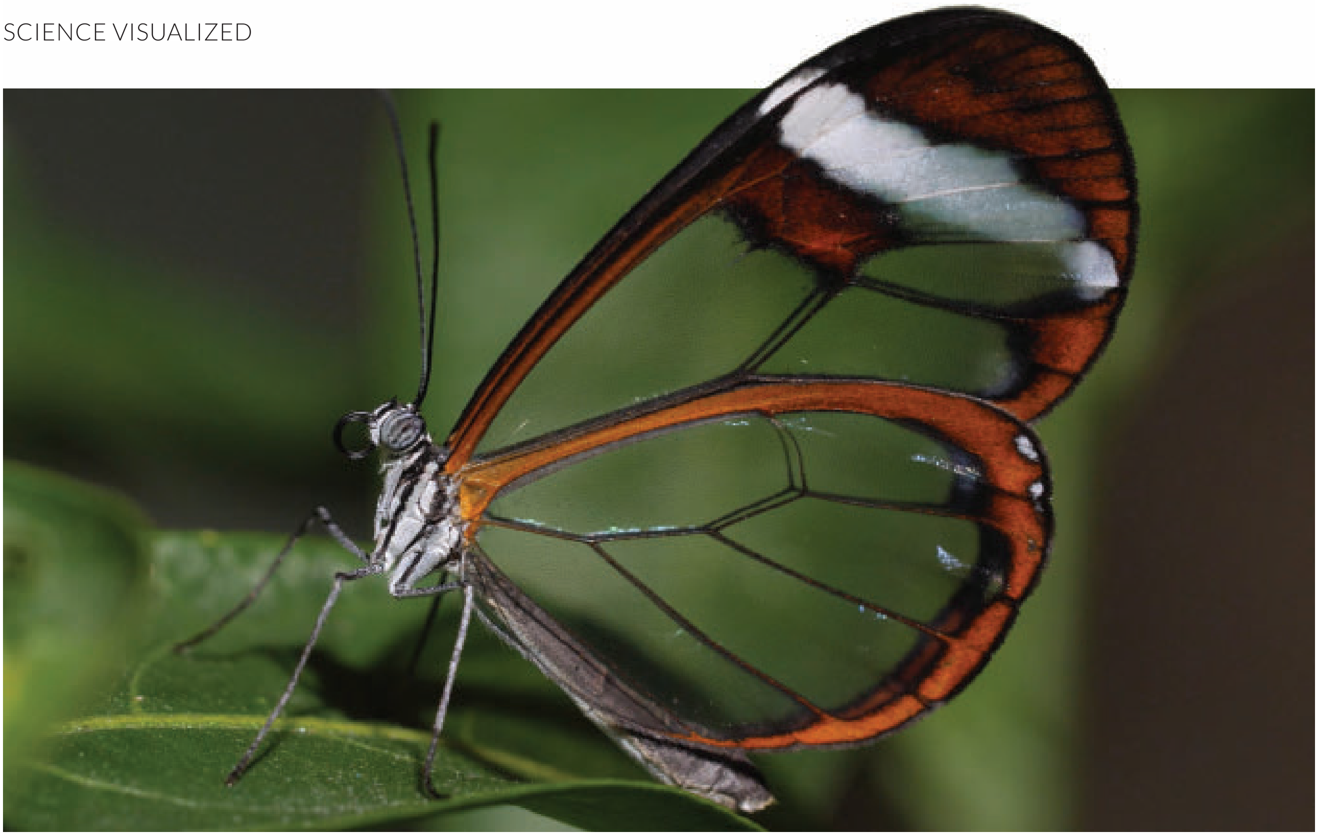
Putting the squeeze on dead stars

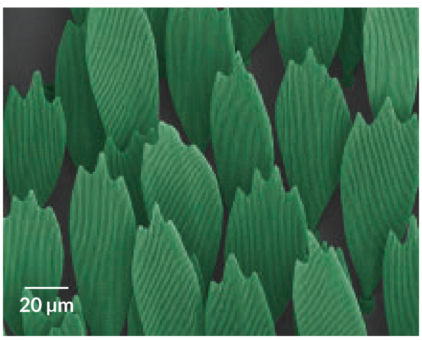
*The most massive neutron star known has a surprisingly large diameter, suggesting that the matter within it is less squeezable than expected, **Emily Conover** reported in "Neutron stars may not be so squishy"* (SN: 6/5/21, p. 8).

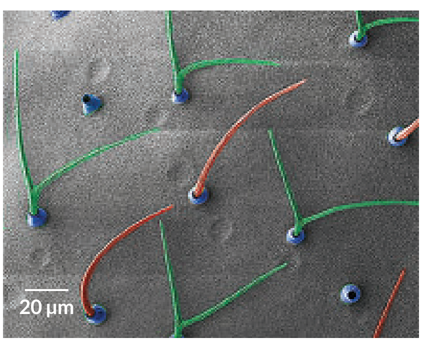
Reader **Jim Barr** wanted to know what "squeezable" means in the context of neutron stars.

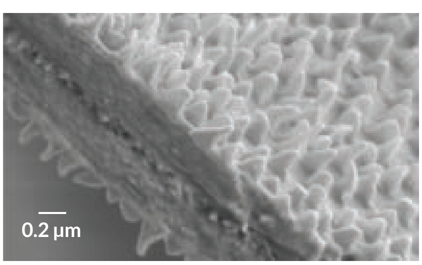
This term refers to how much a material compresses under pressure, **Conover** says. For example, if you squeeze a steel ball in your hand, it won't get significantly smaller. But if you do the same with a foam ball, it will. And the harder you squeeze the foam ball, the smaller it will get.

For neutron stars, the question is whether the core gets smaller when squeezed by gravity. The more massive a star, the greater the gravitational pressure. So whether a more massive star is bigger, smaller or the same size as a less massive one depends on whether the star's core compresses or not.









What's behind this butterfly's see-through wings

Most butterflies sport colorful, eye-catching wing patterns. But some, like the glasswing butterfly (above), use mostly transparent wings to hide in plain sight.

To figure out how these Central and South American insects go incognito, researchers put the wings of glasswing butterflies (*Greta oto*) under microscopes. Sparse, spindly scales overlaying a see-through wing membrane with antireflective properties make these insects so stealthy, researchers report in the May *Journal of Experimental Biology*.

Transparency is the ultimate form of camouflage, says James Barnett, a behavioral ecologist at McMaster University in Hamilton, Canada, who wasn't involved in the work. Transparent animals can instantly blend into any background (*SN: 7/6/19 & 7/20/19, p. 7*). "It's really hard to do," Barnett says. "You have to modify your entire body to minimize any scattering or reflection of light."

Using confocal and electron microscopes, Aaron Pomerantz, a biologist at the University of California, Berkeley, and colleagues found that the black rims of the butterfly's wings are densely packed with flat, leaflike scales (shown in false color at left, top). But transparent areas sport narrow, bristlelike scales spaced farther apart (left, middle). As a result, only about 2 percent of the underlying clear wing membrane is visible in black regions, but about 80 percent of the membrane is exposed in transparent areas.

Butterfly scales repel water. So having at least some in the transparent regions helps prevent wings from sticking together when it rains, says biologist and coauthor Nipam Patel of the Marine Biological Laboratory in Woods Hole, Mass.

The wing membrane's texture also reduces glare. Tiny wax bumps coat the membrane's surface (left, bottom). The bumps help channel more light through the wing rather than reflecting light off, heightening the transparency. The researchers found that the transparent areas naturally reflect only about 2 percent of light. But stripping off the bumps caused those areas to reflect about 2.5 times as much light as they typically do. *— Maria Temming*

TOP: A. POMERANTZ; ALL OTHERS: A.F. POMERANTZ *ET AL/JEB* 2021

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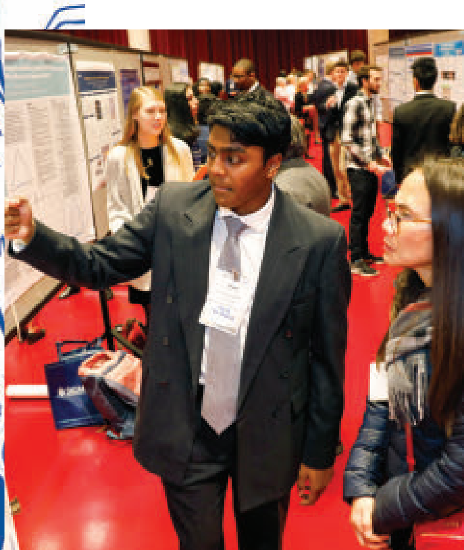

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