Glowing Fur of the Platypus | Humans Cool Down

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ DECEMBER 5, 2020

Showers of Light

The surprising source of the Geminid meteors

TRUST ME, IT'S WORTH IT."

Greg Gotwald, 2001, chemical engineering alumnus

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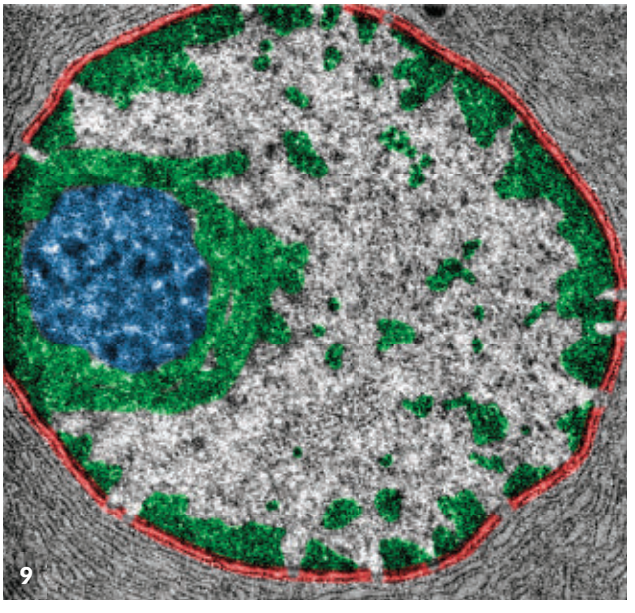
News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Departments

COVER As seen from California's Mojave Desert in 2009, a Geminid meteor streaks past Orion's Belt. *Walter Pacholka, Astropics/Science Source*

FROM TOP: NASA, ESA, E. WHEATLEY/STSCI; JOHN SULLIVAN/INATURALIST (CC BY-NC 4.0); JOSE LUIS CALVO/SCIENCE SOURCE

Amid winter's darkness, flashes of brilliance

The sudden flash of a shooting star is a delight, and its luster isn't dimmed by the knowledge that meteor showers are merely the visible manifestation of space dust.

If there's a clear sky on Sunday, December 13, odds are good for spotting the spectacular meteor shower known as the Geminids. In this issue, astronomer and writer Ken Croswell explains the many mysteries surrounding the Geminids' flamboyant display, including that they have the rare distinction of being a meteor shower spawned by a lowly asteroid, rather than a stylish comet (Page 22).

Scientists have known for over 100 years that comets can spark meteor showers, but it wasn't until 1983 that researchers had the technology needed to connect the Geminids to a small asteroid, dubbed Phaethon because it swings so close to the sun. Decades later, scientists are still trying to figure out just how Phaethon provides such a dazzling show.

While you're in the backyard looking for meteors, it's the ideal time to also scan the skies for Betelgeuse, the massive red star in the constellation Orion. (You can catch a glimpse of it on the right side of our cover image.) Wintertime means Orion has returned to the evening sky in the Northern Hemisphere, and it comforts me to see Betelgeuse glowing on Orion's shoulder. But last year, that star was at the center of an international commotion. Betelgeuse suddenly dimmed — did this mean the aging star was about to explode in a supernova? Stargazers, professionals and amateurs alike, rushed to the telescopes.

Betelgeuse is still with us, having returned to its former brightness earlier this year. But astronomers remain at odds over the cause of its sudden swoon. Some think that the star was obscured by its own dust, while others dis the dust hypothesis. As *Science News* astronomy writer Lisa Grossman reports, shutdowns of major telescopes as a safety measure during the pandemic have stymied efforts to solve the mystery of the dimming star (Page 16). That's frustrating for researchers, in part because the answer could help shed light on the origins of life in the universe.

Ready for one more celestial riddle? Flip to Page 10, where we update you on the latest from STEVE. The unusual sky glow's mauve arc looks a bit like an aurora, but isn't. Ditto for STEVE's bright green "picket fence," researchers now say. "It's really weird, and nobody really knows what's going on just yet," Boston University engineer Joshua Semeter told *Science News* staff writer Maria Temming.

These celestial conundrums remind us just how strange and wonderful the cosmos remains, despite humankind's best efforts to figure it all out. More delightful mysteries, please.

And back on Earth, we're hard at work wrapping up our year-end special issue. It's not hard to guess what we picked as the biggest science story of 2020. But there was plenty else going on, and we spent many hours debating which discoveries or disputations merit inclusion. What would you choose? Write us at feedback@sciencenews.org with your picks for the big science news of 2020. I'm looking forward to seeing your choices. — *Nancy Shute, Editor in Chief*

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SSP

Tears From a Volcano

Uniquely American stone ignites romance

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Excerpt from the December 5, 1970 issue of *Science News*

50 YEARS AGO

Amino acids in a meteorite

[Researchers] present evidence for the presence of amino acids of possible extraterrestrial origin in a meteorite that fell near Murchison, Victoria, Australia, Sept. 28, 1969.... If over the course of time their finding becomes accepted ... it would demonstrate that amino acids, the basic building blocks of proteins, can be and have been formed outside the Earth.

UPDATE: Scientists confirmed in 1971 that the Murchison meteorite contained amino acids, primarily glycine, and that those organic compounds likely came from outer space (*SN: 3/20/71, p. 195*). In the decades since, amino acids and other chemical precursors to life have been uncovered in other fallen space rocks. Recent discoveries include compounds called nucleobases and sugars that are key components of DNA and RNA. The amino acid glycine even has been spotted in outer space in the atmosphere of comet 67P/Churyumov-Gerasimenko. Such findings bolster the idea that life could exist elsewhere in the universe.

THE SCIENCE LIFE

Ecologist catches lizards chilling out

A cold snap in Key Biscayne, Fla., in January immobilized this iguana, causing it to fall out of the tree where it had been sleeping.

After the coldest night in southern Florida in a decade, lizards were dropping out of trees, landing legs up. The scientists who raced to investigate the fallen reptiles have now found that, despite such graceless falls, some of these tropical, cold-blooded creatures are actually more resilient to cold than previously thought.

The finding sheds light on how some species might respond to extreme weather events caused by climate change. Although Earth is gradually warming, extreme events such as heat waves, cold snaps, droughts and torrential downpours could grow in number and strength over time. Scientists have long thought that tropical species, which

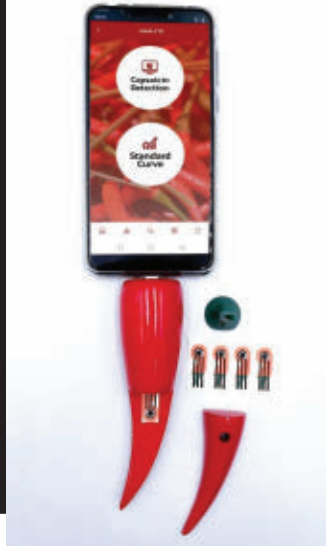
TEASER

How hot is your chili pepper?

A new chili-shaped device could quickly signal whether adding a pepper to a meal might set your mouth ablaze. "Chilica-pod" detects capsaicin, a compound that helps give peppers their sometimes painful kick. In general, the more capsaicin a pepper has, the hotter it tastes. The gadget is sensitive, capable of picking up extremely low levels of the fiery molecule, researchers report in the Oct. 23 *ACS Applied Nano Materials*.

Graphene sheets make up Chilica-pod's sensor. Adding a drop of a chili pepper and ethanol solution to the sensor triggers an electric current through the sheets. The more capsaicin the solution has, the stronger the current. Chilica-pod registers that activity and, once its "stem" is plugged into a smartphone, sends the data to an app for analysis. The device can detect capsaicin levels as low as 0.37 micromoles per liter of solution, the amount from a pepper with no heat. Tests of six dried peppers found capsaicin levels that ranged from 7.5 to 90 micromoles per liter of solution, which corresponds to the spice of mild peppers like serrano or cayenne.

Capsaicin is one of at least 24 compounds that give peppers heat, says Paul Bosland, a chili breeder at New Mexico State University in Las Cruces who was not involved in the study. "I would hope that [future devices] could read them all." —*Erin Garcia de Jesus*



A chili-shaped gadget (shown) detects a molecule that gives peppers heat, then plugs into a smartphone where an app analyzes the data.

FROM TOP: BRETT PIERCE; ADAPTED FROM *ACS APPLIED NANO MATERIALS* 2020

have typically evolved in thermally stable environments, might prove especially vulnerable to major shifts in temperature.

The idea for the new study was born after evolutionary ecologist James Stroud received a photo of a roughly 60-centimeter-long iguana on its back on a sidewalk from a friend in Key Biscayne, an island town south of Miami. The previous night, temperatures dropped to 4.4° Celsius (40° Fahrenheit). "When air temperatures drop below a critical limit, lizards lose the ability to move," says Stroud, of Washington University in St. Louis. Lizards that sleep in trees "may lose their grip." Stunned lizards on the ground are likely easy prey for predators, he notes.

Realizing that the January cold snap could be used to study how future instances of extreme weather events might affect such animals in the wild, Stroud and colleagues rushed to collect live specimens of as many different kinds of lizards as possible in the Miami area. The researchers then tested how well the six species they captured tolerated cold. Stroud's team stuck thermometers in the animals, placed them in a large cooler of ice and observed how cold the lizards got before becoming too stunned to right themselves after getting flipped on their backs.

Some tropical lizards (brown basilisk, shown) may be getting better at withstanding cold.

Similar tests Stroud ran a few years ago suggested that the reptiles might not easily withstand cold snaps like the recent one. Cold tolerances ranged from as low as about 7.7° C for the Puerto Rican crested anole (*Anolis cristatellus*) to roughly 11.1° C for the brown basilisk (*Basiliscus vittatus*).

The new study, however, revealed that the reptiles now could withstand temperatures roughly 1 to 4 degrees C colder and even could endure cold down to 5.5° C on average, the researchers report in the October *Biology Letters*.

Given the variation in size, ecology and physiology among these species, "this was a really unexpected result," Stroud says. It's possible that abnormally cold temperatures are killing off individuals that are less cold tolerant. Or the reptiles' bodies could have changed in some way to acclimate to the colder temperatures. Stroud hopes to look for signs of acclimation by measuring lizards' cold tolerance before and after a cold snap. — *Charles Q. Choi*

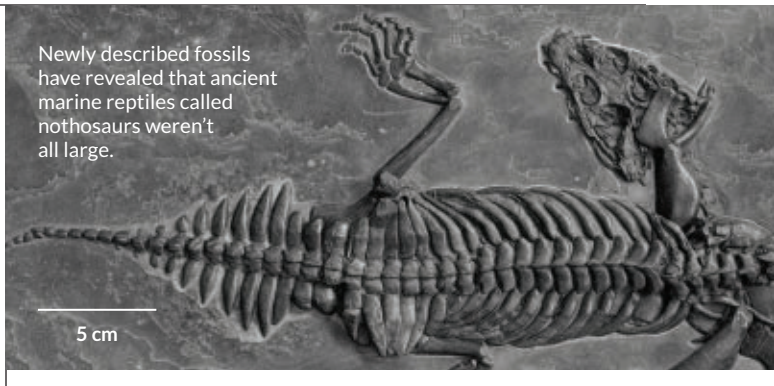
THE –EST

Record time set by X-rays traveling through hydrogen molecules

The time it takes for a particle of light to pass through a hydrogen molecule is now the shortest duration ever measured. This interval was 247 zeptoseconds, or trillionths of a billionth of a second, researchers report in the Oct. 16 *Science*. Past experiments have observed particle interactions as short as attoseconds, which are 1,000 times as long as zeptoseconds.

Physicist Sven Grundmann of Goethe University in Frankfurt and colleagues shined X-ray light on hydrogen molecules in a gas. As each light particle crossed an H_2 molecule, the light booted an electron from one hydrogen atom, then the other. Because electrons can exhibit wavelike behavior, the two ejection events stirred up electron waves that spread out and merged — similar to ripples formed by a stone skipped twice over a pond. An interference pattern created by the overlapping waves should have been symmetric around the H_2 molecule's center had the waves formed simultaneously. But one wave formed before the other and had more time to spread, so the pattern shifted toward the source of the second wave. This shift let the team calculate the 247-zeptosecond delay between the wave emissions. — *Maria Temming*

247
zeptoseconds
Shortest duration ever measured



Newly described fossils have revealed that ancient marine reptiles called nothosaurs weren't all large.

5 cm

INTRODUCING

Tiny sea monster lurked in shallows

Around 240 million years ago, a mini marine reptile may have hunted its meals by floating motionless until prey got too close. Two fossils of the newly discovered nothosaur species, *Brevicaudosaurus jiyangshanensis*, reveal that it had a short, broad and flat tail, and dense bones — traits that could have helped the reptile balance in shallow water, researchers report October 29 in the *Journal of Vertebrate Paleontology*. The find hints that the species' lifestyle differed from that of its kin, a group of ancient reptiles that grew 4 meters long on average and flicked their tails to chase fish. *B. jiyangshanensis* was about a half meter long. The fossils were thought to be baby nothosaurs, but bone shapes revealed the animals were adults. — *Aayushi Pratap*

FROM TOP: JOHN SULLIVAN/INATURALIST (CC BY-NC 4.0); Q.-H. SHANG, X.-C. WU AND C. LI/*JOURNAL OF VERTEBRATE PALEONTOLOGY* 2020

News

Researchers collect sediment inside of a cave on the Tibetan Plateau. Some of the samples contained remnants of Denisovan mitochondrial DNA from as early as 100,000 years ago.

HUMANS & SOCIETY

Denisovan DNA turns up in China

Finding confirms the hominids lived on the Tibetan Plateau

BY BRUCE BOWER

Mysterious, now-extinct members of the human lineage called Denisovans lived at the roof of the world for possibly 100,000 years or more.

Mitochondrial DNA found in sediment in China's Baishiya Karst Cave on the Tibetan Plateau indicates these human-like folk inhabited the high-altitude site about 100,000 years ago and again about 60,000 years ago, say geoarchaeologist Dongju Zhang of Lanzhou University in China and her colleagues. This is the first time Denisovan DNA has been found outside of Siberia's Denisova Cave.

Sediment possibly dating from 50,000 to 30,000 years ago also yielded Denisovan mitochondrial DNA, the scientists report in the Oct. 30 *Science*.

That timing suggests Denisovans may have survived on the plateau long enough to encounter the first humans to reach those heights as early as 40,000 years ago. Humans new to the region's thin air may have gained advantageous traits by mating with Denisovans. Present-day Tibetans carry a Denisovan gene variant that aids high-altitude survival, though it's not clear where interbreeding occurred.

Zhang's group previously identified a fossilized jaw from Baishiya Karst Cave as belonging to a Denisovan that lived at least 160,000 years ago (*SN: 6/8/19, p. 6*). That analysis focused on the jaw's protein structure, not DNA, leaving questions about the jaw's identity.

The newfound Denisovan DNA has close links to mitochondrial DNA from Denisova Cave, over 2,000 kilometers northwest of the Tibetan Plateau site.

Denisovan genetic evidence remains sparse, says Carles Lalueza-Fox, a paleogeneticist at the Institute of Evolutionary Biology in Barcelona. But evidence of Denisovan DNA that has been inherited by people today suggests that Denisovans ranged from the frigid Tibetan Plateau to tropical Southeast Asia. ■

HUMANS & SOCIETY

Early American women hunted game

An ancient grave in Peru challenges notions about gender roles

BY BRUCE BOWER

A woman buried with spearpoints and other hunting tools roughly 9,000 years ago in the Andes has reemerged to claim the title of the oldest known female big-game hunter in the Americas.

Further research suggests that up to half of ancient big-game hunters in the Americas were women, archaeologist Randall Haas of the University of California, Davis and colleagues report November 4 in *Science Advances*.

Until now, many researchers have regarded stones sharpened to a point and other typical hunting items put in ancient women's graves as cutting or scraping tools. The dominance of male hunters in modern hunter-gatherer populations has fueled a tendency to, in essence, give ancient men the spearpoint and ancient women the short end of the stick.

"It is time to stop thinking of [ancient] female large-game hunters as outliers," says archaeologist Ashley Smallwood of the University of Louisville in Kentucky. Gender roles in modern hunter-gatherers can't be assumed to apply, she says.

In 2018, Haas' team, collaborating with members of a local community at a site in Peru called Wilamaya Patjxa, unearthed five burial pits. One pit held a 17- to 19-year-old woman who had been buried with stone tools. Her toolkit included four spearpoints that would have been attached to shafts and likely hurled at prey using handheld spear throwers. Other implements were probably used to cut apart game, extract bone marrow or scrape hides, and perform detailed hide work and hide tanning.

Sediment that filled in the grave had bone fragments from large animals, including Andean deer and vicuñas, a wild relative of the alpaca. Those two animals were the main targets of ancient hunters in this region, Haas suspects.

Another pit contained a 25- to 30-year-old man and two spearpoints, suggesting he also hunted large animals.

Haas' group reviewed evidence from 429 individuals buried at 107 sites, including Wilamaya Patjxa, throughout the Americas. Most of these locations date to about 6,000 to 12,500 years ago. Among individuals of known sex buried with big-game hunting tools, 11 were women from 10 sites and 16 were men from 15 sites. Based on that admittedly limited dataset, the team estimates that, on average, women accounted for between 30 and 50 percent of ancient American big-game hunters. ■

YUANYUAN HAN AND D. ZHANG/LANZHOU UNIV.

GENES & CELLS

Possible trigger of cytokine storms ID'd

A study in mice points to drugs that might help treat COVID-19

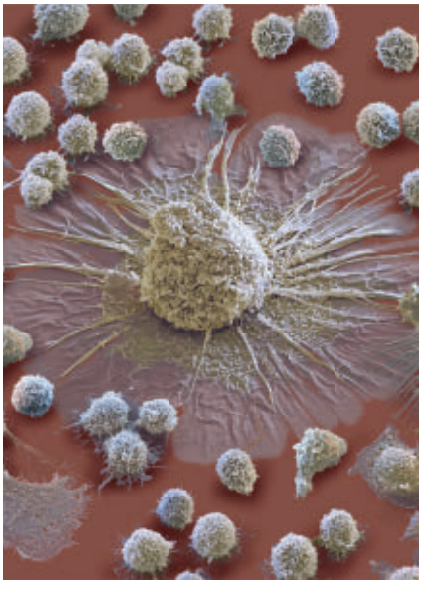
BY TINA HESMAN SAEY

Exactly how the coronavirus kills its victims is a mystery. But part of the problem may be a partnership between two immune system chemicals, which triggers deadly organ damage.

In mice, a combination of the immune chemicals TNF alpha and gamma-interferon trips a chain of reactions that ultimately leads to three types of cell death, researchers report October 29 at bioRxiv.org. That wave of cell death further feeds an escalation of immune chemicals, known as a cytokine storm, that leads to more cell death and causes tissue and organ damage and failure.

If the same process happens in people with severe COVID-19, the research points to existing drugs that might help calm the cytokine storm and prevent severe disease or aid recovery. The preliminary results, however, have not yet been reviewed by other scientists.

Study after study has found that people with severe COVID-19 have elevated levels of cytokines, which are inflammation-stimulating chemicals, in their blood compared with healthy people, says Thirumala-Devi Kanneganti, an immunologist at St. Jude Children's Research Hospital in Memphis, Tenn.



A cytokine storm, an inflammatory response linked to some severe COVID-19 cases, is brewed by immune cells such as macrophages and smaller leukocytes (both shown in this colorized, composite microscope image).

EYE OF SCIENCE/SCIENCE SOURCE

Kanneganti and colleagues selected eight of the most commonly elevated cytokines in severely ill COVID-19 patients to see how the cytokines affect cells growing in lab dishes. Alone, none of the cytokines caused harm to infection-fighting macrophage cells. But when macrophages were exposed to a cocktail of all eight cytokines, "we were seeing dramatic cell death, unbelievable, through the roof," Kanneganti says. The team then tried various combinations of cytokines and discovered that only the pairing of TNF alpha and gamma-interferon was deadly to macrophages.

That's surprising, says Mohamed Lamkanfi, an immunologist at Ghent University in Belgium. These well-studied cytokines haven't previously been implicated in killing cells.

The duo doesn't just kill cells. "When we injected the combination of TNF and interferon gamma ... within 10 hours [the mice] just drop dead," Kanneganti says. And those mice had symptoms similar to those seen in people with severe COVID-19, such as low numbers of infection-fighting T cells and signs of liver and tissue damage.

In a series of experiments, Kanneganti and her colleagues found that the cytokine combo triggers three kinds of cell death. Activating all three types of cell death together leads to an ever-escalating cytokine storm, "like a hurricane," Kanneganti says.

Researchers had thought that each type of cell death was triggered by different biochemical switches, but the new work shows that all three types can result from a single chain reaction, or pathway. At the trailhead of this biochemical pathway sit proteins known as STAT1 and JAK. Inappropriate chemical actions by both have been implicated in some types of cancer and autoimmune diseases, and inhibitors of these proteins are used to treat the disorders.

One JAK inhibitor called baricitinib is already being tested against the coronavirus (*SN Online: 5/13/20*). Preliminary evidence suggests that when given to hospitalized patients along with the antiviral drug remdesivir, baricitinib can shorten hospital stays even more than remdesivir alone has been shown to do.

The new study also found that blocking TNF alpha and gamma-interferon protected coronavirus-infected mice from dying. Mice with other inflammatory conditions were also protected from dying when both cytokines were blocked, and to a lesser extent when only one was blocked. Those findings suggest that both cytokines must be blocked to have a full effect, Lamkanfi says.

Drugs and antibodies that block the two immune chemicals already exist and are used to treat some autoimmune diseases, such as Crohn's disease and rheumatoid arthritis.

The evidence is convincing that the two cytokines may be involved in what goes wrong in severely ill COVID-19 patients, says Craig Coopersmith, a sepsis researcher and director of the Emory Critical Care Center in Atlanta. "It's mechanistically fascinating and gives multiple potential [drug] targets that are worth exploring."

But he's skeptical that blocking the two cytokines will be as effective in people as it was in mice. "I have cured mouse sepsis 15 times, and I know my colleagues have cured mouse COVID," he says. "Most of the time when you do the trials in people, [the trials] turn out to be negative."

And the triad of cell death triggered by TNF alpha and gamma-interferon isn't necessarily the only thing killing COVID-19 patients, Coopersmith says. Blood clotting and cardiovascular issues, as well as lung damage from mechanical ventilation, are also big problems. Still, the new study gives researchers a good place to start teasing out what goes wrong in people with severe COVID-19, he says, and learning how to fix it. ■

HUMANS & SOCIETY

Human body temperature is dropping

98.6° Fahrenheit is no longer the norm, a study in Bolivia finds

BY SUJATA GUPTA

Indigenous Amazon dwellers are helping to bolster recent findings that normal body temperature, about 37° Celsius, or 98.6° Fahrenheit, might not be so normal anymore.

The Tsimane people in Bolivia have experienced a roughly half-degree C drop, on average, in body temperatures over a decade and a half, anthropologist Michael Gurven of the University of California, Santa Barbara and colleagues report October 28 in *Science Advances*.

The finding echoes the half-degree drop in average body temperature reported earlier this year in a study of three U.S. population cohorts over 157 years. In that research, normal body temperature fell by 0.03 degrees C per decade.

Body temperature is a sort of surrogate for basal metabolic rate, the number of calories required to keep the body working while at rest. Higher rates, and thus higher body temperatures, have been linked to shorter life spans and lower body mass. Body temperature — which also reflects circadian rhythms, immune function, the presence or absence of disease, as well as ambient temperature — is affected by age, sex and time of day.

More than a matter of curiosity, lower temperatures could be indicative of a change in basic human physiology, says Jill Waalen, an epidemiologist at the Scripps Research Translational Institute in La Jolla, Calif. And this could mean a rethinking of what constitutes a fever — a timely question given the use of temperature checks to screen for COVID-19.

Reduced rates of infectious disease and inflammation, as a result of lifestyle changes and improved access to medical care, could be the reason for the drops. But making that link definitively has proved difficult, Gurven says.

The 37° C normal was derived in the mid-1800s based on a study of German people. More recent studies suggesting a lower average body temperature today have largely focused on populations in relatively wealthy countries.

In contrast, the new study focuses on an Indigenous group of horticulturist-foragers. Most Tsimane people live in villages without running water or electricity. Rapid community changes over the last few decades include increased access to market foods and antibiotics.

The average body temperature of the Tsimane people of Bolivia fell half a degree from 2002 to 2018.

M. GURVEN

GENES & CELLS

The gut may train the brain's guards

In mice, immune cells learn in the intestines to spot threats

BY AAYUSHI PRATAP

Some of the brain's immune defenses may have their roots in the gut.

A study in mice finds that immune cells are first trained in the gut to recognize and launch attacks on pathogens, and then migrate to the brain's surface to protect it, researchers report online November 4 in *Nature*. These cells were also found on the surface of surgically removed parts of human brains.

Every minute, about 750 milliliters of blood flow through the brain, giving bacteria, viruses or other blood-borne pathogens a chance to infect the organ. For the most part, the invaders are kept out by three membrane layers, called the meninges, that wrap around the brain and spinal cord and act as a physical barrier. If a pathogen manages to breach that barrier, the researchers say, the immune cells trained in the gut are ready to attack.

The most common route for a pathogen to end up in the bloodstream is from the gut. "So, it makes perfect sense for these [immune cells] to be educated, trained and selected to recognize things that are present in the gut," says Menna Clatworthy, an immunologist at the University of Cambridge.

In mice and in humans, Clatworthy and colleagues found plasma cells in the meninges that produced a class of antibodies called immunoglobulin A, or IgA.

These cells and antibodies are mainly found in the inner lining of the gut and lungs, so the team wondered if the cells on the brain had any link to the gut. It turned out they did: Germfree mice, which had no microbes in the gut, didn't have any plasma cells in their meninges. But when bacteria from the feces of other mice and humans were transplanted into these mice's intestines, plasma cells appeared in the meninges.

When the team implanted a fungus commonly found in the intestine into mice's bloodstreams, the fungus attempted to enter the brain through the walls of blood vessels in the meninges. However, plasma cells in the membranes

Gurven and colleagues examined 17,958 temperature measurements from 5,481 Tsimane teens and adults, and found that the half-degree average body temperature drop had taken just 16 years — from 2002 to 2018.

To find a cause for the decrease, the team looked at several variables related to ambient temperature and health. Respiratory illnesses among the Tsimane people declined over time, the team found, but other health conditions such as parasitic infections and blood disease remained common. Overall, the researchers did not find a connection between the decrease in average body temperature and any individual variable or combination of variables.

Gurven and colleagues still suspect that the lower average body temperature could have arisen as a result of increased access to medications, such as painkillers or antibiotics, or better nutrition.

Even without a clear explanation, this growing body of evidence suggests that normal body temperature might be more appropriately viewed as a range that varies from person to person, not as a fixed value across the population, says infectious diseases specialist Waleed Javaid of the Mount Sinai Downtown health network in New York City. ■

formed a mesh of IgA antibodies around the pathogen, blocking entry. The plasma cells are found along the blood vessels, Clatworthy says, where they can quickly launch attacks.

"To my knowledge, this is the first time anyone has shown the presence of plasma cells in the meninges. The study has rewritten the paradigm of what we know about these plasma cells and how they play a critical role in keeping our brain healthy," says Matthew Hepworth, an immunologist at the University of Manchester in England. More research, he says, is needed to classify how many of these plasma cells come from the gut.

For now, Clatworthy and colleagues want to understand what cues plasma cells in the gut to know it is time to embark on a journey to the brain. ■

JOSE LUIS CALVO/SCIENCE SOURCE

GENES & CELLS

'Junk DNA' unlocks a genetic mystery

Genes regulating heterochromatin may rapidly become essential

BY MONIQUE BROUILLETTE

A long-standing puzzle in evolution is why new genes — ones that seem to arise out of nowhere — can quickly take over functions essential for survival.

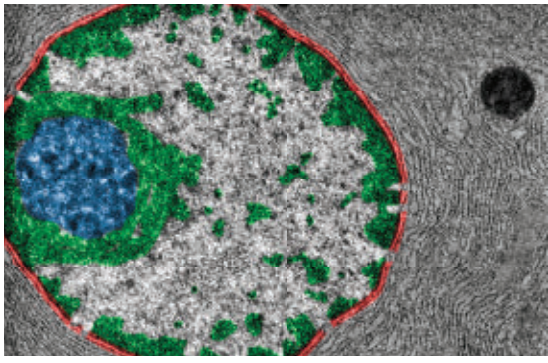
A study in fruit flies may help solve that puzzle, suggesting that some new genes quickly become crucial because they regulate a type of DNA called heterochromatin. Once considered "junk DNA," heterochromatin actually performs many important jobs, including locking up "bad actor" genes to prevent them from turning on and doing damage.

Heterochromatin is a rapidly changing bit of DNA, so the genes that regulate it have to adapt quickly to keep up, evolutionary biologist Harmit Malik at the Fred Hutchinson Cancer Research Center in Seattle and colleagues report November 10 in *eLife*.

"The work is a milestone," says evolutionary biologist Manyuan Long of the University of Chicago. "It is really amazing seeing such an important role the heterochromatin plays in gene evolution."

Scientists have documented many cases of genes that seem to arise from scratch and give an organism a new ability. About a decade ago, researchers discovered that these genes don't just confer new functions; some may be necessary for survival. In the fruit fly *Drosophila melanogaster*, as many as 30 percent of "new" genes are essential, with some arising as recently as 3 million years ago — a flash in evolutionary timescales. The discovery overturned the idea that important genes don't really change much over the course of evolution.

Malik's team investigated a family of genes in fruit flies that regulate other genes — turning them on and off for various tasks in the cell. Of the 85 or so genes, the ones evolving more rapidly were more likely to control essential functions. In fact, 67 percent of rapidly evolving genes were essential compared with 20 percent in the slower-evolving group.



Once called "junk DNA," heterochromatin (shown in green in this cell nucleus) evolves rapidly, and so do the genes that regulate it.

"The dogma is completely opposite than what you would expect," Malik says.

One of the new essential genes, dubbed *Nicknack*, issues instructions for a protein that binds to heterochromatin.

To see how quickly *Nicknack* might have taken over an essential function, the team replaced the *Nicknack* gene in *D. melanogaster* with the *Nicknack* gene from the fruit fly *D. simulans*. The two species split from each other about 2.5 million years ago. If the two genes were the same, the trade would have no effect. But instead, all of the males died — a sign that in just 2.5 million years, *D. melanogaster* evolved its own version of the gene. Malik thinks the difference between the sexes has to do with heterochromatin: The Y chromosome contains a lot of it.

Because the swap adversely affected the males, the researchers concluded the *Nicknack* gene must play a crucial role in regulating heterochromatin. And since heterochromatin evolves so rapidly, *Nicknack* has had to evolve rapidly too.

Next, Malik hopes to uncover the exact function of *Nicknack*. That may help shed light on heterochromatin's role in shaping the speed and course of evolution. Scientists, he says, are just beginning to understand the many ways this "junk DNA" is anything but junk. ■

The purple-and-green glow known as STEVE lights up the sky above Childs Lake in Manitoba, Canada, in this composite image.

ATOM & COSMOS

‘STEVE’ continues to defy explanation

Scientists spot another hard-to-explain aspect of the sky glow

BY MARIA TEMMING

The atmospheric light show nicknamed STEVE may be even weirder than sky watchers thought.

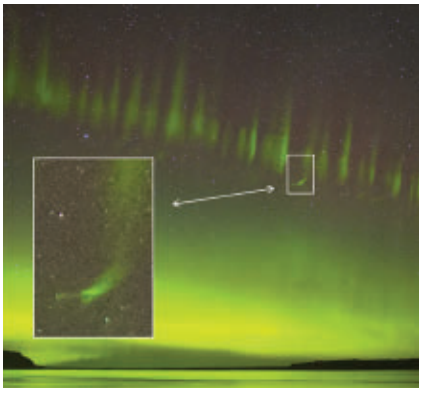
STEVE, short for Strong Thermal Emission Velocity Enhancement, is a sky glow that appears south of the northern lights. STEVE’s main feature is a mauve band of light formed by a stream of plasma flowing westward through the atmosphere — a different phenomenon from the one that gives rise to auroras (*SN: 6/8/19, p. 5*). But STEVE’s purple arc is often accompanied by a “picket fence” of vertical green stripes. That fence looks similar enough to the shimmering green curtains seen in the aurora borealis that scientists thought at least this part of STEVE could be a type of aurora.

Recent studies of the picket fence’s color have cast doubt on its origins. Auroras form when electrons from the magnetic bubble, or magnetosphere, surrounding Earth cascade into the atmosphere. Those electrons make nitrogen in the air glow blue and oxygen glow green. While STEVE’s green picket fence contains glowing oxygen, a dearth of emissions from nitrogen hints that the fence is not the same kind of light show as an aurora.

Now, researchers and citizen scientists have identified an even more unusual aspect of the picket fence: small green streaks that stick out like feet from the bottom of some of the vertical stripes. The structure of these horizontal streaks cannot be formed by the electron showers responsible for auroras, researchers report in the December *AGU Advances*.

“It’s really weird, and nobody really knows what’s going on just yet,” says Joshua Semeter, an engineer at Boston University. But the observations suggest these horizontal streaks — and perhaps the similarly colored fence — arise from some STEVE-specific process.

Semeter and colleagues examined horizontal streaks below the picket fence in high-resolution images of STEVE taken by citizen scientists. The analysis suggested that the streaks in these images were not actually lines extended across the sky, but only appeared that way due to motion blur, as spherical blobs of glowing gas moved through the atmosphere.



The sky glow STEVE includes a row of vertical green stripes. The discovery of horizontal green streaks below those stripes (one shown in the inset) suggests that STEVE’s green features are not a kind of aurora.

These green blobs might arise from turbulence in the torrent of plasma that creates STEVE’s purple band, Semeter says. Positively charged atoms in the plasma may rush through the atmosphere largely unimpeded, forming a smooth purple arc. Meanwhile, electrons in the plasma are far lighter and more liable to get tripped up by Earth’s magnetic field lines — giving those particles a much bumpier ride through the air. As a result, those high-energy electrons may get tangled up in small vortices on the edge of the plasma stream, below the purple streak. There, the particles could excite pockets of oxygen to glow green.

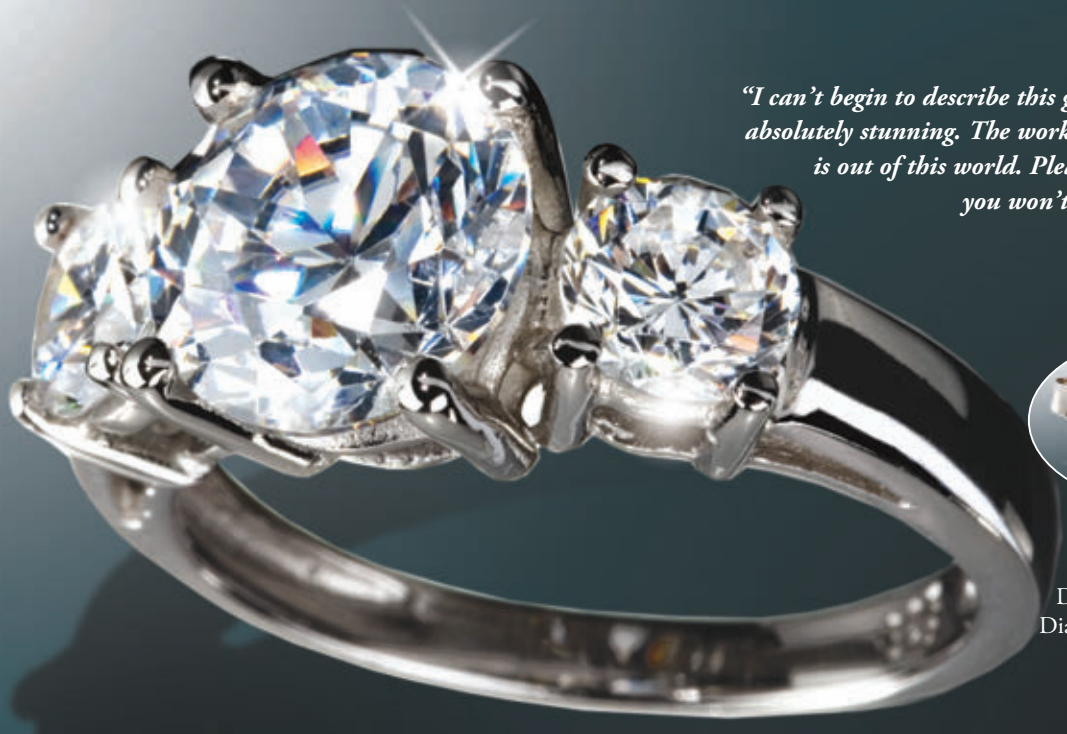
For now, this is just a theory for what might be occurring. Computer simulations of plasma flowing through the atmosphere could test whether the idea is correct.

Whatever is going on with STEVE’s horizontal green features, “there’s some tantalizing evidence” that they’re related to the vertical picket fence, Semeter says. “We found events where these little feet appear before or at the same time as the green column above.” And some horizontal and vertical streaks looked connected. “It appears that the green emission is actually expanding upward along the magnetic field line,” Semeter says. If so, that could explain why STEVE’s picket fence doesn’t have quite the same color as typical auroras.

While these observations do hint that the fence may arise from STEVE-specific particle interactions, it’s hard to be sure based only on photographs from the ground, says Toshi Nishimura, a space physicist at Boston University who has studied STEVE but was not involved in the new work.

Future satellite observations could confirm whether electrons from the magnetosphere are pouring into the atmosphere in the region of a STEVE picket fence, he says. If satellites don’t see such electron showers, that would bolster the idea that the fence is different from normal auroras. ■

FROM TOP: KRISTA TRINDER, NASA GODDARD SPACE FLIGHT CENTER; STEPHEN VOSS, J. SEMETER *ET AL/AGU ADVANCES* 2020



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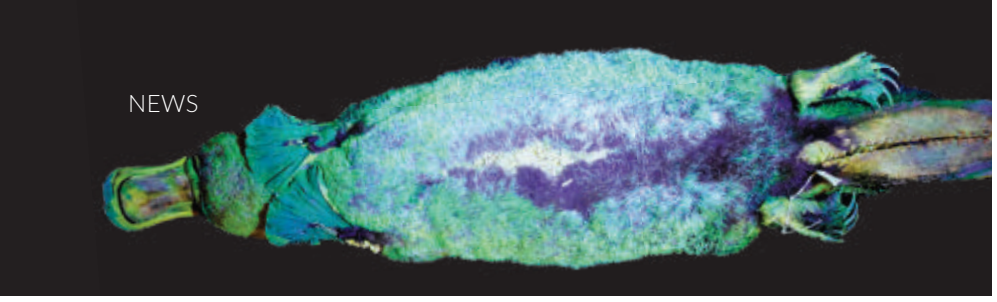


This preserved platypus glows blue-green under ultraviolet light.

LIFE & EVOLUTION

Platypuses shine under ultraviolet light

Fluorescent fur may be more common than scientists thought

BY CHRISTIE WILCOX

With its egg laying, electricity-sensing bill and venomous heel spurs, the platypus was already one of the strangest mammals alive today. Now, researchers have found that this Australian oddity has another unexpected feature: It fluoresces under ultraviolet light.

Platypus fur absorbs ultraviolet light and emits a blue-green glow, mammalogist Paula Spaeth Anich and colleagues discovered somewhat serendipitously. A chance sighting of a fluorescent flying squirrel in the wild led the team to the mammal collection at the Field Museum in Chicago. After examining preserved pelts and finding that fluorescence occurred in at least three flying squirrel species, the team examined marsupials, the only mammals previously known to possess fluorescent fur. It just so happened that the drawer of monotremes — a branch of mammals that today includes only the platypus (*Ornithorhynchus anatinus*) and echidnas — was the next one over from marsupials.

"We were curious," says Anich, of Northland College in Ashland, Wis. "So, we pulled the monotreme drawer, and we shined our [ultraviolet] light on the platypuses. And they were incredibly, vividly fluorescent green and blue."

To make sure the glow wasn't something unusual about the Field Museum's pelts, the team also examined a platypus specimen at the University of Nebraska State Museum in Lincoln. Sure enough, it also glowed, the researchers report online October 15 in *Mammalia*.

Anich is confident that the glow isn't an artifact of preservation, because several of the examined squirrel species and the echidna pelts did not fluoresce. It's likely living platypuses glow, she says, but she hasn't been able to test that theory.

"I'm curious to know myself now," says Josh Griffiths, a wildlife ecologist with the environmental consulting company cesar in Parkville, Australia, who has been working with platypuses for over a decade. "Next time I'm out trapping, I'll take a UV light with me and test it out."

What, if any, purpose fluorescence has a mystery. Anich's hunch is that it helps

ATOM & COSMOS

Europa may glow in the dark

Gleaming ice would reveal the Jovian moon's chemistry

BY MARIA TEMMING

Jupiter's icy moon Europa could give the word "moonlight" a whole new meaning. Lab experiments suggest that the nightside of this moon glows in the dark.

Europa's surface, thought to be mostly water ice laced with salts (*SN: 6/13/15, p. 9*), is continually bombarded with energetic electrons by Jupiter's intense magnetic field. When researchers simulated that interaction by shooting electrons at salty ice samples on Earth, the ice glowed. The brightness of that glow depended on the kind of salt in the ice, the researchers report November 9 in *Nature Astronomy*.

If the same interaction on Europa creates this never-before-seen kind of moonlight, a future mission there, such as NASA's planned Europa Clipper spacecraft, may be able to use the glow to map Europa's surface composition. That, in turn, could give insight into the salinity of the ocean thought to lurk under Europa's icy crust.

"That has implications for the temperature of that liquid water, the freezing point; it has implications for the thickness of the ice shell; it has implications for the habitability of that liquid water," says Jennifer Hanley, a planetary scientist at Lowell Observatory in Flagstaff, Ariz., who wasn't involved in the work. Europa's subsurface ocean is considered one of the most promising places in the solar system to look for extraterrestrial life.

The discovery of Europa's potential ice glow was an accident, says Murthy Gudipati, who studies ice at NASA's Jet Propulsion Laboratory in Pasadena, Calif. Gudipati and colleagues originally set out to investigate how electron bombardment might change the chemistry of Europa's surface ice. But in video footage of the initial lab experiments, the team noticed that ice samples pelted with electrons gave off an unexpected glow.

Intrigued, the researchers turned their electron beam on samples of pure water ice, as well as water ice mixed with different salts. Each ice core was cooled to the surface temperature of Europa (about –173° Celsius) and showered with electrons that had the same energies as those that strike Europa. Over 20 seconds of irradiation, a spectrometer measured the wavelengths of light given off by the ice.

The ice samples all gave off a whitish glow, because they emitted light at many different wavelengths. But the brightness of each ice sample depended on its composition. Ice containing sodium chloride (table salt) or sodium carbonate appeared dimmer than pure water ice. Ice mixed with magnesium sulfate was brighter.

"I was doing some back-of-the-envelope calculations [of] what would be the brightness of Europa, if we were to be standing on it in the dark," Gudipati says. "It's approximately ... as bright as me

JONATHAN MARTIN/NORTHLAND COLLEGE

camouflage the mostly nocturnal platypuses from nighttime predators that have UV vision. By absorbing some UV light, platypuses may reflect less of it.

Griffiths isn't convinced. "Maybe up in northern Queensland they get chomped by a crocodile every now and then," he says. "But essentially, they just don't have any predators." Instead, he thinks the glow could help the solitary animals spot one another or communicate when they do meet up.

In fact, all known fluorescent mammals are active at night or in the low light of dawn and dusk, so Anich thinks the glow has something to do with darkness. "We don't know as much about the nocturnal world," she says, so it's possible lots of fluorescent mammals await discovery.

It may even be that the ancestor of all mammals glowed this way. To see this feature in "all three of the major branches" of mammals — placental mammals, marsupials and monotremes — "is really indicative that it is an ancestral trait," Anich says. ■

walking on the beach in full moonlight."

Gudipati and colleagues estimate that NASA's Europa Clipper spacecraft should be able to see the ice glow during a flyby of Europa's dark side. Dark patches could reveal sodium-rich regions, while brighter areas may be rich in magnesium.

But seeing ice glow in the lab does not necessarily mean it happens the same way on Europa, Hanley cautions. Jupiter's icy moon has been barraged by high-energy electrons for a lot longer than 20 seconds. "Is there ever a point where you might break down the salts, and this glow stops happening?" she wonders.

Other planetary scientists, meanwhile, are not convinced that Europa's surface is highly salted. Roger Clark of the Planetary Science Institute in Lakewood, Colo., thinks the apparent hints of salts are actually created by acids. Europa's surface may be coated in both salts and acids, he says. "What [the researchers] need to do next is irradiate acids ... to see if they can tell the difference between salt with water ice and acids with water ice." ■

LIFE & EVOLUTION

Some spiders are good listeners

Ogre-faced species relies on sound to catch aerial prey

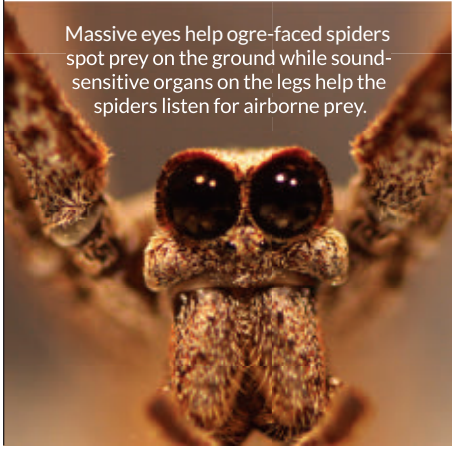
BY CURTIS SEGARRA

Some spiders wait for prey to come and tickle their web. But the ogre-faced spider uses its sense of hearing to take its web to the prey.

Hanging upside down, the spider weaves a rectangular web between its legs. When an insect flies behind the dangling arachnid, it swings backward, casting the web toward the prey. This behind-the-back hunting technique is one clue that the spiders can hear an unexpectedly wide range of sounds, researchers report online October 29 in *Current Biology*.

"A couple years ago, we didn't really have a great idea that spiders could hear," says Jay Stafstrom, a sensory ecologist at Cornell University. But now, he and colleagues have looked at several spider species, and most can hear using specialized organs on their legs, he says. That includes jumping spiders, which respond to low frequencies (*SN: 11/12/16, p. 9*). Surprisingly, ogre-faced spiders (*Deinopis spinosa*) can also hear fairly high frequencies, Stafstrom says.

Stafstrom and colleagues inserted microelectrodes into the brains of 13 ogre-faced spiders and then played tones of varying frequencies from a speaker while monitoring the spiders' auditory nerve cell activity. Spikes of activity revealed that the spiders can sense airborne sounds between 100 and 10,000 hertz, though not at every frequency. (Humans generally hear between 20 and 20,000 Hz.)



Massive eyes help ogre-faced spiders spot prey on the ground while sound-sensitive organs on the legs help the spiders listen for airborne prey.

J. STAFSTROM

Nerve cells in amputated spider legs also responded to the wide range of frequencies. This finding confirms that the spiders hear with their legs, the researchers say.

The team wondered how the spiders would respond to hearing sounds of varying frequencies in the wild. So the scientists took their speaker to part of the spiders' natural range in Gainesville, Fla., and found 25 of the dangling hunters waiting for prey in the dark. Of those, 13 reacted to frequencies of 150, 400 or 750 Hz. And each reacted in the same way — with a blind, backward strike.

"They can obviously catch things out of the air just using sound," Stafstrom says. And because the spiders strike only at low frequencies, they're probably using the lower end of their hearing to listen for prey and hunt. As for the upper frequency range, above 1,000 Hz, "they don't seem to be using it in a foraging context," he says.

Still, the fact that the spiders can detect higher frequencies means that these sounds are probably important to them, says Jayne Yack, a neuroethologist at Carleton University in Ottawa who wasn't involved in the research. Spiders may be using their sense of hearing for a range of things, including eavesdropping on predators, she says.

In fact, those higher frequencies fall in the same range of sounds that predators, including birds, make as they move around or call, so it makes sense for spiders to listen for those frequencies, says Damian Elias, a biologist at the University of California, Berkeley who wasn't involved in the study. The tricky thing, though, is detecting a behavioral response to those higher sounds. Unlike web slinging, the reaction to hearing a predator may simply be to stay put and hide. ■

EARTH & ENVIRONMENT

Hurricanes now linger for longer

Atlantic hurricanes are taking longer to weaken after making landfall than they used to, thanks to climate change. Over the last 50 years, increasingly warm ocean waters have juiced up the storms, giving them more staying power after they roar ashore, scientists report in the Nov. 12 *Nature*. That could potentially extend hurricanes' destructive power farther inland.

The researchers analyzed the intensity of historical Atlantic hurricanes over the first 24 hours after landfall. In 1967, a typical storm's intensity decayed by 76 percent within the first day after landfall. But by 2018, storms were only 52 percent less intense after 24 hours.

That trend, the researchers say, aligns with increasing sea-surface temperatures in the Gulf of Mexico and the western Caribbean Sea. The intense winds of hurricanes feed on moisture and heat picked up from the warm waters, and that warmer air can also hold more moisture. So as the oceans heat up, they not only add more moisture, making hurricanes rainier, they also add more heat — like a portable engine that fuels a storm's fury for just a bit longer. — *Carolyn Gramling*

LIFE & EVOLUTION

Earliest known slingshot tongue belonged to a tiny amphibian

An amphibian that lived 99 million years ago had a secret weapon: a tongue that shot out like a bullet to snatch prey. It's the earliest known example of this "ballistic tongue" style of predation, researchers say.

A small, ancient amphibian used a long bone (yellow in this computer rendering) to shoot its tongue out of its mouth to nab food.

The tiny animal, dubbed *Yaksha perettii*, is known from a few bits of skeleton and soft tissue found in chunks of Myanmar amber. The centerpiece of these finds is a complete skull, preserved in 3-D, that includes a long, thin bone connected to the neck, with some remnants of tongue attached to the end.

The amphibian, just 52 millimeters long (not including the tail), used this bone to shoot its tongue out of its mouth, researchers report in the Nov. 6 *Science*. This "sit-and-wait" style of predation is similar to that of a chameleon.

Y. perettii belonged to an unusual group of amphibians called albanerpetontids that lived roughly 165 million to 2 million years ago. Albanerpetontids had pointy claws and scaly, four-legged bodies. Based on the scaly heads and claws, scientists thought the animals were burrowers, like some salamanders. But the researchers say the new finds suggest that these ballistic-style feeders were actually arboreal, clinging to a tree with their claws while waiting for invertebrates to buzz or stroll by. — *Carolyn Gramling*

ATOM & COSMOS

Scientists rethink how the Red Planet loses water

Mars' water is being skimmed off the top. NASA's MAVEN spacecraft found water molecules lofted into Mars' upper atmosphere, where they are ripped apart, scientists report in the Nov. 13 *Science*.

"This completely changes how we thought hydrogen, in particular, was being lost to space," says planetary chemist Shane Stone of the University of Arizona in Tucson. Previously, scientists thought that Mars' once-abundant water was lost in a "slow and steady trickle," Stone says, as sunlight split water in the lower atmosphere and hydrogen gradually diffused upward.

But MAVEN, which has been orbiting Mars since 2014, scooped up water molecules in Mars' ionosphere, at surprisingly high altitudes of about 150 kilometers.

The concentration of that water varied seasonally, with the peak in the southern summer, when seasonal dust storms are most frequent. During a global dust storm in 2018, water levels jumped even higher, suggesting dust storms lift water in a "sudden splash," Stone says.

The top of Mars' atmosphere is full of charged molecules that are primed for rapid chemical reactions. So water there is split apart quickly, on average lasting only four hours, leaving hydrogen atoms to float away. That process is 10 times faster than previously known ways for Mars to lose water, Stone and colleagues calculated. — *Lisa Grossman*

GENES & CELLS

Penicillin allergies may be linked to an immune system gene

Penicillin is often a first-line antibiotic, yet it is also one of the most common drugs than can cause allergic reactions. Now researchers have reported a genetic link to the hypersensitivity.

People who report penicillin allergies sometimes have a genetic variation on an immune system gene that helps the body distinguish between its own cells and harmful bacteria and viruses. That variant is on the major histocompatibility complex gene *HLA-B*. Pharmacogenomics researcher Kristi Krebs of the University of Tartu in Estonia presented the finding October 26 at the American Society of Human Genetics 2020 virtual meeting.

Krebs and colleagues found the variant after hunting through more than 600,000 health records that included genetic information for people who self-reported penicillin allergies. The team found the same link after studying 1.12 million people of European ancestry in the research database of the genetic-testing company 23andMe. A check of smaller databases including people with East Asian, Middle Eastern and African ancestries found no connection, but those sample sizes were too small to be sure, Krebs said.

Several recent studies have connected HLA genes to bad reactions to drugs. For example, an *HLA-B* variant is linked to adverse reactions to an HIV/AIDS medication called abacavir, and a different *HLA-B* variant is associated with allergic reactions to the gout medicine allopurinol. — *Jeanne Erdmann*

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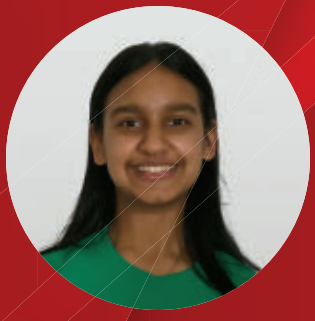

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What look like dramatic flames are actually clouds of dust surrounding the red supergiant star Betelgeuse, as photographed in infrared light by the Very Large Telescope in Chile. The black disk blocks the star's bright light to allow the dust plumes to show. Betelgeuse itself, photographed by the SPHERE instrument in Chile, is superimposed in the center of the black disk.

ESO, PIERRE KERVELLA, M. MONTARGES *ET AL*

The Dust Up Over Betelgeuse

Making sense of the star's sudden dimming

By Lisa Grossman

Astrophysicist Miguel Montargès has a clear memory of the moment the stars became real places to him. He was 7 or 8 years old, looking up from the garden of his parents' apartment in the south of France. A huge, red star winked in the night. The young space fan connected the star to a map he had studied in an astronomy magazine and realized he knew its name: Betelgeuse.

Something shifted for him. That star was no longer an anonymous speck floating in a vast uncharted sea. It was a destination, with a name.

"I thought, wow, for the first time ... I can name a star," he says. The realization was life-changing.

Since then, Montargès, now at the Paris Observatory, has written his Ph.D. thesis and about a dozen papers about Betelgeuse. He considers the star an old friend, observing it many times a year, for work and for fun. He says goodbye every May when the star slips behind the sun from the perspective of Earth, and says hello again in August when the star comes back.

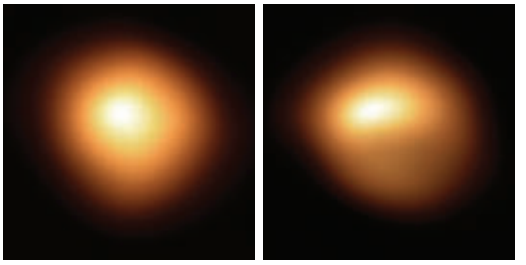
So in late 2019, when the bright star suddenly dimmed for no apparent reason, Montargès was a little alarmed. Some people speculated that Betelgeuse was about to explode in a brilliant supernova that would outshine the full moon. Astronomers know the star is old and its days are numbered, but Montargès wasn't ready to see it go.

"It's my favorite star," he says. "I don't want it to die."

Other researchers, though, were eager to watch Betelgeuse explode in real time. Supernovas mark the violent deaths of stars that are at least eight times as massive as the sun (*SN: 11/7/20, p. 20*). But astronomers still don't know what would signal that one is about to blow. The outbursts sprinkle interstellar space with elements that ultimately form the bulk of planets and people — carbon, oxygen, iron (*SN: 2/8/17, p. 24*). So the question of how supernovas occur is a question of our own origins.

But the explosions are rare — astronomers estimate that one occurs in our galaxy just a few times a century. The last one spotted nearby, SN 1987A, was more than 33 years ago in a neighboring galaxy (*SN: 2/18/17, p. 20*). Betelgeuse is just one of the many aging, massive stars — called red supergiants — that could go supernova at any moment. But as one of the closest and brightest, Betelgeuse is the one that space enthusiasts know best.

So when the star started acting strangely at the end of last year, Montargès and a small band of



January 2019 **December 2019**

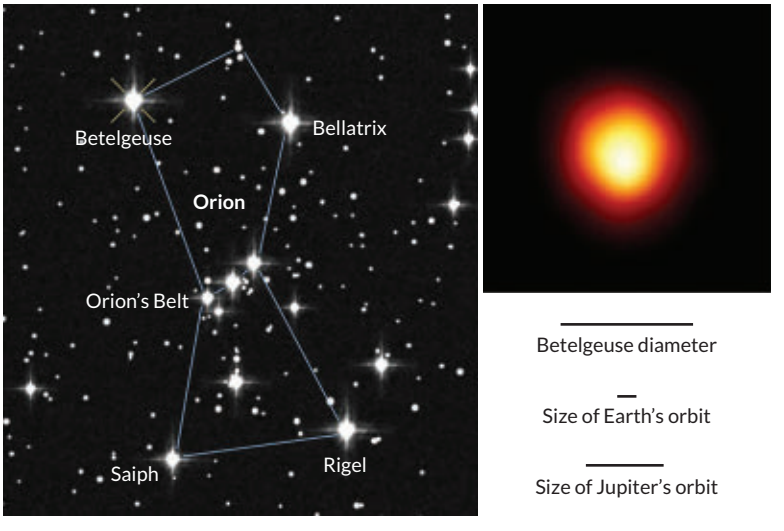
The SPHERE instrument in Chile took images of Betelgeuse in January (left) and December (right) 2019. The December image shows a dark splotch, a dimming, over Betelgeuse's southern hemisphere.

Betelgeuse diehards aimed every telescope they could at the dimming giant. Over the following months, the star returned to its usual brightness, and the excitement over an imminent supernova faded. But the flurry of data collected in the rush to figure out what was happening might help answer a different long-standing question: How do massive, old stars send their planet-building star stuff into the cosmos even before they explode?

Orion's shoulder

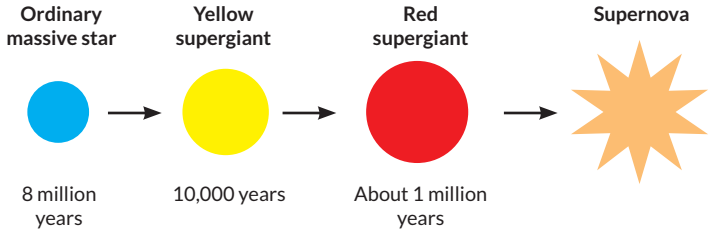
If you've looked up at the stars during winter in the Northern Hemisphere, you've probably seen Betelgeuse, whether you realized it or not. The star is the second brightest in the constellation Orion, marking the hunter's left shoulder from our perspective.

Big deal Betelgeuse is the left shoulder of the Orion constellation (left). The star's first portrait, made with the Hubble Space Telescope in 1996, took some doing. Hubble's operators worried that the bright star would fry the telescope's detectors. So astrophysicist Andrea Dupree had to use every filter Hubble had — "like wearing four sets of sunglasses," she says. "There was nothing. Black. No light got through." Only by taking off the sunglasses could she finally see the massive star, with a diameter that rivals the width of Jupiter's orbit.



TOP, BOTH: ESO, M. MONTARGÈS *ET AL*.; BOTTOM, BOTH: A. DUPREE/HARVARD & SMITHSONIAN'S CENTER FOR ASTROPHYSICS, R. GILLILAND/STSCI, NASA, ESA

Betelgeuse's life cycle



Living large After millions of years, stars that are between eight and 30 times the sun's mass evolve into yellow supergiants, spend a few thousand years as such, then become red supergiants like Betelgeuse. Ultimately these stars explode violently as supernovas. The images above are not to scale. SOURCES: KATHRYN NEUGENT/UNIV. OF WASHINGTON; S. EKSTRÖM *ET AL*/*ASTRONOMY & ASTROPHYSICS* 2012

And it's huge. Estimates for Betelgeuse's vital statistics vary, but if it sat at the center of our solar system, the star would fill much of the space between the sun and Jupiter. At about 15 to 20 times as massive as the sun, somewhere between 750 and 1,000 times its diameter and just about 550 light-years from Earth, Betelgeuse is typically between the sixth- and seventh-brightest star in the sky.

Betelgeuse's brightness varies, even under normal circumstances. Its outer layers are a bubbling cauldron of hot gas and plasma. As hot material rises to the surface, the star brightens; as material falls toward the core, the star dims. That convection cycle puts Betelgeuse on a semiregular dimmer switch that fluctuates roughly every 400 days or so. The star's brightness also varies about every six years, though astronomers don't know why.

What they do know is that Betelgeuse is running out of time. It's less than 10 million years old, a youngster compared with the roughly 4.6-billion-year-old sun. But because Betelgeuse is so massive and burns through its fuel so quickly, it's already in the final life stage of a red supergiant. Someday in the not too distant future, the star won't be able to support its own weight — it will collapse in on itself and rebound in a supernova.

"We know one day it's going to die and explode," says Emily Levesque, an astrophysicist at the University of Washington in Seattle. But no one knows when. "In astronomical terms, 'one day' means sometime in the next 200,000 years."

In October 2019, Betelgeuse started dimming, which wasn't too strange in and of itself. The change fit within the normal 400ish-day cycle, says astronomer Edward Guinan of Villanova University in Pennsylvania, who has been tracking Betelgeuse's cycles of brightness since the 1980s.

But by Christmas, Betelgeuse was the dimmest it had been in the 100-plus years that astronomers have measured it. And the dimming continued all the way through February.

Guinan was one of the first to sound the alarm. On December 7, and again on December 23, he and colleagues posted a bulletin on The Astronomer's Telegram website announcing the star's "fainting" and encouraging fellow astronomers to take a look.

There was no reason to think that the dimming was a harbinger of a supernova. "I never said it was going to be one," Guinan says. But because these explosions are so rare, astronomers don't know what the signals of an imminent supernova are. Dimming could be one of them.

That report of odd behavior was all astronomers and amateur space enthusiasts needed to hear. Online, the story caught fire.

"On Twitter, it was hysterical," says Andrea Dupree, an astrophysicist at the Harvard & Smithsonian's Center for Astrophysics in Cambridge, Mass. She recalls seeing one tweet suggesting that the explosion was going to happen that night, with the hashtag #HIDE. "Where am I going to hide? Under my desk?" (When Betelgeuse finally explodes, it probably won't hurt life on Earth — it's a safe distance away.)

Most astronomers didn't really believe that Betelgeuse's end was nigh, even as they rushed to schedule telescope time. But some got caught up in the excitement.

"I don't expect it to blow," Guinan recalls thinking. "But I don't want to blink." He signed up for phone alerts from telescopes that detect invisible particles called neutrinos and ripples in spacetime called gravitational waves. A detection of either one might be an early sign of a supernova. He found himself outside at 1 a.m. in January after a report of gravitational waves from the direction of Orion. "It was cloudy, but I thought I might see a brightening," he says. "I've gotten crazy about it."

Others were believers too, until their data cast doubt on the notion.

"I thought it might," says astrophysicist Thavisha Dharmawardena of the Max Planck Institute for Astronomy in Heidelberg, Germany. "We knew there were other explanations, and we might have to look into it. But we know Betelgeuse is an old star, close to the end of its life. It was exciting."

Two camps

Once the star started returning to its usual brightness in mid-February, talk of an imminent supernova faded. A paper published in the Oct. 10 *Astrophysical Journal* boosted confidence in

C. CHANG

Betelgeuse's longevity, suggesting that the star is just at the beginning of its old age and has at least 100,000 years to go before it explodes. But what was it up to, if it was not on the verge of exploding?

As results from telescopes all over the world and in space flooded in, most astronomers have fallen into two camps. One says Betelgeuse's dimming was caused by a cloud of dust coughed out by the star itself, blocking its glow. The other camp isn't sure what the explanation is, but says "no" to the dust speculation.

If the dust theory proves true, it could have profound implications for the origins of complex chemistry, planets and even life in the universe. Red supergiants are surrounded by diffuse clouds of gas and dust that are full of elements that are forged only in stars — and those clouds form before the star explodes. Even before they die, supergiants seem to bequeath material to the next generation of stars.

"The carbon, oxygen in our body, it's coming from there — from the supernova and from the clouds around dying stars," Montargès says. But it's not clear how those elements escape the stars in the first place. "We have no idea," he says.

Montargès hoped studying Betelgeuse's dimming would let scientists see that process in action.

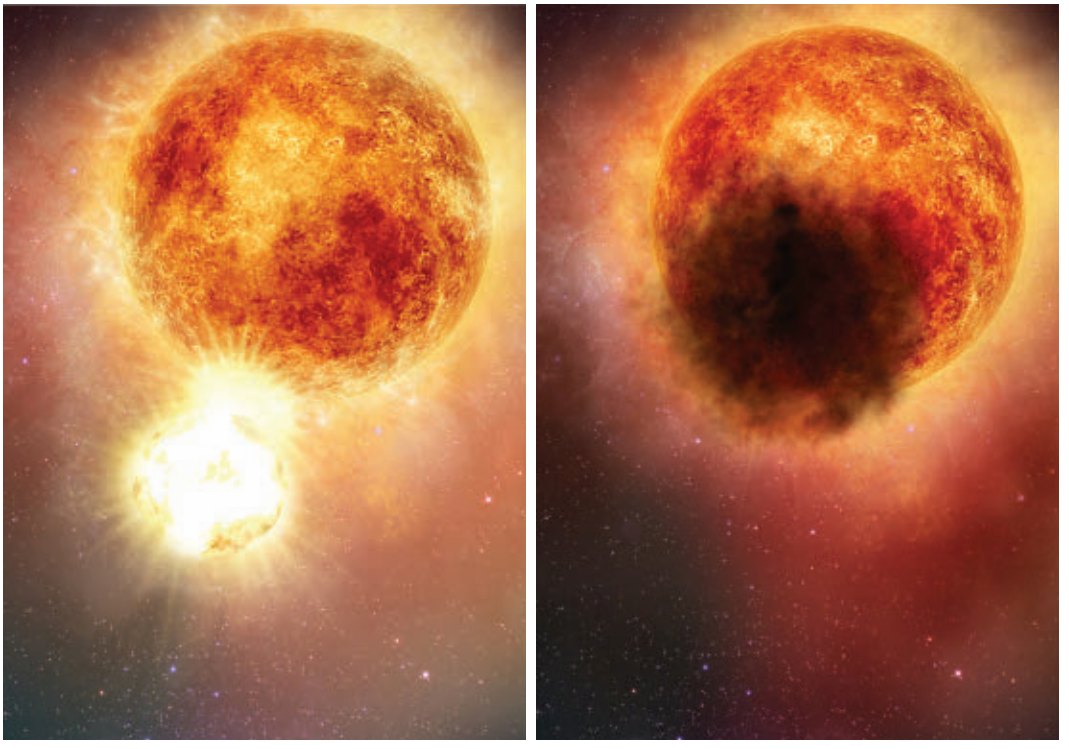
In December 2019, he and colleagues took an image of Betelgeuse in visible light with the SPHERE instrument on the Very Large Telescope in Chile. That image showed that, yes, Betelgeuse was much dimmer than it had been 11 months earlier — but only the star's bottom half. Perhaps an asymmetrical dust cloud was to blame.

Observations from February 15, 2020, seem to support that idea (*SN: 4/11/20, p. 6*). Levesque and Philip Massey of the Lowell Observatory in Flagstaff, Ariz., compared the February observations with similar ones from 2004. The star's temperature hadn't dropped as much as would be expected if the dimming was from something intrinsic to the star, like its convection cycles, the pair reported in the March 10 *Astrophysical Journal Letters*.

That left dust as a reasonable explanation. "We know Betelgeuse sheds mass and produces dust around itself," Levesque says. "Dust could have come toward us, cooled and temporarily blocked the light."

Dark cloud

A strong vote for dust came from Dupree, who was watching Betelgeuse with the Hubble Space Telescope. Like Guinan, she has a decades-long relationship with Betelgeuse. In 1996, she and colleague Ronald Gilliland looked at Betelgeuse with Hubble to make the first real image of any star other than the sun. Most stars are too far and too faint to show up as anything but a point.



NASA, ESA, E. WHEATLEY/STSCI

One explanation for why Betelgeuse went dark in 2019 is that the star sneezed out a burst of gas and dust (illustrated, left), which condensed into a dark cloud. That cloud blocked the star's face from the perspective of Earth (right).

Betelgeuse is one of the few stars whose surface can be seen as a two-dimensional disk — a real place.

By the end of 2019, Dupree was observing Betelgeuse with Hubble several times a year. She had assembled an international team of researchers she calls the MOB, for Months of Betelgeuse, to observe the star frequently in a variety of wavelengths of light.

The goal was the same as Montargès': to answer fundamental questions about how Betelgeuse, and perhaps other red supergiants, lose material. The MOB had baseline observations from before the dimming and already had Hubble time scheduled to track the star's brightness cycles.

Those observations showed that in January and March 2019, Betelgeuse looked "perfectly normal," Dupree says. But from September through November, just before the dimming event, the star gave out more ultraviolet light — up to four or five times its usual UV brightness — over its southern hemisphere.

The temperature and electron density in that region went up, too. And material seemed to be moving outward, away from the star and toward Earth.

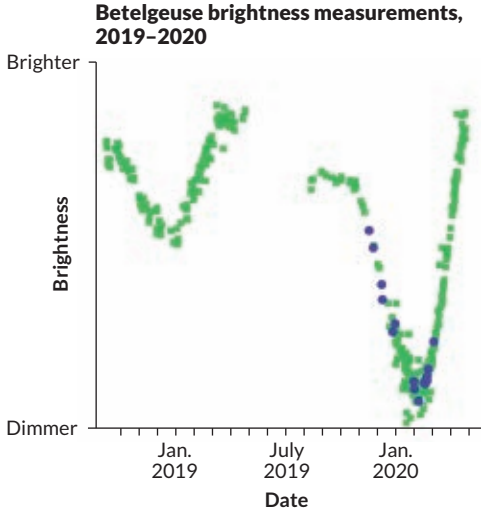
Dupree and colleagues' theory of what happened, reported in the Aug. 10 *Astrophysical Journal*, is that one of the giant bubbles of hot plasma always churning in the star's outer layers rose to the edge of the star's atmosphere and escaped, sending huge amounts of material flowing into interstellar space. That could be one way that red supergiants shed material before exploding.

Once it had fled the star, that hot stuff cooled, condensed into dust and floated in front of Betelgeuse for several months. As the dust cleared, Betelgeuse appeared brighter again.

"It seems to us that what we saw with the ultraviolet is kind of the smoking gun," Dupree says. "This material moved on out, condensed and formed this dark, dark dust cloud."

Paul Hertz, director of NASA's astrophysics division, shared the Hubble results in a NASA online town hall meeting on September 10 as if it were the final answer. "Mystery solved," he said. "Not gonna supernova anytime soon."

Yo-yo In late 2019, Betelgeuse started dimming (V curve, right) more than its normal up and down (V curve, left). The blue and green dots are brightness measurements from ground-based observatories.



Cycles and spots

Maybe not — but that doesn't mean dust explains the dimming.

In the July 1 *Astrophysical Journal Letters*, Dharmawardena and colleagues published observations of Betelgeuse that ran counter to the dust explanation. Her team used the James Clerk Maxwell Telescope in Hawaii in January, February and March to look at Betelgeuse in submillimeter wavelengths of light. "If we think it's a dust cloud, the submillimeter is the perfect wavelength to look at," she says.

Dust should have made Betelgeuse look brighter in those wavelengths, as floating grains absorbed and reemitted starlight. But it didn't. If anything, the star dimmed slightly. "Our first thought was that we'd done something wrong — everyone in the community expected it to be dust," she says. But "the fact that it didn't increase or stay constant in the submillimeter was pretty much a dead giveaway that it's not dust."

Infrared observations with the airborne SOFIA telescope should have found the glowing signature of dust too, if it existed. "It never showed up," Guinan says. "I don't think it's dust."

Instead, Guinan thinks the dimming may have been part of Betelgeuse's natural convection cycle. The star's outer atmosphere constantly pulsates and "breathes" in and out as enormous bubbles of hot plasma rise to the surface and sink down again. "It's driven by the internal core of the star," he says. "You have hot blobs rising up, they cool, they get more dense, they fall back."

Multiple cycles syncing up could explain why the 2019 dimming was so extreme. Guinan and colleagues analyzed about 180 years of observations of Betelgeuse, dating back to astronomer John Herschel's 1839 discovery that the star's brightness varies. Guinan's group found that,

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in addition to the roughly six-year and 400-day cycles, Betelgeuse might have a third, smaller cycle of about 187 days. It looks like all three cycles might have hit their brightness nadirs at the same time in late 2019, Guinan says.

Or maybe the darkness in the southern hemisphere that Montargès' team saw with SPHERE was an enormous star spot, Dharmawardena offers. In the sun's case, those dark splotches, called sunspots, mark the sites of magnetic activity on the surface. Betelgeuse is one of a handful of stars on which star spots have been directly seen.

But to cause Betelgeuse's dimming, a star spot would have to be enormous. Typical star spots cover about 20 to 30 percent of a star's surface, Dharmawardena says. This one would need to cover at least half, maybe up to 70 percent.

"That's rare," Dharmawardena admits. "But so is this kind of dimming."

Pandemic disruptions

Analyses are still coming in. But just as Betelgeuse was returning to its normal brightness, the COVID-19 pandemic hit.

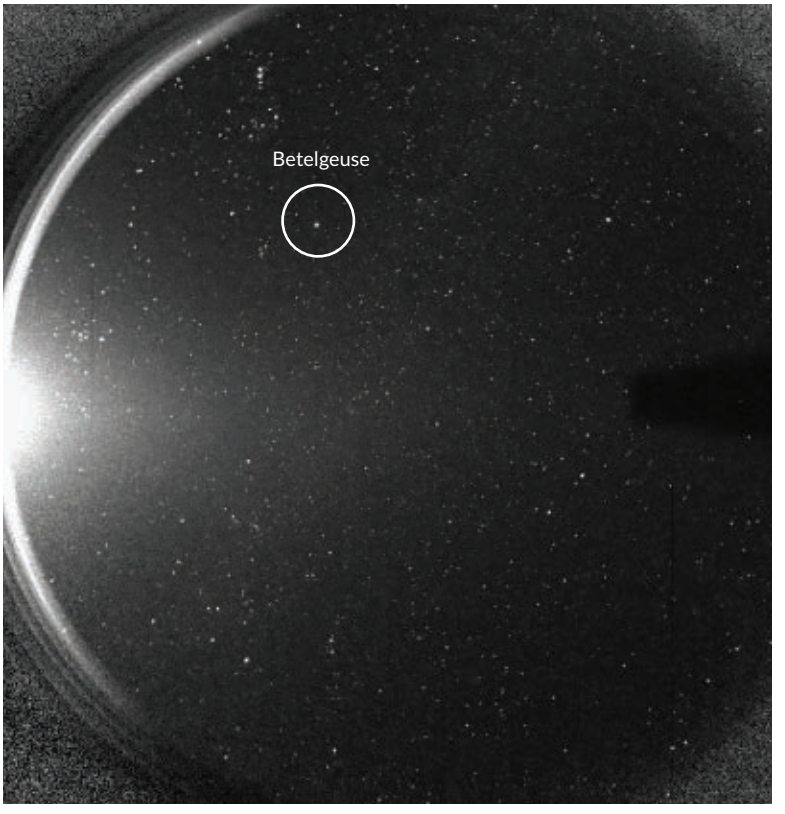
"We were hoping to have a lot more data," Dharmawardena says.

A few observations came in right under the wire. The SOFIA observations were made on one of the last flights before the pandemic grounded the plane that carries the telescope. And Montargès took another look with SPHERE just days before its observatory shut down in mid-March.

But one of Montargès' most hoped-for results may never come. Eager to solve the dust versus not-dust mystery, his plan was to combine two kinds of observations: making a 2-D picture of the whole star's disk, like Dupree did with Hubble in the '90s, but in longer wavelengths such as infrared or submillimeter, like Dharmawardena's images from early 2020. That way, you could differentiate the dust from the star, he reasoned.

Only one observatory can do both at once: the Atacama Large Millimeter/submillimeter Array, or ALMA, in Chile. Montargès had planned to ask to observe Betelgeuse with ALMA in June and July, when the winter skies in the Southern Hemisphere are most free of turbulence. But ALMA closed in March and was still closed in September.

"When I realized ALMA will not get the time in June, I thought ... we are never going to solve it," he says. "We may never be completely certain, because of COVID."



In mid-July 2020, astronomers announced that STEREO, a sun-watching spacecraft, had seen signs that the star Betelgeuse was beginning to dim yet again.

HI/STERO/NASA

Any other star

Montargès and his colleagues have submitted their analysis of the SPHERE pictures from March for publication. Though he's not yet willing to share the results, he thinks they could pull the two camps together.

Ultimately, if Betelgeuse did cough out a cloud of dust last year, it could teach us about the origins of life in the universe, Montargès says. If the dust camp is even partially right, Betelgeuse's dimming may have been the first time humans have watched the seeds of life being launched into the cosmos.

In the meantime, he's relieved to see his favorite star shining bright again. "I must admit that since [last] December, since this whole stuff started, every time I see it, I am like, phew, it's still there," he says.

People keep asking him if he would like Betelgeuse to go supernova so he can study it. "I would like another star to go supernova," he says. "Antares, I don't care about it; it can explode anytime. But not Betelgeuse." ■

Explore more

- Andrea K. Dupree *et al*. "Spatially resolved ultraviolet spectroscopy of the Great Dimming of Betelgeuse." *Astrophysical Journal*. August 10, 2020.

Origins of a Mighty Meteor Shower

How does a space rock make such a stunning display of shooting stars?

By Ken Croswell

On Sunday night, December 13, countless meteors will shoot across the sky as space particles burn up in our atmosphere and meet a fiery end. Most meteor showers occur when Earth slams into debris left behind by a comet.

But not this meteor shower, which is likely to be the most spectacular of the year. Known as the Geminid shower, it strikes every December and arises not from a flamboyant comet but from an ordinary asteroid — the first, but not the last, linked to a meteor shower.

Although both comets and asteroids are small objects orbiting the sun, icy comets sprout beautiful tails when their ice vaporizes in the heat of the sun. In contrast, asteroids have earned the name "vermin of the skies" for streaking through and ruining photographs of celestial vistas by reflecting the sun's light.

So how can a mere asteroid outdo all of the glamorous comets and spawn a meteor shower that surpasses its rivals? "It remains a mystery," says David Jewitt, an astronomer at UCLA. It's akin to an ugly duckling's offspring usurping the beautiful swan's to win first place in a beauty contest.

Astronomers still don't know the secret to the asteroid's success in creating a shower that at its peak normally produces more meteors per hour than any other shower of the year. Three years ago, however, the asteroid swung extra close to Earth and gave scientists their best chance to study the humble space rock. They now look forward to the launch of a spacecraft that will image the asteroid's surface.

Cosmic connections

Astronomers first linked a meteor shower to a comet in 1866. They connected the well-known Perseid meteors, visible to most of the world every August, with a comet named Swift-Tuttle that had passed Earth four years earlier. Astronomers later matched most major meteor showers with one comet or another.

When a comet's ice vaporizes in sunlight, dust

The Geminid meteor shower produces a vivid display of shooting stars every December, but unlike most meteor showers, the show is from an asteroid, not a comet.

JEFF DAI

grains also fly off the comet. These dust particles, called meteoroids, sprinkle along the comet's orbit like a dandelion gone to seed. If Earth plows into this long dust stream, we see a fiery shower as the particles hit our atmosphere. The typical meteoroid is no larger than a grain of sand, but it travels so fast that it energizes electrons both in its own atoms as it disintegrates and in atmospheric atoms and molecules. As these electrons lose energy, they emit the streak of light — the meteor — that looks as though a star has fallen from the sky.

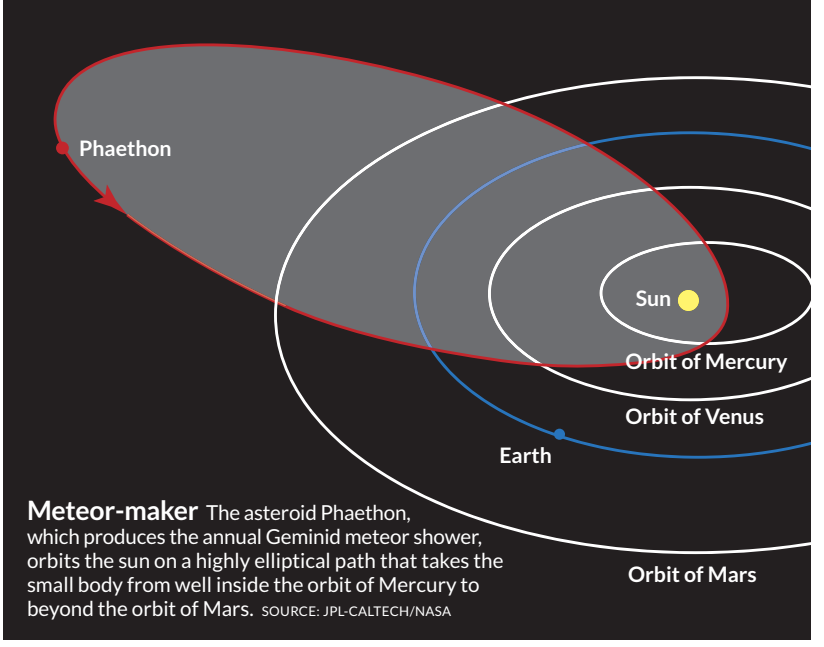
Still, as comet after comet was linked to different meteor showers, the Geminids remained apart; no one knew their source.

The Geminid meteors stood out in other ways, too. Unlike the Perseid meteors, which people have been observing for nearly 2,000 years, the Geminids are relatively new. First reports of their existence came from England and the United States in 1862. The shower in those days was weak, producing at most only one or two dozen meteors an hour. During the 20th century, however, the shower strengthened. Nowadays, at the shower's peak, a single observer under a dark sky can see more than 100 meteors an hour. That's better than most Perseid performances.

On top of that, the Geminid meteoroid stream, the ribbon of dust that traces the asteroid's orbit around the sun, is newer than many other streams. Over time, streams spread out, but this one is so narrow it must have formed less than 2,000 years ago and maybe only a few hundred years ago. And based on how little the meteoroids slow down when they hit the air, astronomers deduced that Geminid meteoroids are fairly dense, about three times as dense as water and twice as dense as the Perseid meteoroids.

In 1983, astronomers finally found the Geminids' parent. Jewitt, then a graduate student at Caltech, remembers walking home one January evening when he happened to see a rocket lift off from a military base. "I assumed it was an ICBM or something that the Air Force was launching to test," he says. Instead, it was a heat-seeking spacecraft named the Infrared Astronomical Satellite.

In October of that year, the satellite discovered a small asteroid. To Harvard astronomer Fred Whipple, best known for his "dirty snowball" model of comets (*SN: 3/14/92, p. 170*), that small object stood out. It followed the same path around the sun as the particles in the Geminid meteoroid stream. Half a century earlier, Whipple himself had determined the orbit of the meteoroids by photographing the paths of the meteors against the sky. The newfound asteroid, Whipple declared, must be their long-sought source. The find also explained why the meteoroids were so dense: They come from a space rock rather than an icy comet.



Meteor-maker The asteroid Phaethon, which produces the annual Geminid meteor shower, orbits the sun on a highly elliptical path that takes the small body from well inside the orbit of Mercury to beyond the orbit of Mars. SOURCE: JPL-CALTECH/NASA

The asteroid revolves around the sun every 1.43 years and comes very close to the sun, cutting well inside the orbit of Mercury, the innermost planet. Astronomers therefore christened the asteroid Phaethon, a son of Helios the sun god in Greek mythology. At its farthest, Phaethon ventures beyond the orbit of Mars and reaches the asteroid belt, home of the largest space rocks, between the paths of Mars and Jupiter.

For a quarter century after Phaethon's discovery, though, no one saw it shedding any dust particles or pebbles that could account for the many meteors that make up December's show. Because of the sun's glare, astronomers couldn't observe Phaethon when it was closest to the sun. Observing during a close pass might be especially interesting because calculations indicated that the intense sunlight caused Phaethon's surface temperature to soar to roughly 1,000 kelvins (1,340° Fahrenheit), hotter than any planet in the solar system. The torrid temperature might cause the asteroid to shoot particles into space.

A lucky break came about because Jewitt married an astrophysicist who studies the sun. "Really, the key was talking to my wife about this," he says. Jing Li, also at UCLA, and Jewitt realized that a solar spacecraft might be able to pick up details about the asteroid when it's nearest the sun and thus offer clues to why the space rock is such a fertile meteor-maker.

Sure enough, in 2009 and again in 2012, images taken by a NASA solar spacecraft named STEREO A caught Phaethon brightening when near the sun, which suggested the asteroid was throwing off

T. TIBBITTS

dust particles. Then, in 2013, Jewitt and Li noticed a short dust tail in that data. The tail lasted only two days. "It's really, really faint in basically the world's crappiest data," Jewitt says. The bright background sky makes the tail hard to see.

The researchers attribute Phaethon's dust production to the extreme heat, which breaks rocks on the asteroid's surface and sends particles aloft. Phaethon has so little gravity that those particles can escape into space. Additional dust may result from desiccation, Jewitt says: In the presence of such heat, hydrated minerals on the asteroid may dry out and crack, the way empty lake beds do on Earth, releasing more particles.

Phaethon's fast spin causes further stress. The asteroid makes a full turn every three hours and 36 minutes. Such rapid rotation is typical of small asteroids, and it means the surface freezes and then fries over a short period of time. The spin also creates a centrifugal force that might help lift particles into space.

Yet these findings don't solve the mystery of how a modest asteroid produces such a stunning meteor shower, Jewitt says. For one thing, as he and colleagues noted in 2013 in the *Astrophysical Journal Letters*, the particles in Phaethon's temporary tail are much too small.

Most of the Geminid meteors we see come from particles roughly a millimeter across. But the particles in the tail are even tinier, spanning only about one one-thousandth of a millimeter. Jewitt and Li deduced the small size because sunlight exerts radiation pressure, which is weak, that pushes the tail straight back away from the sun; if the particles were larger, they would resist the weak pressure and the tail would be curved.

Plus, Phaethon's close passages to the sun don't eject nearly enough particles to populate the Geminid stream. This suggests that some catastrophe hit the asteroid in the recent past and made so many meteoroids that they continue to delight meteor observers today.

In 2014, astronomer Richard Arendt of the University of Maryland, Baltimore County reported the first direct sighting of the Geminid meteoroid stream itself. He had reanalyzed old data from a spacecraft whose chief mission had nothing to do with the solar system: the Cosmic Background Explorer, which NASA had launched a quarter century earlier to study the Big Bang's afterglow and probe the universe's birth.

"They didn't really have the tools to look at the data in the right way back then," Arendt says. With modern computers, he made movies of the data and glimpsed glowing strands of dust threading the solar system that emit infrared light as the sun heats them. He used this approach to view the never-before-seen dust trail along the orbit of Halley's comet, as well as Phaethon's dust trail: the Geminid meteoroid stream, which looked like a narrow filament along Phaethon's orbit. Arendt published his work in the *Astronomical Journal*.

More recently, NASA's Parker Solar Probe also detected the stream (*SN: 1/18/20, p. 6*). "This is the first time it's been seen in visible light," says Karl Battams, an astrophysicist at the U.S. Naval Research Laboratory in Washington, D.C. Sunlight hits the dust, reflecting the light to the probe. The observations put the stream's mass at roughly 1 percent that of Phaethon itself. This is much more material than the asteroid produces when closest to the sun, which Battams says again favors the idea that the bulk of the Geminid meteoroid stream owes its existence to some past catastrophe.

Phaethon visits Earth

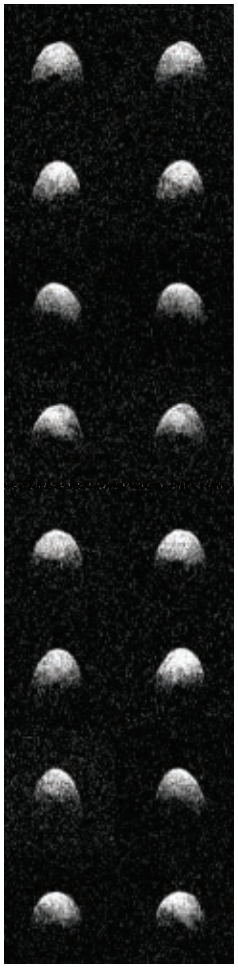
In December 2017, the asteroid helped astronomers by flying only 10 million kilometers from Earth, the closest the rock will come until 2093. "This was a great opportunity to look at Phaethon," says Patrick Taylor, an astronomer then at Arecibo Observatory in Puerto Rico.

Hurricane Maria had devastated the island and damaged the radio telescope just three months earlier, yet the observations succeeded. "That was the result of a tremendous amount of effort by the observatory staff, the community and the local government," Taylor says. The telescope was repaired, and commercial power was restored to the observatory by clearing roads and replacing downed poles and cables to the site. "Everyone was aware how important this observation was going to be," he says.

Over a period of five days, his team bounced radar signals off the asteroid, watching different features come into view as the rock rotated. As published in 2019 in *Planetary and Space Science*, the observations indicate that Phaethon's equatorial diameter is about 6.25 kilometers, which means the asteroid is a bit more than half the size of the one that hit Earth and did in the dinosaurs (*SN: 2/15/20, p. 7*). The images show what may be craters, one more than a kilometer across, on Phaethon's surface. There's also a possible boulder 300 meters wide.

The radar images suggest Phaethon isn't perfectly round. Instead, it may resemble a spinning top, like Bennu and Ryugu, two even smaller

Speedy spinner
Radar images from December 2017 show some details on Phaethon as it rotates. A Japanese mission named DESTINY+, scheduled to launch in 2024, should yield a much better view.



ARECIBO/NSF, NASA

asteroids that spacecraft have recently visited. Both of those asteroids have equatorial diameters larger than their polar diameters. More than a thousand Bennus could fit inside Phaethon, but the two asteroids have similar shapes, Taylor notes. He thinks Phaethon may owe its shape to its rapid spin.

Jewitt also tried to take advantage of Phaethon's close visit. "It was a bit of a letdown," he says, laughing. "We saw absolutely nothing at all." Neither the Hubble Space Telescope nor the Very Large Telescope in Chile discerned any dust or rocks coming off the asteroid.

But the future should hold much better views. In 2024, Japan will launch the DESTINY+ spacecraft, which will fly past Phaethon several years later. Japan has already sent spacecraft to two other small asteroids, and the new mission promises sharp images that should reveal Phaethon's shape, structure, geologic features and dust trail. The spacecraft may even see the asteroid emit particles in real time, as NASA's OSIRIS-REx mission did for Bennu (*SN: 4/13/19, p. 10*).

The DESTINY+ spacecraft will search for signs of a recent catastrophe that could have excavated enough material to create the Geminid meteoroid stream. The most obvious possibility — an impact with another asteroid — is also the least likely, Jewitt says, because Phaethon is a small target and the impact would have had to occur less than 2,000 years ago. Nevertheless, if such an impact did happen, it surely carved a fresh scar, which a spacecraft might pick up.

Perhaps some other catastrophe made the meteoroids. Maybe the asteroid was once a larger object that broke apart, because sunlight stressed it or it spun too fast. In fact, one or two other asteroids, smaller than Phaethon, follow similar paths around the sun and could be remnants of a super-Phaethon. After DESTINY+ zips by Phaethon, it may visit one of these other asteroids to investigate.

There's another question the spacecraft might address: The Geminids come from Phaethon, all right, but where did Phaethon come from? It wasn't born where it is, because it crosses the paths of four planets. Within just a few tens of millions of years, it will either crash into one of them or else their gravity will hurl the rock into the sun or far away from it.

Some astronomers have proposed that Phaethon is really a chunk kicked off of the large asteroid Pallas, a resident of the asteroid belt. "Could Phaethon be a piece of Pallas? Yes," Jewitt says. "Is it likely to be a piece of Pallas? I'm not really sure about that." The two asteroids resemble each other in composition, but there are also differences. Those distinctions may merely mean that strong sunlight has altered Phaethon's surface. Or they may indicate the two asteroids have nothing to do with each other.

Whatever the case, this month's show should be especially good because moonlight won't interfere. Any astronomers watching may make a wish on the falling stars for greater insight into how those meteors and their unlikely parent came to be. ■

JEFF DAI

Skywatchers around the world marvel at the annual Geminids, as shown here in 2014 from Mount Balang in Sichuan, China.

See the meteors

In recent years, the peak numbers of December's Geminid meteors often surpass those of the Perseids in August. The Perseids are better known because they occur during summer. But the cold-weather Geminids offer most observers a great show — minus the mosquitoes.

Celestial conditions in 2020 will be ideal. The moon will be new around the shower's peak, ensuring dark skies for those away from city lights.

The shower should crest on the night of Sunday, December 13. The Geminids owe their name to Gemini, because every meteor radiates from that constellation. To see the show, though, you don't need to know where Gemini is nor do you need a telescope.

Instead, bundle up, head outside and look up, because meteors can streak through any part of the sky. The best place to look is probably wherever your sky is darkest and unobstructed by trees and artificial light. Give your eyes at least 20 minutes to get used to the dark.

If you are in North America, the show should start by 10 p.m. local time but will likely reach its peak after midnight. At maximum, you may see more than 100 meteors an hour. Most are white or yellow; all are slow and graceful, because the meteoroids orbit the sun in the same direction as Earth does. They hit the air at only 35 kilometers per second — versus 71 km/s for the Leonids, which occur in November and whose meteoroids orbit the sun backward, opposite the direction of Earth's motion. — *Ken Croswell*

Explore more

- David Jewitt *et al.* "Hubble Space Telescope observations of 3200 Phaethon at closest approach." *Astronomical Journal.* November 2018.

Ken Croswell is an astronomer and author of The Alchemy of the Heavens. *The first meteor he ever saw was a Geminid.*

SCREENTIME

An online time capsule captures life during the coronavirus pandemic

Imagine if, at the height of the 1918 flu pandemic, researchers studying how society was changing had captured the moment in a time capsule. What information might social scientists today have gleaned from such an effort? How might that repository inform the global response to the current pandemic? Theoretically such an artifact could be buried somewhere, but for now, researchers are out of luck.

When the next pandemic invariably strikes, though, social scientists might find themselves better situated. The nonprofit Social Science Research Council, based in Brooklyn, N.Y., has assembled a collection of images that aims to freeze in time the myriad ways the COVID-19 crisis is transforming societies worldwide. And unlike time capsules of yesteryear, this version will live entirely online. The capsule currently includes an eclectic mix of photographs, charts and even a drawing appearing to depict infectious diseases expert Anthony Fauci as a saint.

Among the images included in a COVID-19 time capsule curated by social scientists is this drawing of Anthony Fauci.

Alondra Nelson, president of the council, says she and colleagues knew by spring that the pandemic was going to trigger massive societal change. Council staff came up with numerous initiatives to help scientists discuss and study those changes, including grants for COVID-19 research. With support from outside sponsors, council staffers also set up an essay forum in which scientists evaluated the pandemic from varying vantage points — from its effect on democracy to what society might look like in the aftertimes. The group also began a crowdsourced "syllabus" covering scholarly and creative writings addressing all things pandemic.

But Nelson also wanted to capture the flood of images emerging from such a massive global upheaval. That led to the idea of a visual time capsule. Starting in the spring, the council began asking prominent researchers to select any image that spoke to their understanding of the crisis and then explain the choice in an interview.

Some researchers honed in on how the pandemic illuminated the United States' racial and socioeconomic disparities, while others went more obscure or even darkly humorous, including, for example, a graphic asking viewers if they want to pay by Visa, Mastercard or toilet paper. So far, the time capsule consists of 21 images and corresponding interviews.

What's most striking when viewing the images in aggregate is that, in the midst of a pandemic that has taken more than 1.3 million lives as of mid-November, few images speak directly to death or dying. More common are depictions of everyday life, such as a screenshot of a virtual classroom. There are also individuals, mostly people of color, still going about their jobs in person: A Black worker cleans a chair in a U.S. Senate chamber. A Black bike messenger passes a boarded-up Louis Vuitton store to make a delivery.

This catalog is both academic and personal. Economic sociologist Brooke Harrington of Dartmouth College selected an image of a Danish mother and son waiting to enter a school building in April. Harrington says the photo is a reminder that had she stayed in Denmark, where she worked for nearly a decade, that could have been her standing in line with her own son. Instead, her boy is attending school from home, and Harrington, like so many working parents, especially mothers, is simultaneously juggling work and family. "If you're asking me in my capacity as an individual trying to stay alive and do my job in 2020, this is what is at the forefront of my mind," she told *Science News*.

The problem of shuttered day care and schools in the United States and elsewhere is ongoing. But other images in the collection remind present-day viewers of moments that may have already been forgotten amid a frenetic news cycle. Consider the image of the *Diamond Princess* cruise ship berthed in Yokohama, Japan. After hundreds of passengers fell ill with the coronavirus in February, nobody on the ship was allowed to disembark for weeks. Remember when the passengers' plight was the news *du jour*? I didn't.

Which perhaps illustrates the point of preserving these moments in perpetuity. — *Sujata Gupta*

In an interview accompanying his time capsule selection, historian Jelani Cobb of Columbia University said he chose this image of a bike messenger in front of a boarded-up luxury store because "it said a lot to me about how different people were experiencing this pandemic."

FROM TOP: DANIEL STETSON; JELANI COBB

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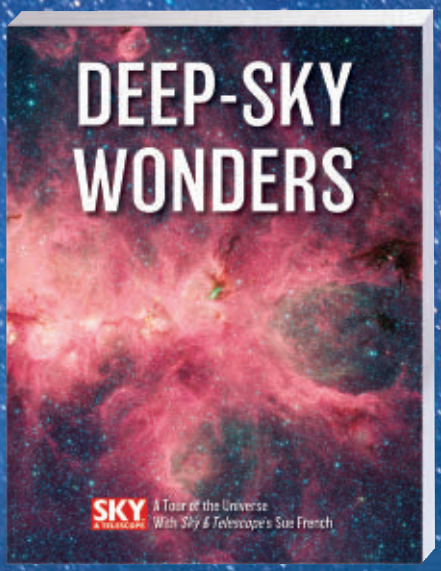

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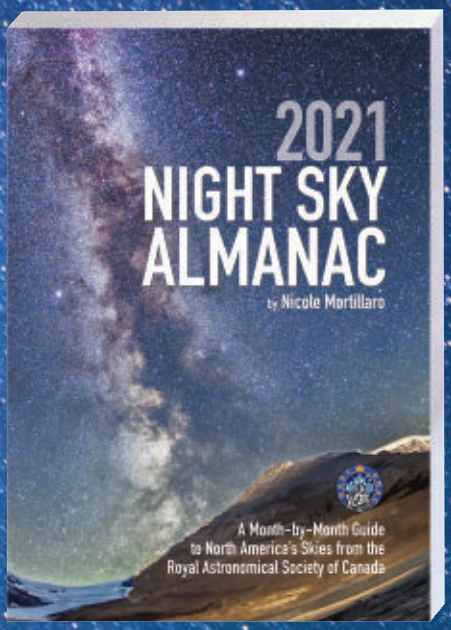

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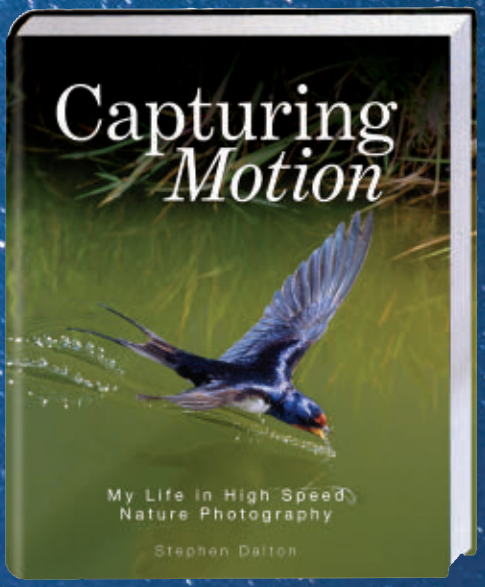

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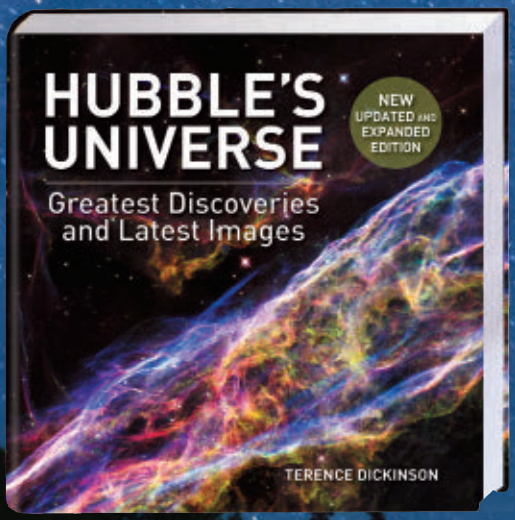

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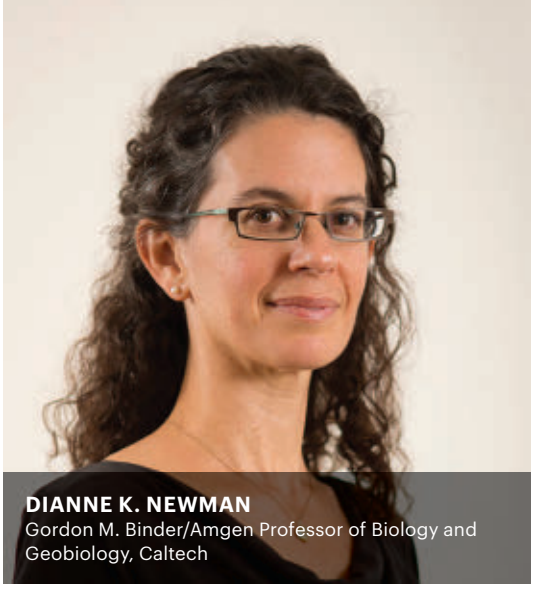

DIANNE K. NEWMAN
Gordon M. Binder/Amgen Professor of Biology and Geobiology, Caltech

Maya Ajmera, President & CEO of the Society for Science & the Public and Publisher of *Science News*, chatted with Dianne K. Newman, an alumna of the International Science and Engineering Fair and the Gordon M. Binder/Amgen Professor of Biology and Geobiology at Caltech. She is a MacArthur Fellow, Fellow of the American Academy of Microbiology and member of the National Academy of Sciences. We are thrilled to share an edited summary of their conversation.

You are an alumna of the 1987 and 1988 International Science and Engineering Fair (ISEF). How did the competition impact your life?

ISEF was by far the most memorable thing I did in high school. ISEF 1987 was the highlight because it was held in Puerto Rico. I grew up in South America, so I really enjoyed going back to a Spanish-speaking place. Beyond the tourist value, I loved the experience of being taken seriously as a scientist at that very young age. It gave me confidence.

I also gained lifelong friendships with the two women who took me to ISEF: Nancy Aiello and Sally Wrenn, who were the directors of the Virginia State Science and Engineering Fair (VSSEF). More than anything, the encouragement they gave me during that fair, and ever since, has been the most important thing I took from ISEF.

That particular year at ISEF, I won a second-place award in physics, which was shocking. I didn't expect to win anything. The most important memory I have is of my father, who joined me at VSSEF. I'll never forget the look of joy and pride in his eyes as I was explaining my project during the final round of judging. It's one of my most cherished memories.

My love for scientific research was enabled by my parents, neither of whom were scientists, and my confidence in my scientific abilities was reinforced by participating in science fairs. It motivated me to pursue science and engineering in graduate school.

You originally entered an environmental engineering program at MIT but then moved to microbiology. What prompted the change?

Serendipity. During my first semester at MIT, I took a course in environmental microbiology where I wrote a research paper about the degradation of perchloroethylene, a solvent that was contaminating groundwater. Through this assignment, I learned that microbes could eat toxic molecules and oxidize them to CO_2. I thought bioremediation was remarkable and totally fascinating. When I realized that microbes are quite literally the best chemists on Earth, I was captivated and wanted to know more.

Your lab looks at the coevolution of life and Earth. Tell me more about what you're working on right now.

I am fascinated by how microbes thrive under conditions where oxygen is scarce and they are growing slowly. For almost two decades, we've been researching a versatile class of metabolites called phenazines, which are redox-active pigments made by diverse bacteria. Phenazines are fun to play with in the lab because they are so colorful, but they also have many important physiological and ecological functions. They can be both lifelines, sustaining cells' viability under anoxic conditions, or agents of chemical warfare, serving as natural antibiotics. Which effect they have depends on the organism and its environment. Bacteria that make phenazines hail from the soil, yet can become important human opportunistic pathogens.

Accordingly, we strive to take what we learn in the laboratory about phenazine biology and see how relevant it is in the context of crop rhizospheres, the zone of the soil in the vicinity of plant roots, and human chronic infections. Trying to understand how phenazines affect their producers and other organisms in their vicinity under conditions that are environmentally relevant is challenging, but offers the chance to gain new insights into what structures and sustains microbial communities and how these communities, in turn, affect the host—plants or humans. These insights help us think creatively about how to modulate such communities towards good ends, such as new strategies to control chronic infections that tolerate conventional antibiotics.

You received the MacArthur Fellowship in 2016. How has the fellowship impacted your career?

The fellowship provided tremendous encouragement to keep taking risks and trying to aim high. It further inspired me to think about creative ways that we could extend what we know in directions that are beneficial to society. Since receiving the award, I took a step back and asked where our work could have a greater impact. I concluded that one area is soil fertility and food security, and we are beginning to turn some of our research in that direction.

In 2019, you were inducted into the National Academy of Sciences—a year when a historic number of women were elected to the academy. In your opinion, what challenges are women facing today in science and engineering?

There's never been a better time to be a woman in science. There are many mechanisms in place to enable women to succeed, from greater efforts to recruit women to the workplace, to foundations that provide research support to women, to programs that allow for balancing career with family. In fact, an academic career is very compatible with raising a family. I like to spotlight that for young people because sometimes that message gets lost in conversations about work-life balance. It's difficult to imagine a career that provides more independence and flexibility than a life in academia.

In my direct experience, I feel I've been given every opportunity and even some advantages because I am a woman. That said, as I've advanced in my career, I've become more aware of the subtle ways that there is still bias in the workplace. In some departments, the culture of testosterone can still be felt in something as simple as how questions are asked in seminars. There have been a few moments where I felt that the way certain senior male colleagues were talking to me was impacted by my gender in a way that was not OK and was uncomfortable. I hope that those types of interactions fade out with time.

Dianne Newman, Carl Leonard, Nancy Aiello and Sally Wrenn pose at the airport on their way to ISEF in Puerto Rico.

What strategies are you employing around diversity, equity and inclusion?

All my life I have been invested in diversity, equity and inclusion. I volunteered in various communities where I was doing my studies to encourage young people of color and help them get into STEM. As a faculty member, I made a point to recruit women, minorities and international students to my lab. In fact, when I started, more Spanish was spoken in my lab than English. Attracting the greatest pool of talent to STEM is very important to me.

I am now working to start local partnerships with schools near Caltech that have a high proportion of first-generation and underrepresented minority students to develop teaching and mentoring relationships between our graduate students and the students at those institutions. We believe that the pool of talent is distributed uniformly across the population. In order for Caltech to continue to be one of the best schools for science and engineering in the world, it needs to look like our population.

We've been doing much better with regard to Latinx recruiting at the undergrad level. We're aspiring to do as well at the graduate, postdoctoral and faculty levels for all people of color. It takes time, but we are building a pipeline in a very sincere way. I'm optimistic and think we're going to get there.

What advice do you have for young people? Do you have any words of wisdom?

Be true to yourself and what excites you. Don't be afraid of failing. If you are genuinely interested in something, go for it. Don't let getting one bad grade deter you. Recognize that you're playing the long game, and that you can excel in something long-term even if you need a little bit of a stepping stone in the short term.

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

I worry that our society is too focused on individualism and individual rights, before the collective good. That is something that is very troubling, and we must change our mind-sets if we're going to address the myriad challenges in the century ahead. I think that climate change is the existential challenge of our time. It's the type of thing that must be handled in a collective way, internationally, globally. And so the worry is, are we going to be able to pull that off? I don't know.

OCTOBER 10, 2020 & OCTOBER 24, 2020

Venusian recollection

Phosphine gas detected in the clouds of Venus could be a sign of life or some strange unknown chemistry, ***Lisa Grossman*** *reported in "Possible sign of life is found on Venus"* (SN: 10/10/20 & 10/24/20, p. 6).

The story brought back memories for reader **Bruce Hapke**, a professor of planetary science at the University of Pittsburgh.

"In 1975, my colleague Robert M. Nelson and I published the first high-quality, broadband spectrum of the clouds of Venus ... which we obtained using the 106-inch telescope at McDonald Observatory in Texas," **Hapke** wrote. "This spectrum turned out to be identical to that of a form of elemental sulfur, and we suggested that tiny particles of sulfur in the clouds are responsible for their yellowish color. The sulfur comes from volcanic eruptions."

By then, "Russia had launched several unmanned spacecraft that had successfully landed on the surface of Venus. In the paper, we pointed out that these spacecraft had not been sterilized and probably were badly contaminated with microscopic, single-cell forms of life, which the landers would then shed as they parachuted down through the clouds," **Hapke** wrote. "We also pointed out that many types of microbes are extremely hardy and can readily survive the vacuum of space by going dormant until they are in a hospitable environment. Many can live in sulfuric acid. On Earth they are found in acid drainage from coal mines. Many are anaerobic and do not require oxygen. Instead they generate energy for their metabolism by chemically changing ... sulfur that they ingest. Essentially, they survive by eating sulfur," he wrote. "If life does exist in the Venus clouds, it is highly likely to consist of immigrants from Earth."

Other research groups have been questioning the phosphine detection (*SN: 11/21/20, p. 16*). "Based on reanalyses of the data, one of those groups suggests the phosphine signal actually was sulfur dioxide. That would mean there's no reason to get excited about possible life signs — at least not yet," **Grossman** says. The theory that microbes can travel from planet to planet, either by hitching a ride on spacecraft or by some other means, is gaining traction among some scientists. Recent evidence suggests some Earth microbes are hardy enough to make such journeys (*SN: 9/26/20, p. 10*).

Cosmic connections

Magnetized corpses of stars could be a source of fast radio bursts and high-energy neutrinos, ***Lisa Grossman*** *reported in "Magnetars could solve dual mystery"* (SN: 10/10/20 & 10/24/20, p. 8).

Reader **James Ash** wondered how neutrinos interact with another mysterious phenomenon: high-energy cosmic rays.

Neutrinos are nearly massless subatomic particles with no electric charge. That means they rarely interact with normal matter, including cosmic rays — a type of charged particle with mass, **Grossman** says. But the two are connected, produced in tandem by energetic celestial objects. Similar to how magnetars might produce both fast radio bursts and high-energy neutrinos, evidence suggests bright galaxies called blazars eject both high-energy cosmic rays and high-energy neutrinos (*SN: 8/4/18, p. 6*).

Editor's note

On October 29, *Scientific Reports* retracted the study described in "Mouthbrooder lives in the deep" (*SN: 4/11/20, p. 12*) at the researchers' request. Eggs found in the mouth of a deep-sea fish species, *Parazen pacificus*, belonged to a species of crab — not the fish, a reanalysis of the eggs confirmed. Though *P. pacificus* appears to possess traits that suggest it could house fertilized eggs and perhaps hatchlings in the mouth, "the original data is not sufficient to confirm that this species is a mouthbrooder," ichthyologist Randy Singer of the University of Michigan in Ann Arbor and colleagues wrote in the retraction.

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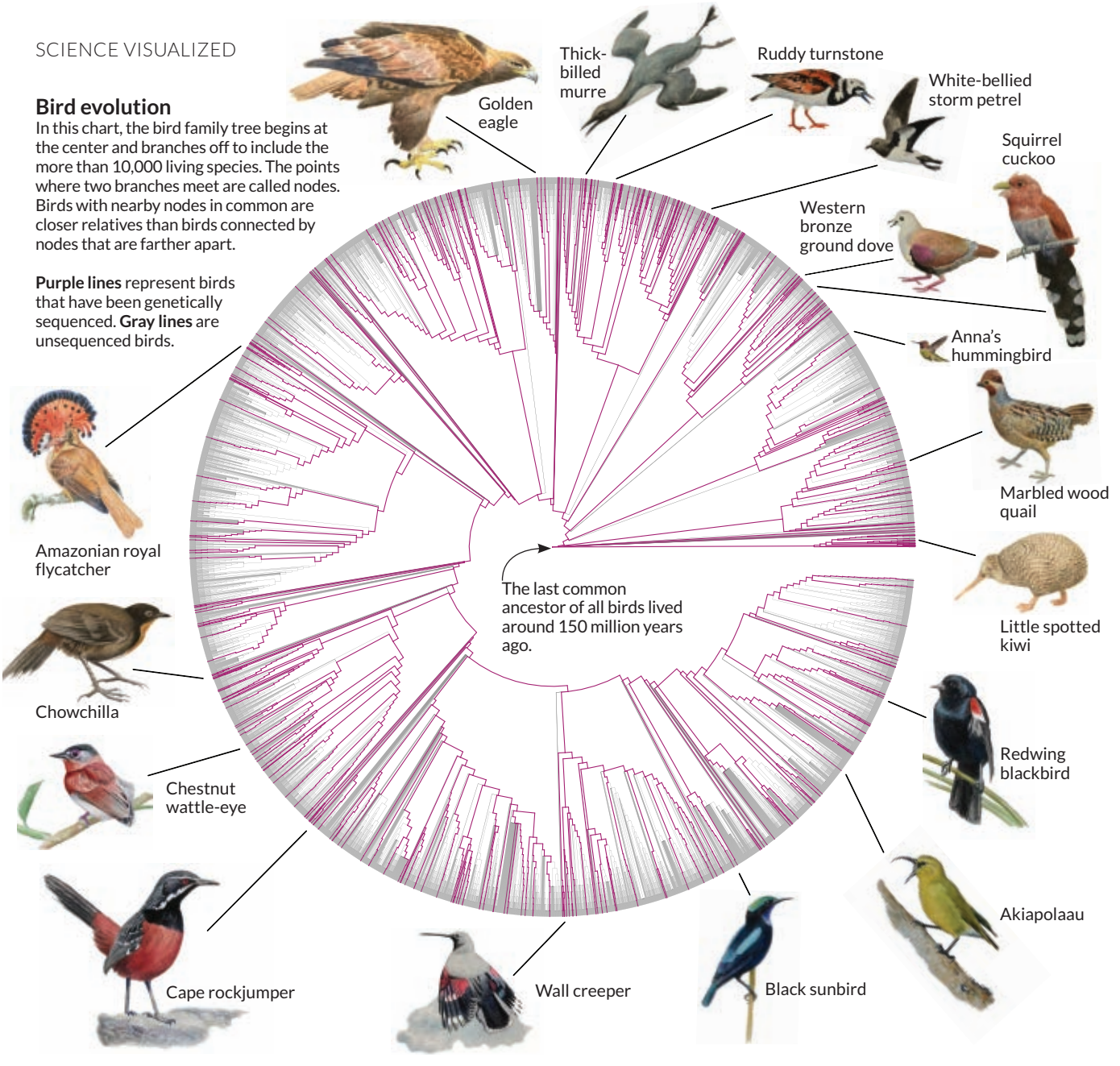


Filling in the bird tree of life

From gulls to grouse to grackles, more than 10,000 species of birds live on the planet. Now, scientists are closer than ever to understanding the evolution of all this feathered diversity.

An international team of researchers has released the genetic instruction books of 363 bird species, including 267 genomes assembled for the first time. Marking which birds have deciphered genomes on the avian tree of life (shown, with selected sequenced species illustrated) reveals that birds from nearly every major branch are now included.

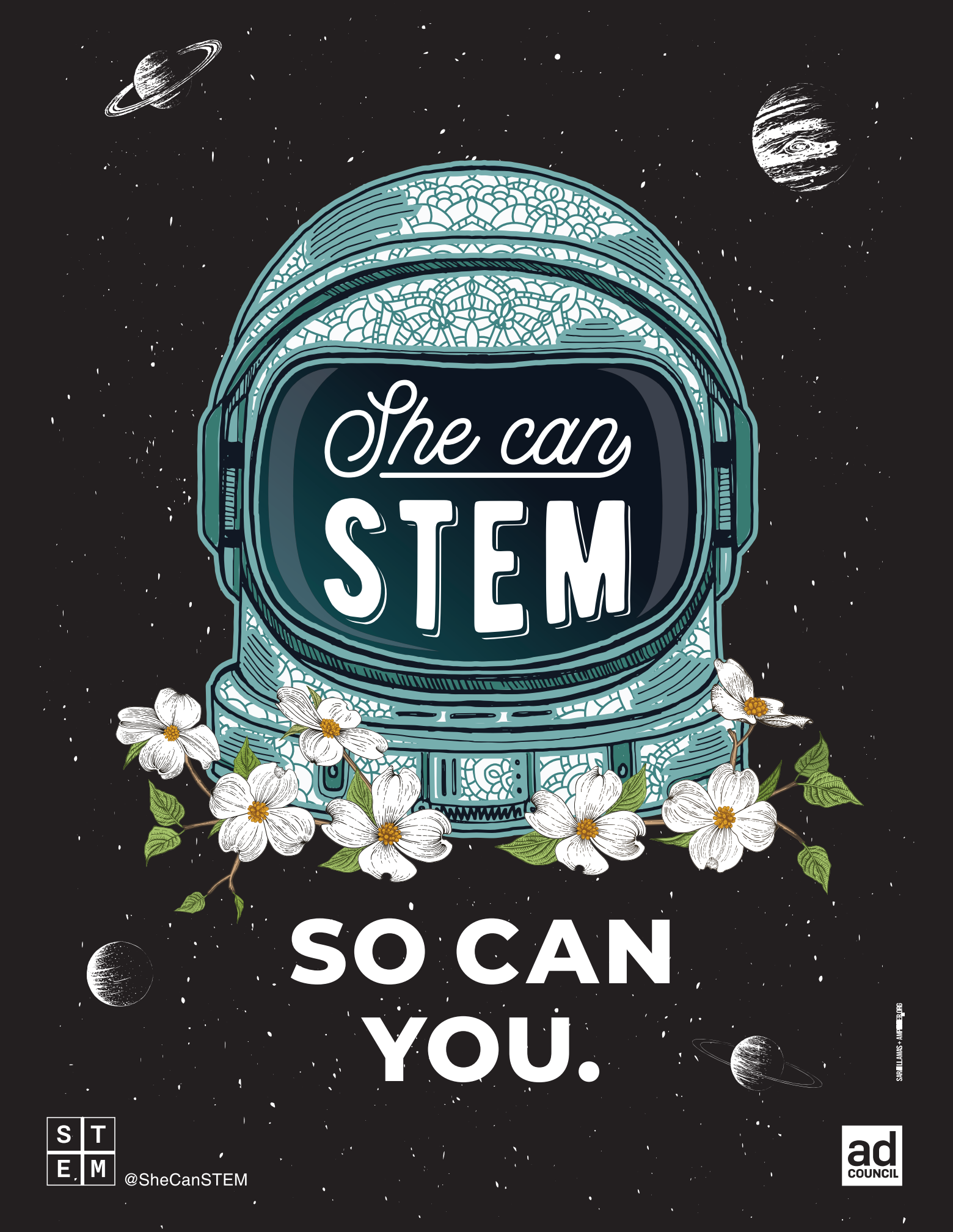
Comparing that genetic data can help scientists figure out how the varied traits of birds — from their diverse, spellbinding songs and courtship displays to their adaptations for flight — have evolved, the team says in the Nov. 12 *Nature*.

To compile some of the newly assembled genomes, the team took DNA from bird tissue samples in 17 scientific collections. Overall, the data cover roughly 92 percent of all modern bird families. Some species, such as chickens, are familiar; others are rare, such as the Henderson crake (*Zapornia atra*), found only on remote Henderson Island in the South Pacific.

Scientists are just starting to uncover the secrets of avian evolution hidden in the genomes. In the future, the data could be used to better understand everything from the parallel evolution of flightlessness in ratites like emus and kiwis to the evolution of song learning in birds overall.

The new information is the latest from the Bird 10,000 Genomes Project, but it won't be the last. The international collaboration doesn't plan to stop releasing avian genomes until every last bird species is included. — *Jake Buehler*

VISUALIZATION: S. FENG *ET AL*/*NATURE* 2020; ILLUSTRATIONS: JON FJELDSÅ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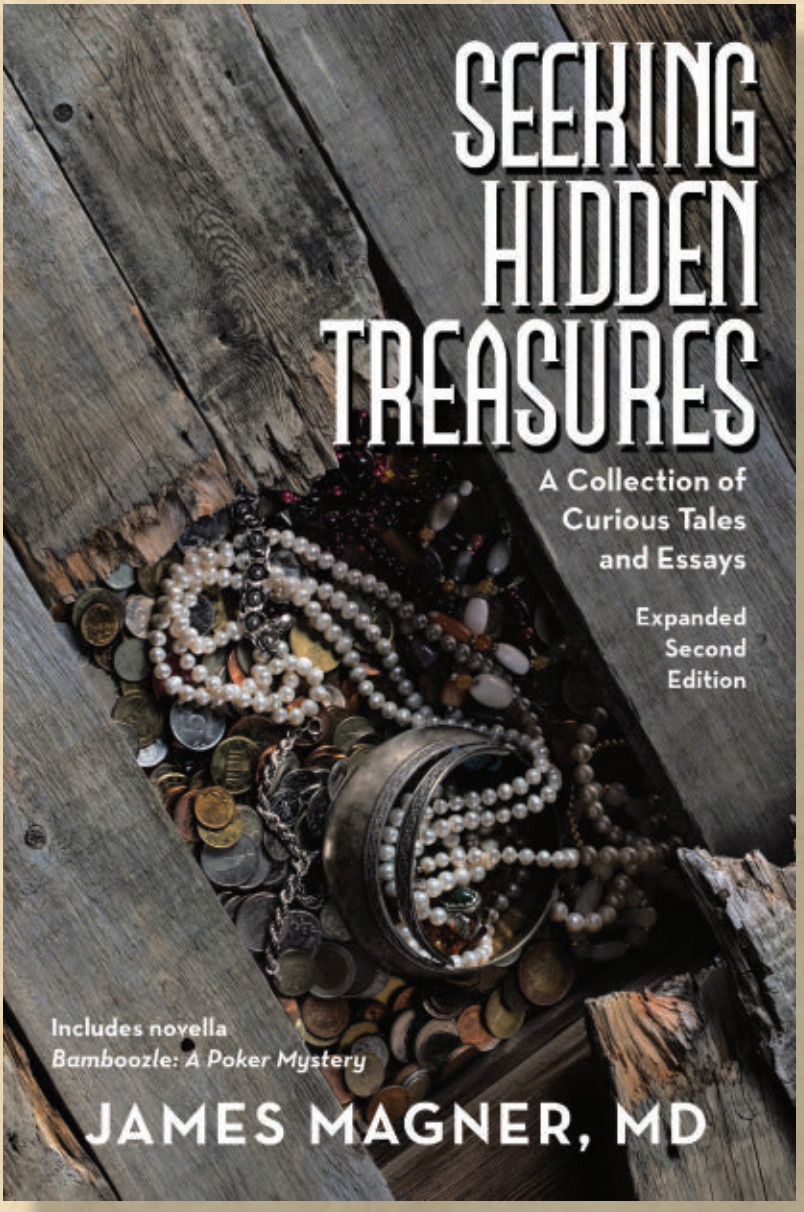

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