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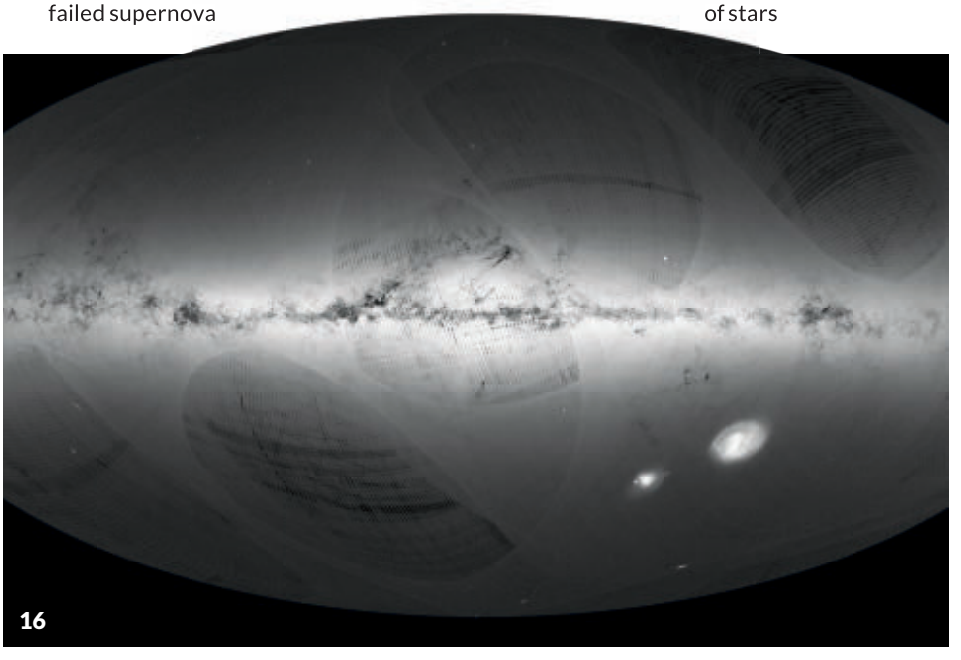
Features

News



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Departments

SOCIETY UPDATE
Science News for Students features women in STEM

COVER Ultraviolet lights make minerals glow at New Jersey's Sterling Hill Mine, one of 14 spots that may hide new carbon minerals. © *Kenneth Carroll*

CLOCKWISE FROM TOP: JAMES CAREY; MATTHIEU PAQUET; DPAC/GAIA/ESA

Sometimes failure is the springboard to success

Some discoveries originate in failures. Lab failures, of course, can lead to serendipitous findings. Observations that fail to meet your expectations create space for a new idea to take hold. Imperfections — small failures — may tell volumes about how something was made or what it is made of. Exposing flaws in a theory inches scientists closer to a better one. Failure forces us to ask hard questions and look for new answers.

Our cover story follows the aftermath of a recent acknowledgment of a major fail: We haven't yet taken a complete census of all minerals on Earth. Akin to the search to name all living species on the planet (but less of a moving target), a campaign is under way to add to the more than 5,000 known minerals, freelancer Sid Perkins writes on Page 18. It's a kind of treasure hunt, as these minerals presumably have not yet been found because they are incredibly rare, perhaps existing at only a single location. Especially interesting to rock hounds are the scores of as yet unseen carbon-based minerals predicted to exist by a recent statistical analysis. Hidden in these unexplored gems might lie untold stories about how Earth's carbon and water cycles have changed over the eons. Just as adding a new bird species to a life list is exciting for bird watchers, finding a new kind of mineral is what many rock hounds aspire to.

Another kind of failure may explain a mysterious missing star, Christopher Crockett reports (Page 8). A giant star, 25 to 30 times as massive as the sun, flared and then fizzled in 2009. Scientists now say it might be a failed supernova, a dying star that didn't have quite the right stuff to explode and instead went from star straight to black hole. If the star is not just hiding somewhere in the dust, it's a new cosmic character, a new type of behavior to watch for.

Imperfections in humans' DNA help make each of us unique. These imperfections, viewed at a population scale, also offer a way (still imperfect in itself) to track ancestry, to get some idea of how human populations moved, mingled and changed in the deep past. In a story on Page 22, Bruce Bower describes how recent DNA studies of ancient hominids are changing views of human evolutionary history. Early humans, the data show, mated with Neandertals and possibly other hominids, producing viable hybrid offspring. The research gives support to a longtime contention by some paleoanthropologists that certain ancient skeletons might represent human-Neandertal mixes. Further evidence for this point of view is now coming from studies of hybrid baboons and other modern species. Mixing species, it seems, was sometimes a success.

Examining the DNA of wide swaths of living people is also revising ideas about when early humans migrated out of Africa to settle the rest of the globe. Three new studies, described by Tina Hesman Saey on Page 6, suggest that the major ancestral mass migration from Africa occurred between 50,000 and 75,000 years ago. Those migrants succeeded in leaving their genetic mark on all of today's non-Africans. Other evidence points to earlier, smaller migrations from Africa. Perhaps those were failures in a sense, failing to seed lasting populations in far-off outposts. But, perhaps those earlier, smaller scale treks were just the first steps toward success. — *Eva Emerson, Editor in Chief*

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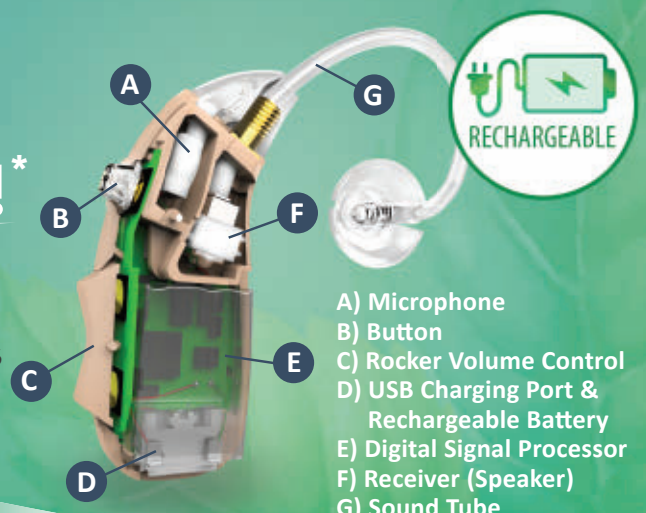

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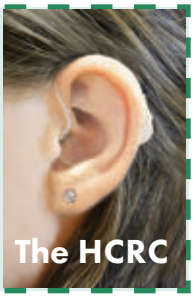

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Excerpt from the October 15, 1966 issue of *Science News*

50 YEARS AGO

Noise menace threatens man

Noise, forever bombarding urban and suburban man, is becoming an increasing menace to his psychological and physical well-being. Little cars with oversized engines, enormous trucks, sirens, construction projects and jet planes are exacting high prices in frazzled nerves, fatigue and poor hearing.

UPDATE: Concerns about sounds in urban settings may have fallen on deaf ears: Noise levels have increased. In 1966, *Science News* reported that the "acceptable" noise level for a restaurant was about 55 decibels — the intensity of an easy conversation. Modern establishments routinely inflict between 68 and 82 decibels on patrons and staff, a 2014 study found. The cacophony from sidewalks, subway cars and earbuds may be taking a toll. In 2014, 17 percent of adults complained of trouble hearing, according to the National Health Interview Survey. Of those, 25 percent blamed long-term noise exposure. A good rule of thumb: If other people can hear the music coming out of your headphones, turn down the volume.

IT'S ALIVE

Extreme bird nests bring comforts, catastrophe

That heap of hay in a tree is not a typical animal commune. Huge group nests of sociable weaver birds across southern Africa are about as close as nature gets to building condos.

Ant nests, beaver lodges and many other marvels of animal architecture enclose shared space. But small, sparrowlike *Philetairus socius* push together beakful after beakful of grass to create a haystack of apartments. The nests can grow to weigh a ton and last about a century. Tunnels opening from the shaggy underside lead to each family's unit. For better and worse, a weaver bird nest "in practice is like a block of flats," says evolutionary biologist Rita Covas of CIBIO Research Center at the University of Portugal.

The condos have great insulation, an important perk for birds that don't migrate from the hot-then-cold Kalahari. In summer, Covas can feel shady relief when she reaches up into a nest. In winter, condos are heated by snuggle power. The thatch keeps a chamber with a lone bird at about 12° Celsius. An apartment crowded with five birds reaches a toasty 33° C, Covas and colleagues reported in June in the *Journal of Avian Biology*.

Like most weaver bird homes, the underside of this nest is covered with dark holes — entrances to tunnels that lead to each family's private unit.

An apartment can fill up as a few young birds linger for a gap year before venturing away. The stay-at-homes pitch in to hunt food for the newest nestlings. The help lets parents ease off a bit in foraging, though oddly enough, mom's life lengthens when her offspring stay close while dad's tends to shorten. Why is still a puzzle.

Even with help, raising chicks is chancy when a nest offers a feast for marauders. "Those poor birds," Covas says. "Snakes climb the trees to get into the colony and then they inspect every single chamber — they're very thorough." Adult weavers will mob loudly and frantically, but a cape cobra or boomslang ignores them, bingeing on eggs and chicks by the dozen.

Black-chinned *Philetairus socius* birds cooperate to keep a roof over and a floor under a multifamily colony.

The birds can cause trouble for each other, too. "There are lots of chases," Covas says. Outright murder is rare, but during food shortages, a neighbor on occasion pushes into the chamber next door and kills the chicks for causes still unknown. "Reducing competition?" Covas speculates. "Spite?"

— *Susan Milius*

FROM TOP: PETROVA MARIA/SHUTTERSTOCK; MATTHIEU PAQUET

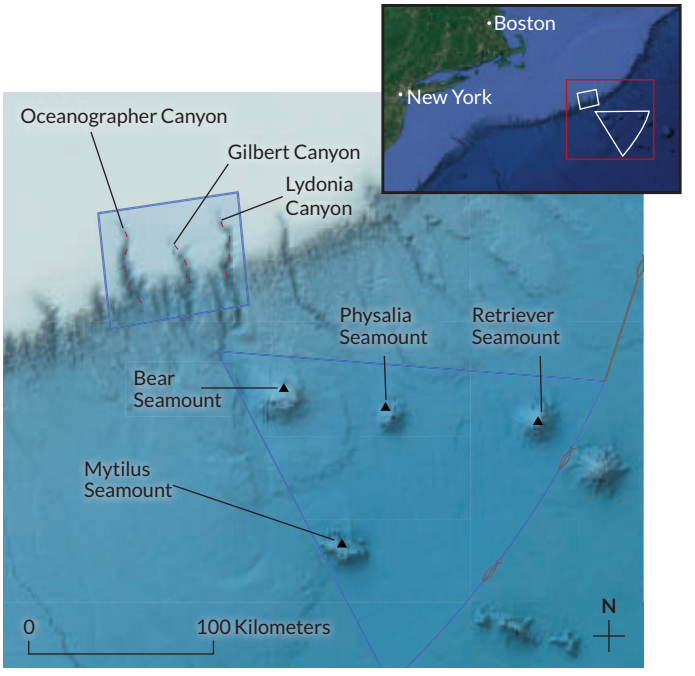
FIRST

Atlantic ocean gets its first U.S. national monument

Two stretches of ocean about 210 kilometers southeast of Cape Cod have become the Atlantic Ocean's first U.S. marine national monument.

The 12,725-square-kilometer area is called the Northeast Canyons and Seamounts Marine National Monument. The new designation is intended to help protect the region's fragile deep-sea ecosystem, which includes whales, sea turtles and corals, by gradually phasing out commercial fishing, including for crab and lobster.

"In these waters, the Atlantic Ocean meets the continental shelf in a region of great abundance and diversity as well as stark geological relief," President Barack Obama said at the September 15 announcement. The new monument includes underwater canyons deeper than the Grand Canyon and submerged extinct volcanoes called seamounts. Expeditions in 2013 and 2014 by the research vessel *Okeanos Explorer* uncovered species of starfish and deep-sea corals thought to have never been seen before. — *Thomas Sumner*



Marine majesty The new Northeast Canyons and Seamounts Marine National Monument (outlined) will help protect marine life around the monument's massive canyons and mountains. SOURCE: NOAA

INTRODUCING

Pterosaurs weren't all super-sized

Pterosaurs didn't have to be gargantuan to survive in the Late Cretaceous.

Fragmentary fossils of a roughly 77-million-year-old pterosaur found in British Columbia suggest it had a wingspan of just 1.5 meters, close to that of a bald eagle. The ancient flier is the smallest pterosaur discovered during this time period — by a lot, paleontologist Elizabeth Martin-Silverstone of the University of Southampton in England and colleagues report in the August *Royal Society Open Science*.

Some 77 million years ago, little pterosaurs (illustrated here) shared the sky with gigantic ones, according to new fossils of a small flying reptile found in British Columbia.

Many larger pterosaurs, some with wings spanning more than 10 meters (nearly the length of a school bus), have been unearthed. But until now, scientists had found only two small-scale versions, with wingspans 2.5 to 3 meters long, from the epoch stretching from 100 million to 66 million years ago.

Some scientists blamed competition with birds for the scarcity of little flying reptiles. Researchers have proposed that "the only way pterosaurs could survive was by evolving completely crazy massive sizes," Martin-Silverstone says.

The new find, she says, may mean that "pterosaurs were doing better than we thought." — *Meghan Rosen*

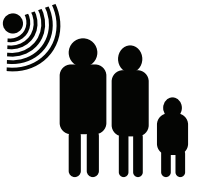
FOR DAILY USE

Wi-Fi helps house distinguish between occupants

In smart homes of the future, computers may identify inhabitants and cater to their needs using a tool already at hand: Wi-Fi. Human bodies partially block the radio waves that carry the wireless signal between router and computer. Differences in shape, size and even gait among household members yield different patterns in the received Wi-Fi signals. A computer can analyze the signals to distinguish dad from mom, according to a report posted online August 11 at arXiv.org.

Scientists built an algorithm that was nearly 95 percent accurate at distinguishing two adults walking one at a time between a wireless router and a computer. For six people, accuracy fell to about 89 percent. Scientists tested the setup on men and women of various sizes, but it should work with children as well, says study coauthor Bin Guo of Northwestern Polytechnical University in Xi'an, China.

In a home rigged with Wi-Fi and a receiver, the system could eventually identify family members and tailor heating and lighting to their preferences — maybe even cue up a favorite playlist. — *Emily Conover*



CLOCKWISE FROM TOP: GOOGLE EARTH PRO; T. TIBBITTS; MARK WITTON

See the wildlife in the new Atlantic monument at **bit.ly/SN_marinemonument**

HUMANS & SOCIETY

One Africa exodus populated globe

DNA data point to migration less than 75,000 years ago

BY TINA HESMAN SAEY

One wave of ancient human migrants out of Africa gave rise to all non-Africans alive today, three new genetic studies conclude.

Those human explorers left Africa 50,000 to 75,000 years ago, mixed with Neandertals and spread across the world, researchers report online September 21 in *Nature*. The studies, using data from genetically diverse and previously unrepresented populations, offer details of deep human history and add fuel to long-standing debates.

All non-Africans stem from one major founding population, the studies agree. But earlier migrations are recorded in some present-day people's DNA, one study finds. A fourth study (also in *Nature*), focusing on ancient climate, also makes the case for an earlier exodus.

Scientists have long debated when modern humans first trekked out of Africa and how many waves of migration there were. Archaeological evidence suggests modern humans were in Asia by at least 80,000 years ago. Human DNA in a Neandertal woman from Siberia suggests humans interbred with Neandertals outside Africa as long as 110,000 years ago (*SN: 3/19/16, p. 6*). But those people died out and didn't contribute much, if any, DNA to later generations, says evolutionary geneticist Swapan Mallick of Harvard Medical School, coauthor of a paper that traced the genetic history of 300 people from 142 populations around the world. Ancestors of today's non-Africans probably left Africa about 50,000 years ago, Mallick and colleagues calculate.

Another study describes remnants of a much earlier exodus from Africa in the genomes of present-day Papuans. Biological anthropologist Luca Pagani of the Estonian Biocentre in Tartu and colleagues report that at least 2 percent of the Papuan genome can be traced to small bands of humans who left Africa 120,000 years ago. "This expansion was successful in leaving descendants today," Pagani says. But a massive wave of migrants who left Africa after about 75,000 years ago probably overwhelmed that small trickle, swamping out their genetic signature, the team's data show.

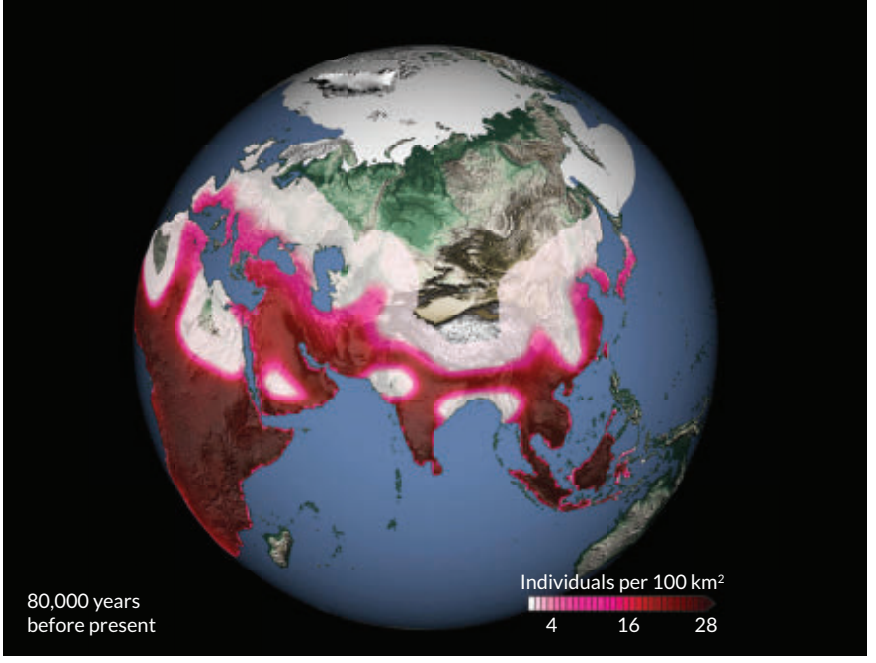
A third study, focusing on the genetic history of aboriginal Australians and Papuans from the New Guinea highlands, didn't find traces of a 120,000-year-old migration, but didn't rule it out either, says study coauthor Eske Willerslev, an evolutionary geneticist at the University of Copenhagen.

Previous studies have suggested that ancestors of Australians and Papuans came from an early wave of migration. "Australians and Papuans are descendants of some of the earliest modern human explorers," Willerslev says. His group's evidence suggests a single wave of migrants left Africa about 72,000 years ago and settled initially in the Middle East. Ancestors of Europeans and Asians stayed put for thousands of years before splitting into different groups. But Australian and Papuan ancestors kept going. "These guys were heading off on this marvelous journey across Asia," ending up in Australia and Papua New Guinea about 50,000 years ago, Willerslev says.

Mallick and colleagues also found evidence of a main wave of migration into the Middle East that split into two groups after breeding with Neandertals. Those groups took different routes. One ended up in Europe, the other populated Asia. Instead of Australians and Papuans sprinting ahead independently of everyone else, they moved with the ancestors of East Asians and continued to the islands only later, the researchers say.

Pagani and colleagues' analysis method picks out older chunks of DNA, says evolutionary geneticist Mattias Jakobsson of Uppsala University in Sweden. That method revealed evidence of the older migration that the other studies couldn't. But genetic dating methods are imperfect; they can differ because of inaccurate mutation rates, skewed sampling, biased analyses or other reasons.

Even though Pagani's study results seem to disagree with the other two, "it's a superficial disagreement," says evolutionary geneticist Joshua Akey of the University of Washington in Seattle. "One group is saying 98 percent" of DNA came from the main wave of migration, "while the



Earth wobbles on its axis, causing major climate shifts. Some of those shifts turned the Arabian Peninsula into lush grassland that ancient humans could have traversed as they migrated out of Africa. Researchers simulated climate conditions over the last 125,000 years and predicted how those changes would have allowed humans to spread around the globe (increasing intensity of red shows greater predicted population density on this topographic map).

T. FRIEDRICH

See a simulation of human migration out of Africa at **bit.ly/SN_migration**

other groups say it's 100 percent.... The main conclusion is that the vast majority of ancestry in non-Africans can be traced to a single out-of-Africa dispersal."

A study of ancient climates suggests the departure window geneticists propose was the worst time to leave Africa. "Every 20,000 years or so, Earth's axis wobbles caused massive shifts in climate and vegetation," says Axel Timmermann, a climate scientist at the University of Hawaii at Manoa. Those fluctuations opened green corridors across northern Africa and the Arabian Peninsula, then turned those areas to deserts.

Computer simulations of climate and sea level over the last 125,000 years by Timmermann and Hawaii colleague Tobias Friedrich show when and where humans might have easily moved. A mass human migration out of Africa 60,000 to 70,000 years ago "is the most unlikely scenario from a climate point of view," Timmermann says. "Northeastern Africa was completely dry. It was one of the worst drought periods in the entire history, so the corridor was closed."

The researchers found conditions were favorable for migration from Africa to the Arabian Peninsula between 107,000 and 95,000 years ago and again 90,000 to 75,000 years ago. (Another window didn't open until 59,000 years ago, after humans were probably already in Australia.) That ease of travel would have allowed people to mate and move freely out of and back into Africa. Back-and-forth mating would make the Africans and non-Africans genetically indistinguishable, obscuring the real date at which people left Africa, Timmermann speculates. Allowing for cross-continent mingling puts people's exodus from Africa at about 80,000 to 100,000 years ago, he says.

The climate study reinforces the idea that people spread out of Africa sooner than the new genetic evidence indicates, says archaeologist Michael Petraglia of the Max Planck Institute for the Science of Human History in Jena, Germany. He is a coauthor of the Pagani study, but says genetics alone won't end the debates over when people left Africa and who they interbred with as they spread. ■

BODY & BRAIN

Sugar industry shifted health focus

Payments to authors influenced 1967 report indicting fat

BY LAURA BEIL

Records unearthed from library storage vaults reveal that, in the 1960s, the sugar industry paid Harvard University nutrition experts to downplay studies linking sugar to heart disease, helping to redirect the scientific narrative for decades.

The documents — which include correspondence, symposium programs and annual reports — show that the Sugar Research Foundation (its name at the time) paid professors who wrote a two-part review in 1967 in the *New England Journal of Medicine*. That report was highly skeptical of the evidence linking sugar to cardiovascular problems but accepting of the role of fat. The now-deceased professors' overall conclusion left "no doubt" that reducing the risk of heart disease was a matter of reducing saturated fat and cholesterol, according to researchers from the University of California, San Francisco, who published their report online September 12 in *JAMA Internal Medicine*.

"Why does it matter today? The sugar industry helped deflect the way the research was developing," says study coauthor Cristin Kearns, a dentist at UCSF's Institute for Health Policy Studies. The Harvard team's scientific favoritism helped direct research and policy attention toward fat and cholesterol. The first dietary guidelines published by the federal government in 1980 said there was no convincing evidence that sugar causes heart disease, stating "the major health hazard from too much sugar is tooth decay."

Following the Harvard report, fat and cholesterol controlled the scientific agenda for decades, leading to a craze of low-fat foods that often added sugar. Kearns points out that it was only in 2015 that dietary guidelines finally made a strong statement to limit sugar. Researchers writing this year in *Progress in Cardiovascular Diseases* note that current studies estimate that diets high in added sugars carry a three times higher risk of death from cardiovascular disease. (The Sugar Association says on its website that "the last several decades of research have concluded that sugar does not have a unique role in heart disease.")

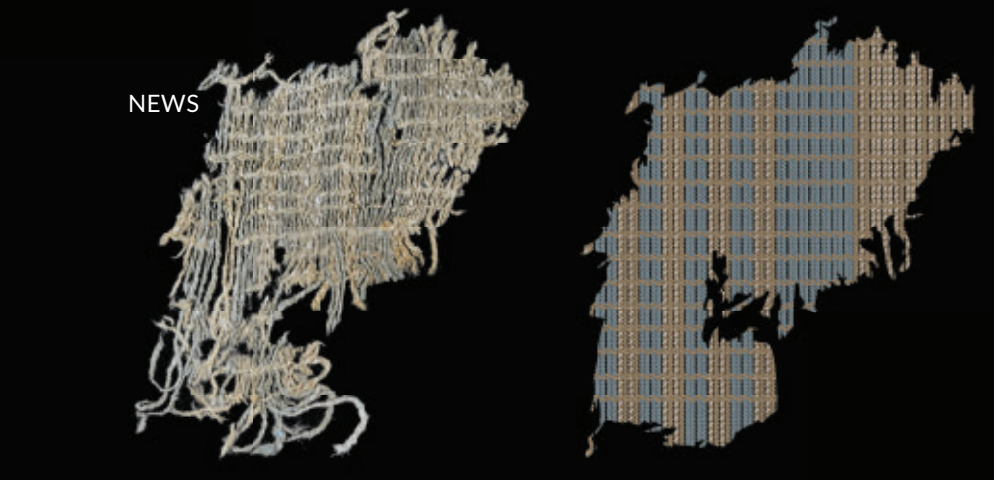
The Sugar Association also acknowledged the secret deal, but noted that "when the studies in question were published, funding disclosures and transparency standards were not the norm they are today." Journals now require all authors to list conflicts of interest, especially funding from a source that has a vested interest in the outcome.

That doesn't mean that industry groups no longer have an influence, says Andy Bellatti, strategic director of Dietitians for Professional Integrity. But the influences may be more subtle, he says. "We're not talking about making up data, but perhaps influencing how a research question is framed."

In a commentary published with the new study, Marion Nestle, a nutrition researcher at New York University, cited recent *New York Times* investigations of Coca-Cola–sponsored research and Associated Press stories revealing that a candy trade group sponsored research attempting to show that children who eat sweets have a healthy body weight.

Bellatti says that researchers sometimes turn to commercial sources because "there is such little public funding for nutrition and disease" research.

For that reason, scientists should not reject industry money wholesale, says John Sievenpiper, a physician and nutrition researcher at the University of Toronto. A study of his was once ridiculed on Nestle's blog because the disclosures covered two pages. He says that any scientist who takes industry money should adhere to a higher standard of openness, including releasing protocols ahead of time so reviewers can make sure the research question was not changed midstream to favor a certain conclusion. ■



A roughly 6,000-year-old patch of woven cotton (left) found in Peru is the oldest known evidence of the use of indigo blue. Diagram at right denotes parts of the material dyed blue.

HUMANS & SOCIETY

Oldest indigo-dyed fabric found

Ancient Peruvians used blue hue 6,000 years ago

BY BRUCE BOWER

Ancient South Americans made blue fabrics to dye for. A piece of approximately 6,000-year-old woven cotton material from Peru gets its blue hue from indigo dye, making it the oldest known example of the colorfast dye's use anywhere, researchers find.

Until now, the earliest indigo-dyed fabrics dated to around 4,400 years ago in Egypt and about 3,000 years ago in what's now China, say archaeologist Jeffrey Splitstoser of George Washington University in Washington, D.C., and colleagues. Chemical analyses of fabric unearthed at Huaca Prieta, an ancient site on Peru's northern coast, unveiled the presence of indigo dye roughly 1,600 years before this fabric coloring showed up in Egypt, the team reports September 14 in *Science Advances*.

Huaca Prieta was first excavated in the 1940s. Radiocarbon dating of charcoal from hearths and other material indicates that people occupied Huaca Prieta from around 14,500 to 4,000 years ago. From roughly 7,600 to 4,000 years ago, residents built carefully designed layers of stone dwellings, plazas, burial chambers and other structures that now form a huge stone and earthen mound.

Splitstoser's group identified indigo blue in 3-centimeter- to 5-centimeter-long yarn strands from five of eight woven, blue-striped cloth fragments excavated in 2009. One patch of material was found in sediment with an estimated age of 6,200 to 6,000 years. Other pieces dated to no more than around 4,100 years ago. It's not known what types of items these swatches came from.

The dye probably came from an indigo-producing plant native to South America, the team says. Other such plants grow in many parts of the world. Indigo blue has

ATOM & COSMOS

Lost star may be failed supernova

Despite no signs of explosion, black hole marks stellar grave

BY CHRISTOPHER CROCKETT

A star that mysteriously disappeared might be the first confirmed case of a failed supernova, a star that tried to explode but couldn't finish the job. A newborn black hole appears to have been left behind to snack on the star's remains.

In 2009, a star in the galaxy NGC 6946 flared up over several months to become over 1 million times as bright as the sun. Then it seemed to vanish. While the star could just be hiding behind a wall of dust, new observations with the Hubble Space Telescope, reported online September 6 at arXiv.org, strongly suggest that the star did not survive. A faint trickle of infrared light, however, emanates from where the star used to be. The remnant glow probably comes from debris falling onto a black hole that formed when the star died, write Caltech astronomer Scott Adams and colleagues.

Black holes are typically thought to form in the aftermath of a supernova, the explosive death of a massive star. But multiple lines of evidence have recently hinted that not all heavyweights go out with a bang. Some stars might skip the supernova and collapse into a black hole. Until now, though, evidence that this happens has been either spotty or indirect.

"This is the first really solid observational evidence for a failed supernova," says astronomer Elizabeth Lovegrove of the University of California, Santa Cruz.

This attempt at a supernova, first observed with the Large Binocular Telescope in Arizona, occurred about 19 million light-years away in the constellation Cygnus. Only one other known star — a yellow supergiant that faded away in 2010 — is suspected to be a failed supernova, though there's not enough data to say for certain.

When a star at least eight times as heavy as the sun runs out of thermonuclear fuel, it can no longer support its own weight. Gas crashes down on the star's core, bounces and sends a shock wave racing back toward the surface, tearing the star apart. Some stars might be so massive that the shock wave doesn't have enough oomph to push against the onrush of collapsing star stuff. The shock fizzles, the supernova fails and the core gathers enough mass to collapse into a black hole, possibly taking the rest of the star down with it.

If the dying star is a red supergiant — which can be over 1,000 times as wide as the sun — it might give a signal before vanishing. As the core collapses, it releases a lot of gravitational energy. A second shock wave ripples through the star — just powerful enough to burp off the loosely held outer layers of the super-

LAUREN A. BADAMS, J. SPLITSTOSER

also been produced from sea snails.

"What surprises me is that the indigo dye process was discovered at all and developed independently so early in multiple parts of the world," Splitstoser says.

Even now, indigo blue isn't easy to make, he says. The several-step process of extracting the dye from plants includes soaking and fermenting leaves to produce a colorless substance before stirring the mixture in the open air, which eventually yields the main blue-dye component.

It's hard to know precisely when and where people first used indigo blue. It wouldn't be surprising, Splitstoser says, if the earliest indigo blue–tinged textiles came from the Middle East, where some of the earliest civilizations emerged.

The new discovery joins other "firsts" at Huaca Prieta, says archaeologist Daniel Sandweiss of the University of Maine in Orono. For instance, the site hosted some of the Americas' earliest known farmers and corn cultivation. "This shows the value of multidisciplinary, long-term research at a single site by a large, well-funded team," Sandweiss says. ■

giant and expose the feeding black hole.

That's exactly what Adams and colleagues think they saw. Hubble images from before 2009 reveal a star about 25 to 30 times as massive as the sun sitting where the flash of light came from. The star doesn't show up in images taken since the eruption. Neither the brightness of the flash, the rate at which the brightness evolved nor the amount of light coming from there now fully matches other types of stellar incidents, such as collisions between a pair of stars.

If the star did give birth to a black hole, X-rays may be radiating from debris spiraling down its gravitational throat. Adams and collaborators are waiting on observations from the space-based Chandra X-ray Observatory to check that idea. They also continue to monitor what's left of the star. The star might still be there, hiding within a shell of dust expelled during the 2009 eruption. If that's the case, it should become visible again as the cloak dissipates. ■

AUDREY SNIDER-BELL/SHUTTERSTOCK

GENES & CELLS

Rattlesnakes have lost venom genes

Ancient common ancestor produced more types of toxins

BY LAUREL HAMERS

Modern rattlesnakes have pared down their weaponry stockpile from their ancestor's massive arsenal. Today's rattlers have lost entire toxin-producing genes over the course of evolution, narrowing the range of toxins in their venom, scientists report in the Sept. 26 *Current Biology*.

"After going through all the work of evolving powerful toxins over time, some snakes have dispensed with them," says Sean B. Carroll, a Howard Hughes Medical Institute investigator at the University of Wisconsin–Madison. These modern rattlesnakes produce smaller sets of toxins that might be more specialized to their prey.

Carroll, an evolutionary biologist, and his colleagues focused on a family of enzymes called phospholipase A2, or PLA2. Genes in the PLA2 family are one of the main sources of toxic proteins in rattlesnake venom. This set of genes can be shuffled around, added to and deleted from to yield different toxin collections.

Data from the genome — an organism's complete set of genetic material — can reveal how those genetic gymnastics have played out. Carroll's team looked at the relevant genome regions in three rattlesnake species (western diamondback, eastern diamondback and Mojave) and analyzed messenger RNA molecules that help turn genetic instructions into proteins. That showed how the genes were arranged and which genes the snakes were actually using. Then, the scientists blended that data with genetic information about closely related rattlesnakes to construct a potential evolutionary story for the loss of PLA2 genes in one group of rattlesnakes.

The most recent common ancestor of this group, which lived 22 million years ago, probably had a large suite of PLA2 genes, the scientists found. Those genes, which probably came about through gene duplications, coded for toxins affecting the nervous system, blood and muscles of prey. But 4 million to 7 million years ago, some species independently dropped different combinations of genes to get more specialized sets of toxins. For instance, three closely related rattlesnake species lost genes to make neurotoxic venom.

Environmental shifts might have encouraged this off-loading, Carroll says. If a certain species' main food source stopped responding to a neurotoxin, the snake would waste energy producing a protein that didn't do anything helpful.

Evolutionary biologist Todd Castoe points out that a rattlesnake doesn't just invest energy in producing venom. It also makes antibodies and other proteins to protect itself from its own poison, says Castoe, of the University of Texas at Arlington. As a snake's weapon becomes more complex, its shield does too — and that protection uses up resources.

Carroll's team also found that venom genes are not always consistent even within a single species, perhaps because snakes in different areas specialize in different prey. One western diamondback rattlesnake that was sampled had unexpected extra genes that other western diamondbacks didn't have. Carroll's lab is looking into these within-species differences to see how dynamic the PLA2 genome regions still are today. ■

Editor's note: Sean B. Carroll is on the board of trustees of Society for Science & the Public, which publishes Science News.

A loss of genes 4 million to 7 million years ago narrowed the range of toxins that some rattlesnakes use to attack prey.

GENES & CELLS

Color vision strategy defies textbooks

Cone cells fill in hues on black-and-white image, study suggests

BY TINA HESMAN SAEY

Color vision may actually work like a colorized version of a black-and-white movie, a new study suggests.

Cone cells, which can sense red, green or blue light, detect white more often than colors, researchers report September 14 in *Science Advances*. The textbook-rewriting discovery could change scientists' thinking about how color vision works.

For decades, researchers have known that three types of cells, or cones, in the retina are responsible for color vision. Those cones were thought to send "red," "green" and "blue" signals to the brain. The brain supposedly combines the colors, much the way a color printer does, to create a rainbow-hued picture of the world (including black and white). But the new findings indicate that "the retina is doing more of the work, and it's doing it in a more simpleminded way," says Jay Neitz, a color vision scientist at the University of Washington in Seattle who was not involved in the study.

Red and green cones each come in two types: One type signals "white" and another signals color, vision researcher Ramkumar Sabesan and colleagues at the University of California, Berkeley discovered. (The team didn't test blue cones.) A large number of cones detect white (and black—the absence of white) and create a high-resolution black-and-white picture of a person's surroundings, picking out edges and fine details. The rest of the red and green cones signal to the brain low-resolution color information. The process works much like filling in a coloring book or adding color to black-and-white film, says Sabesan, who is now at the University of Washington.

> The process works much like filling in a coloring book or adding color to black-and-white film.

Sabesan and colleagues discerned this color vision strategy by stimulating 273 individual cones in the eyes of two men. The technological accomplishment of stimulating single cones in the retina is akin to getting people to walk on the moon, Neitz says. "It is a super technological achievement. It is an amazing thing."

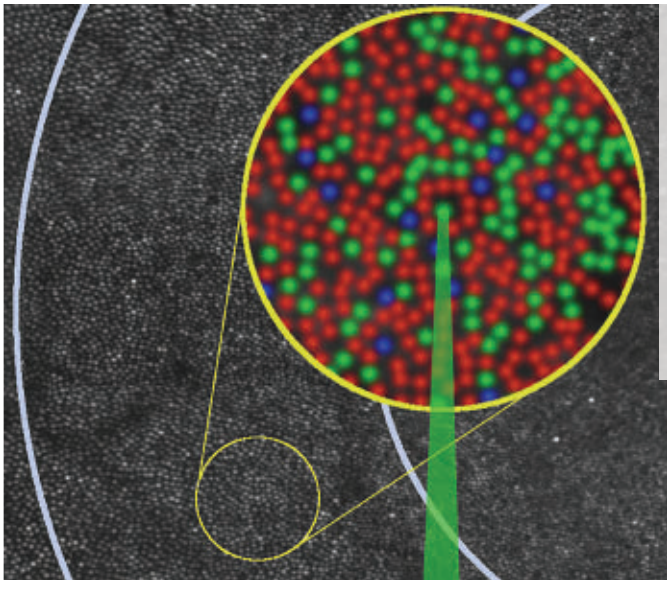
Sabesan's team first used a microscope that could peer into living human eyes to map light-detecting cones in the two volunteers. To get a clear picture of the cells through the distortion of the lens and cornea, the researchers borrowed techniques that astronomers use to compensate for disturbances in the atmosphere.

With the blur from imperfections in the eye corrected, the researchers had to precisely target individual cells to hit with the laser. Because the eye is constantly jiggling, the researchers had to determine the pattern of the eye movements to predict where cone cells would be several milliseconds in the future. Over about two years, the researchers repeatedly stimulated 273 red or green cones one by one. After a flash of laser light was delivered to the cone, the men would indicate on a keyboard what color they had seen.

Of the red cones the researchers stimulated, 119 made the men see white, while only 48 flashed red. Similarly, only 21 of the green cones tested actually signaled green, while 77 registered white. Each individual cone probably signals only white or a single color, the researchers say. "It's a rather inefficient arrangement," says Donald MacLeod, a vision scientist at the University of California, San Diego. All the cones are capable of detecting color, but few actually seem to do so.

Cells surrounded by cones that detect a different color were more likely to send white signals to the brain. That finding is unexpected and runs counter to a popular idea that cones ringed by cells detecting other colors would be better at color detection, MacLeod says.

These findings could be good news for people with color blindness. The results suggest that gene therapy that adds red or green cones could work even in adults, Neitz says. Although his group gave a monkey full color vision (*SN: 10/10/09, p. 14*), many researchers thought human brains would never be able to incorporate additional color information even though the eye could detect it. The new findings indicate that all the brain needs to learn is that there is an additional color needed to fill in a basically black-and-white picture, a task the brain should accomplish easily, Neitz says. ■



Researchers have learned surprising lessons about color vision by using precisely targeted lasers (green line) to stimulate single cone cells (red, green and blue dots) in human retinas. The inset area is about 100 micrometers in diameter.

R. SABESAN, BRIAN SCHMIDT, WILLIAM TUTEN, AUSTIN ROORDA

GENES & CELLS

Scientists watch superbugs evolve

Growth patterns reveal *E. coli*'s path to drug resistance

BY LAUREL HAMERS

For bacteria, practice makes perfect: Adjusting to increasing levels of antibiotics preps them to morph into super-resistant strains, and scientists can now watch it happen. A huge petri dish coated with a gradient of antibiotics makes this normally hidden process visible, a team led by Roy Kishony of Technion-Israel Institute of Technology and Harvard Medical School reports in the Sept. 9 *Science*. The setup enables scientists to create a step-by-step picture of how microbes become antibiotic-resistant superbugs.

"As someone who's studied evolutionary biology for a long time, I think it has a real wow factor," says Sam Brown, a microbiologist at Georgia Tech in Atlanta.

Scientists often study microbial evolution in flasks where everything is mixed together. "In order for a new strain to evolve, the new mutant has to be more fit than everything around it," says study coauthor Michael Baym of Harvard. "But in nature, we see a second dynamic: You don't necessarily need to be more fit than everything around you. You just need to make it into a new environment."

Baym and colleagues modeled those spatial dynamics using a giant rectangular dish more than a meter long instead of a standard palm-sized dish. That let the researchers create a gradient of antibiotics on the plate. Low concentrations of trimethoprim or ciprofloxacin antibiotics at the edges ramped up to much higher levels in the middle. Then the team put *Escherichia coli* bacteria on each end of the plate and watched the microbes multiply for up to two weeks.

In general, as bacteria gained new mutations that let them handle higher and higher levels of antibiotics, their descendants could press into new territory on the plate. Those that made it to the middle could tolerate doses of antibiotics a thousand times higher than what was needed to kill the original bacteria.

Scientists visualized the evolution of antibiotic resistance in *E. coli* (bacterial growth shown in white) in a petri dish more than a meter long and coated with a gradient of antibiotics.

KISHONY LAB/HARVARD MED. SCHOOL AND TECHNION-ISRAEL INST. OF TECH.

But resistance didn't always make bacteria competitive colonizers. Highly resistant bacteria sometimes spread more slowly. Trapped behind faster-moving bacteria, the stragglers' descendants formed pockets of super-resistance at lower antibiotic levels.

Baym and colleagues think the setup could be used to study how pathogens spread during infection. ■

BODY & BRAIN

Brain's physical structure aids wiring

Stiffness and softness determine how nerve cells' axons move

BY LAURA SANDERS

In growing brains, billions of nerve cells must make trillions of precise connections. As they snake through the brain, nerve cell tendrils called axons use the brain's stiffness to guide them on their challenging journey, a study of frog nerve cells suggests.

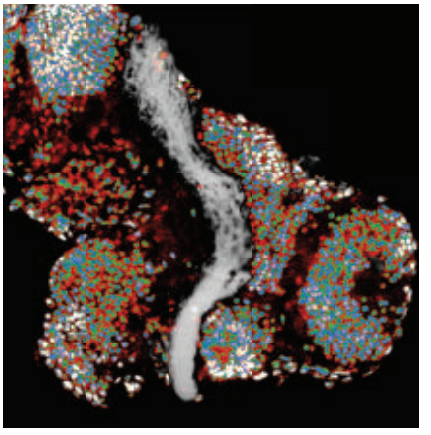
The results, described September 19 in *Nature Neuroscience*, show that along with chemical guidance signals, the brain's physical properties help shape its connections. That insight may be key to understanding how nerve cells wire the brain, says study coauthor Kristian Franze. "I strongly believe that it's not enough to look at chemistry," says Franze, a mechanobiologist at the University of Cambridge. "We need to look at environmental factors, too."

The notion that physical features help guide axons is gaining momentum, says UCLA neuroscientist Samantha Butler. "It's a really intriguing study." A better understanding of how nerve cells find their targets could help scientists coax new cells to grow after a spinal cord injury or design better materials for nerve cell implants.

Franze and colleagues studied nerve cells from the retina of frogs. Experiments on cells in dishes suggested that axons, signal-transmitting tendrils led by tiny pioneering structures called growth cones, grew differently on hard and soft material. Axons grew longer and straighter on stiff surfaces and seemed to meander more on softer material.

In the developing brain, retinal axons grew toward softer tissue, further experiments revealed. When researchers softened brains with a compound, axons veered from their usual route and made more exploratory jaunts. And when researchers squeezed part of the brain with an atomic force microscope, axons avoided the artificially stiff area.

A protein called piezo1 seems to help axons sense stiffness, Franze and colleagues found. When piezo1 levels were reduced, axons grew as if they were in a softer environment; they were shorter and less straight. Soft and hard tissues may both send messages to axons traversing the brain. Hard tissue may signal axons to motor through quickly; softer areas could cue slower exploration as the axons home in on their target.



Axons (grayish-white strands, center) that form a signal-sending pathway in the visual system grow toward their destination in an embryonic frog brain.

It's not clear whether nerve cells respond to stiffness in species other than frogs. If they do, the results could help people design scaffolds on which implanted nerve cells grow. The results could also improve understanding of how wiring can go wrong, which can lead to certain developmental disorders. "There are tremendous implications," Franze says. ■

LIFE & EVOLUTION

X-rays identify preteen tetrapods

Improved technique picks out juveniles in ancient mass burial

BY SUSAN MILIUS

Better bone scanning of fossils offers a glimpse of preteen life some 360 million years ago.

Improved X-ray scanning techniques reveal accumulating growth zones in four fossil upper forelimb bones from salamander-shaped beasts called *Acanthostega*, scientists report in the Sept. 15 *Nature*. Vertebrate bones typically show annual growth zones diminishing in size around the time of sexual maturity. But there's no sign of that slowdown in these four individuals from East Greenland's mass burial of *Acanthostega*, says study coauthor Sophie Sanchez of Uppsala University in Sweden. They were still juveniles.

The bones came from tropical Greenland of the Devonian Period. Aquatic vertebrates were developing four limbs, which would serve tetrapods well when vertebrates eventually conquered land. A mass die-off doomed at least 20 individuals, presumably when a dry spell after a flood trapped them all in a big, vanishing puddle.

Not many other species were found in the mass burial. So young tetrapods may have stuck together much as young fish school, Sanchez speculates. The limb structure indicates that the youngsters took a long time to start adding hard bone to the initial soft cartilage, she says. So these early tetrapods were at least 6 years old and probably 10 years old or more.

For identifying stages of life, the improved technique "allows greater resolution and rigor, so in that regard, it is a plus," says Neil Shubin of the University of Chicago, who studies a fossil fish with some tetrapod-like features called *Tiktaalik*. There are *Tiktaalik* preteens, too.

What interests Nadia Fröbisch of Museum für Naturkunde in Berlin is that some of these *Acanthostega* individuals were different sizes but had reached the same stage of bone development. She muses that they might even have been developing along different trajectories of growth, a flexibility that would be useful in a changeable environment. ■

EVA PILLAI

MATTER & ENERGY

New steps toward quantum internet

Researchers make advances in teleportation and memory

BY EMILY CONOVER

WASHINGTON — A quantum internet could one day allow ultrasecure communication worldwide — but first, scientists must learn to tame unruly quantum particles such as electrons and photons. Several new developments in quantum technology, discussed at a recent meeting, have brought scientists closer to such mastery. Physicists are now teleporting particles' properties across cities, satellite experiments are gearing up for quantum communication in space and other scientists are developing ways to hold quantum information in memory.

In one feat, researchers achieved quantum teleportation across long distances. Quantum teleportation transfers quantum properties of one particle to another instantaneously. (It doesn't allow for faster-than-light communication because additional information has to be sent through standard channels.)

Using a quantum network in Calgary, scientists teleported quantum states of photons over 6.2 kilometers. "It's one step towards ... achieving a global quantum network," said Raju Valivarthi of the University of Calgary in Canada, who presented the result at the International Conference on Quantum Cryptography, QCrypt, on September 12.

A second group of scientists teleported photons using a quantum network spread through the city of Hefei, China. Both teams published their results September 19 in *Nature Photonics*.

Quantum particles' weird properties make quantum communication possible: The particles can be in two places at once, or have their properties linked through quantum entanglement. Tweak one particle in an entangled pair, and you can immediately seem to affect the other — what Einstein called "spooky action at a distance." Using quantum entanglement, people can securely exchange quantum keys — codes that can encrypt top secret messages (*SN: 11/20/10, p. 22*). Any eavesdropper spying on the quantum key exchange would be detected.

In practice, quantum particles can travel only so far. As photons are sent back and forth through optical fibers, many are lost along the way. But quantum teleportation systems could create quantum repeaters, which could be chained together to extend networks farther. Quantum repeaters would also require a quantum memory to store entanglement until all the links in the chain are ready, said Ronald Hanson of Delft University of Technology in the Netherlands. Using a system based on quantum entanglement of electrons in diamond chips, Hanson's team developed a quantum memory by transferring the entanglement of the electrons to atomic nuclei for safekeeping, he reported September 15 at QCrypt.

Satellites could likewise allow quantum communication from afar. In August, China launched a satellite to test quantum communication from space. Particles can travel farther when sent via satellite than through optical fibers. In the emptiness of space, fewer photons are absorbed or scattered away. "A free-space link is essential if you want to go to [a] real long distance," Giuseppe Vallone of the University of Padua in Italy said September 14 at the meeting.

The quantum internet relies on the principles of quantum mechanics, which physicists generally accept — spooky action and all. In 2015, physicists finally confirmed that a key example of quantum weirdness is real, with a souped-up version of a test known as a Bell test, which closed loopholes that had weakened earlier Bell tests (*SN: 9/19/15, p. 12*). Loophole-free Bell tests squelched any lingering doubts.

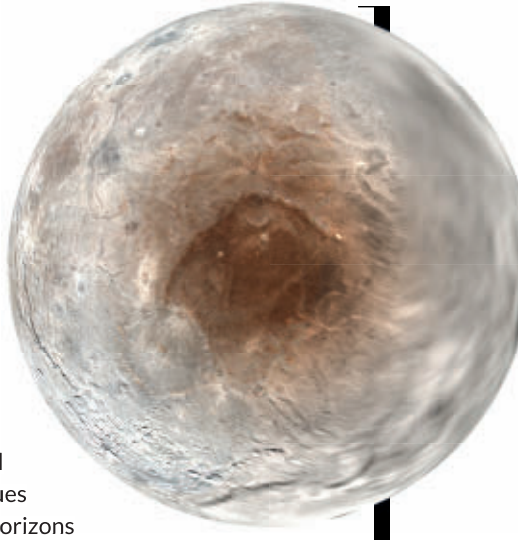
Bell tests have applications for the quantum internet as well — they are a foundation of an even more secure type of quantum communication, called device-independent quantum key distribution. Typically, secure exchanges of quantum keys require that the devices used are trustworthy, but device-independent methods do away with this requirement. This is "the most safe way of quantum communication," said Hanson. "It does not make any assumptions about the internal workings of the device." ■

ATOM & COSMOS

Pluto probably colored Charon's north pole

The ruddy north pole of Charon, the largest moon of Pluto, is probably a stain from Pluto itself, researchers report online September 14 in *Nature*. Methane gas wafting from Pluto's surface sticks to the frigid pole during the moon's decades-long winter; ultraviolet light from the sun then transforms the methane into reddish organic goop known as tholins.

Planetary scientist Will Grundy of Lowell Observatory in Flagstaff, Ariz., and colleagues used images of Charon taken by the New Horizons spacecraft and computational analysis to demonstrate that methane from Pluto is a reasonable culprit for Charon's rust-colored pole (shown here in a mosaic of images). — *Christopher Crockett*



NASA, JHUAPL, SWRI

EARTH & ENVIRONMENT

Anthropocene has begun, group says

Controversial proposal would add epoch to geologic time scale

BY THOMAS SUMNER

Humankind's bombs, plastics, domesticated chickens and more have altered the planet enough to usher in a new chapter in Earth's geologic history. That's the majority opinion of a group of 35 experts tasked with evaluating whether the current human-dominated time span, unofficially dubbed the Anthropocene, deserves a formal place in Earth's geologic timeline alongside the Eocene and the Pliocene.

In a controversial move, the Anthropocene Working Group has declared that the Anthropocene warrants being a full-blown epoch (not a lesser age), with its start pegged to the post–World War II economic boom and nuclear weapon tests of the late 1940s and early 1950s. The group made these provisional recommendations August 29 at the International Geological Congress in Cape Town, South Africa.

If eventually approved by the International Commission on Stratigraphy — the gatekeepers of geologic time — and the Executive Committee of the International Union of Geological Sciences, the Anthropocene would cut short the Holocene Epoch, which has reigned since the end of the last glacial period around 11,700 years ago. The Holocene would become the shortest completed epoch in history, just thousandths the length of the next shortest epoch.

"We've left an indelible mark on the Earth," says Jan Zalasiewicz, a geologist at the University of Leicester in England and convener of the working group. "We now cannot go back to anything that's ostensibly the same as the Holocene."

Not all scientists are on board with the plan. Critics say it's grounded in politics and pop culture, not science, and that not enough time has passed to put just decades-old changes in context. Any proposal advocating for the Anthropocene will face strong skepticism, says Whitney Autin, a sedimentary geologist at the State University of New York at Brockport. "The idea of amending geologic time carries the same weight as eliminating an amendment to the U.S. Constitution," he says.

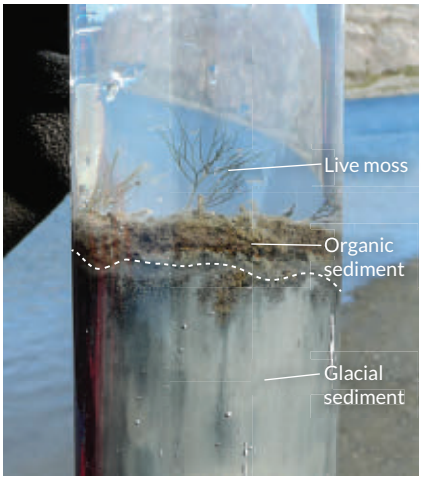
To build its case for the new epoch, the working group will spend the next two to three years scouring natural records, such as rocks, mud and tree rings, for evidence that humankind's impacts have brought about a distinct new phase in the stratigraphic record. The group will then submit a formal proposal for approval.

"We're leaving physical signals in sediments, in corals, in trees that are going to be long lasting if not permanent," says Colin Waters, a geologist at the British Geological Survey in Keyworth and a member of the working group. "It's not just history, it's geology as well." And those geologic changes merit official recognition as a new epoch, Waters says.

The goal of the geologic time scale is to label and formalize discrete phases in Earth's stratigraphic record as a tool for geologists and other scientists. This time scale allows scientists to easily identify, describe and discuss rocks of similar age across the planet.

The term "Anthropocene" (pronounced AN-throh-puh-seen) has risen in popularity among scientists and the general public in recent years, driven in part by its use in a 2002 article by atmospheric chemist and Nobel laureate Paul Crutzen. The article argued that humans' exploitation of natural resources has reshaped the planet enough to bring about a new epoch.

While "Anthropocene" now appears in the titles of papers, conference talks and books about everything from climate change to philosophy, those who embrace the term nonetheless disagree on its definition. Some researchers pin the start of the epoch to when humans first started converting forests to farmland thousands of years ago, while others, such as Crutzen, point to the beginning of the Industrial Revolution or the recent acceleration in fossil fuel burning.



Human-caused climate change left its mark on these sediments collected in Greenland. The retreat of a glacier caused an abrupt transition from gray sediment to brown organic matter — evidence for designating the Anthropocene as a geologic epoch, a group of experts says.

J.P. BRINER

The Anthropocene Working Group was convened by the stratigraphy commission in 2009 to sort out the definition of the Anthropocene and assess whether the time interval should be formally added to the geologic time scale. Among its 35 members, the working group contains an international mix of geologists, climate scientists, archaeologists and other experts.

In January, members of the working group published a review of evidence for the Anthropocene in *Science*. Arguments in favor of the Anthropocene come from multiple areas of science, from biology and climate to chemistry, the researchers reported. For instance, humans have introduced species such as the domestic chicken worldwide and driven many other species to extinction (*SN Online: 8/26/15*). Emissions from human activities such as fossil fuel burning have altered Earth's climate (*SN: 4/16/16, p. 22*). Manufactured materials such as plastics, aluminum and concrete will remain embedded in the ground as "technofossils." Fallout from nuclear weapons tests has left a radioactive mark in soils, marine sediments and even ice. These human impacts make the Anthropocene

distinct in the stratigraphic record from the Holocene, the researchers concluded.

For the Anthropocene to become official, the working group will have to establish a starting point for the proposed epoch. That can be accomplished by picking a nice round number — the Hadean-Archean switchover is an even 4 billion years ago, for instance — or by linking the starting point to a physical marker in the global sedimentary record, an approach now favored by the stratigraphy commission.

The marker for the start of the Holocene, for instance, is linked to chemical and physical changes in the Greenland ice sheet caused by the warming that brought Earth out of its last bout of glacial growth. Such markers — also called "golden spikes," similar to the ceremonial spike that marked the union of the first U.S. transcontinental railroad — are chosen for being ubiquitous and consistent throughout the world.

Golden spikes are not necessarily important or even relevant to the differences that distinguish geologic time frames, says Stan Finney, a geologist at California State University, Long Beach and former International Commission on Stratigraphy chair. For instance, the Thanetian Age — a 3.2-million-year stretch during the Paleocene Epoch — is marked by just one of many reversals in Earth's magnetic field.

While a golden spike's geologic signal may be global, the official representative physical spike itself is literally a single point in the stratigraphic record somewhere on Earth. The golden spike for the Holocene is inside an ice core collected from Greenland and kept chilled in a freezer at the University of Copenhagen.

The need for a golden spike shaped the working group's Anthropocene proposal, Zalasiewicz says. While phases in human history such as early agriculture and the Industrial Revolution have had profound impacts on the planet, they didn't have a simultaneous worldwide effect that could be used to mark the start of the new epoch. Had a major volcanic eruption spewed a distinctive layer of ash across the globe near the start of the Industrial Revolution, "it would have been a pretty good candidate," says Zalasiewicz. Even though the eruption would have had nothing to do with human activity, the ash would have been a ubiquitous and easily identifiable marker for geologists.

> "The idea of amending geologic time carries the same weight as eliminating an amendment to the U.S. Constitution."
>
> WHITNEY AUTIN

Radioactive carbon and plutonium blasted from atmospheric nuclear tests during the 1950s is a pervasive signal. And the timing is so recent that it opens up many new places to hunt for the proposed epoch's golden spike, including in living organisms such as trees and corals. "We're a bit like confused kids wandering around an enormous sweetshop wondering how we're going to choose," Zalasiewicz says.

Even if the group finds an appropriate golden spike, its proposal will face criticism from scientists who contend that the Anthropocene doesn't warrant its own epoch. Radioactive fallout "is a widespread marker that qualifies for the rules that they need to follow to make a recommendation," says paleoclimatologist William Ruddiman of the University of Virginia in Charlottesville, "but that doesn't mean that it's right, or that it makes sense."

Not enough time has passed since the proposed start date of the Anthropocene to have enough perspective to put the observed changes in the sedimentary record in proper context, Autin says. "A lot of stratigraphers would say that maybe in thousands or millions of years there will be a distinctive demarcation in the rock record at this point in time, but right now it's a proposal that's premature."

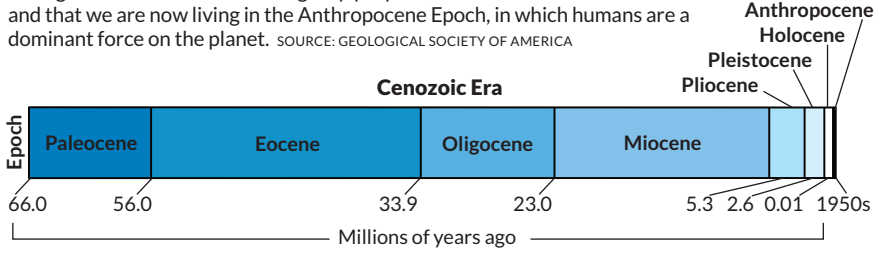
Placing the boundary so recently is "dubious, to say the least," agrees Mike Walker of the University of Wales Trinity Saint David who helped establish the golden spike that represents the start of the Holocene. Divisions of geologic time "should have a utility for geoscientists, archaeologists, anthropologists, et cetera," he says. "I see little of value to the wider science community in an epoch boundary at A.D. 1950."

The formalization of the Anthropocene is not just scientifically motivated, but also driven by a desire to highlight humankind's impact on the environment, suggests Lucy Edwards, a geologist with the U.S. Geological Survey in Reston, Va. "It's a meme," she says. "The thinking is that if you have a concept and you give it a new word, it carries more weight."

The motivation behind the new proposal isn't overly focused on humankind being to blame for recent changes, Zalasiewicz responds. "If we had all the same changes, but caused by something else, like volcanoes or a meteorite or my cat, then it would be just as significant."

More time isn't needed to recognize that modern sediments are unique, he adds. After all, he says, if humans had been around 50 years after the catastrophe that wiped out the dinosaurs about 66 million years ago, they would have clearly seen that Earth's environment and ecology had permanently changed. ■

Time for a change Earth's official geologic history is divvied up among various slices of time. Earth's current era, the Cenozoic, is made up of several smaller epochs. Modern humans emerged during the Pleistocene Epoch about 200,000 years ago, though the rise of civilization took place during the Holocene. A research group proposes that the Holocene has ended and that we are now living in the Anthropocene Epoch, in which humans are a dominant force on the planet. SOURCE: GEOLOGICAL SOCIETY OF AMERICA



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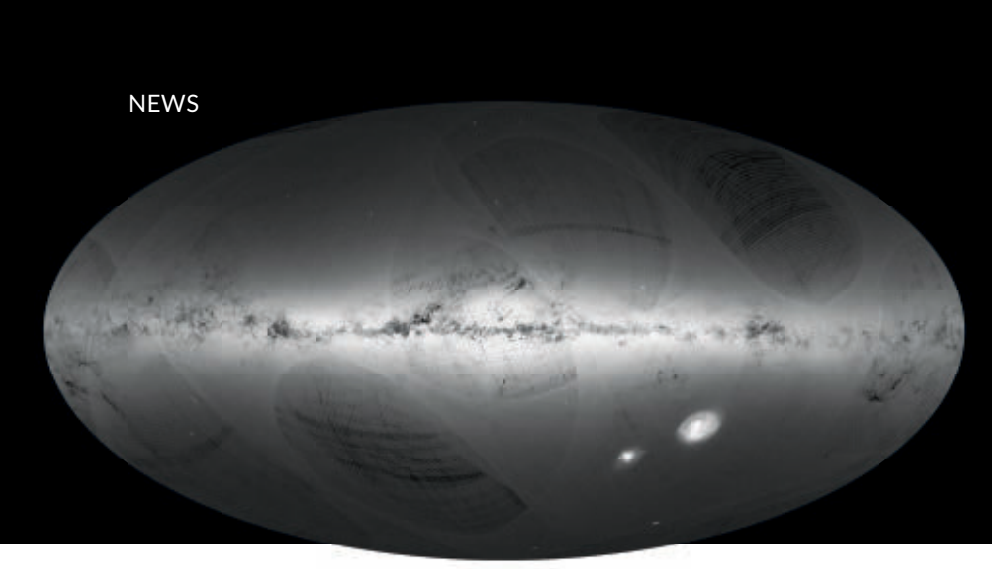

This panoramic view of the Milky Way from the Gaia satellite shows the density of stars on the sky (brighter areas indicate denser star concentrations). The two bright patches at lower right are the Magellanic Clouds.

DPAC/GAIA/ESA

ATOM & COSMOS

Gaia mission maps over 1 billion stars

With additional data, satellite will make 3-D atlas of Milky Way

BY CHRISTOPHER CROCKETT

A new map of the galaxy, the most precise to date, reveals positions on the sky for over 1 billion stars both within and beyond the Milky Way.

This new galactic atlas, courtesy of the European Space Agency's Gaia spacecraft, also provides distances to roughly 2 million of those stars, laying the groundwork for astronomers who want to piece together the formation, evolution and structure of the Milky Way.

"This is a major advance in mapping the heavens," Anthony Brown, an astrophysicist at Leiden University in the Netherlands, said September 14 at a news briefing. "Out of the 1 billion stars, we estimate that over 400 million are new discoveries."

There are no major cosmic revelations yet; those will develop in the months and years to come as astronomers pore over the data. This catalog of stars is just a first peek at what's to come from Gaia, which is spending five years gathering intel on a wide variety of celestial objects.

The final survey will eventually provide a 3-D map of the more than 1 billion stars, revealing not just their positions but also their distances. It will also chart positions of roughly 250,000 asteroids and comets within the solar system, 1 million galaxies and 500,000 quasars — the blazing cores of galaxies lit up by gas swirling around supermassive black holes. Mission scientists also expect they will turn up more than 10,000 undiscovered planets orbiting other stars.

"It's a very democratic mission," project scientist Timo Prusti said at the briefing. "Anything that looks like a [point of light] gets caught up and observed."

Gaia launched on December 19, 2013, and eventually settled into its home about 1.5 million kilometers from Earth on an orbit that follows our planet around the sun (*SN Online: 12/19/13*). Regular science observations started in July 2014. This first data release, described in a series of papers published online starting September 14 in *Astronomy & Astrophysics*, contains data obtained through September 2015.

The spacecraft repeatedly scans the sky with two telescopes pointed in different directions. To make the 3-D map, Gaia measures each star's parallax, a subtle apparent shift in the position of the star caused by the changing viewing angle as the spacecraft loops around the sun. By measuring the amount of parallax, and knowing the size of Gaia's orbit, astronomers can triangulate precise distances to those stars.

With distances in hand, astronomers can figure out how intrinsically bright those stars are, crucial information for understanding how stars evolve over time. A detailed stellar map could also help chart the Milky Way's distribution of dark matter, the elusive substance that is thought to make up the bulk of the mass in all galaxies and reveals itself only through gravitational interactions with stars and gas.

One controversy that astronomers are eager to resolve with Gaia is the distance to the Pleiades star cluster, one of the closest repositories of youthful stars. A previous Gaia-like mission, the Hipparcos satellite, came up with a distance of about 392 light-years. Estimates based on simulations of how stars evolve as well as observations from the Hubble Space Telescope and ground-based radio observatories put the Pleiades at about 443 light-years away (*SN Online: 4/28/14*).

"Clusters give you a sense of the evolution of stars at different ages," says Jo Bovy, an astrophysicist at the University of Toronto who is not involved with the Gaia mission. "The Pleiades is a nearby cluster that we can study well — it's one of the cornerstones." All of the stars in the Pleiades are roughly 100 million years old, and so provide a snapshot of how stars develop in their early years.

Gaia appears to be leaning toward the larger distance for the Pleiades, Brown said, but there's still too much uncertainty in the data to say anything definitive. "It's too early to say how the controversy will be resolved," he said. "But Gaia will pin it down."

Resolving the Pleiades distance debate, as well as creating a clearer picture of how the Milky Way is put together, will have to wait for future data releases from Gaia. The next release is planned for late 2017; the final 3-D catalog won't be available until 2022.

"Those will be much more interesting," Bovy says. "Then we can actually start using our modeling machinery and see how stars are distributed throughout the galaxy. We can test our understanding of dark matter and our understanding of how the Milky Way formed." ■

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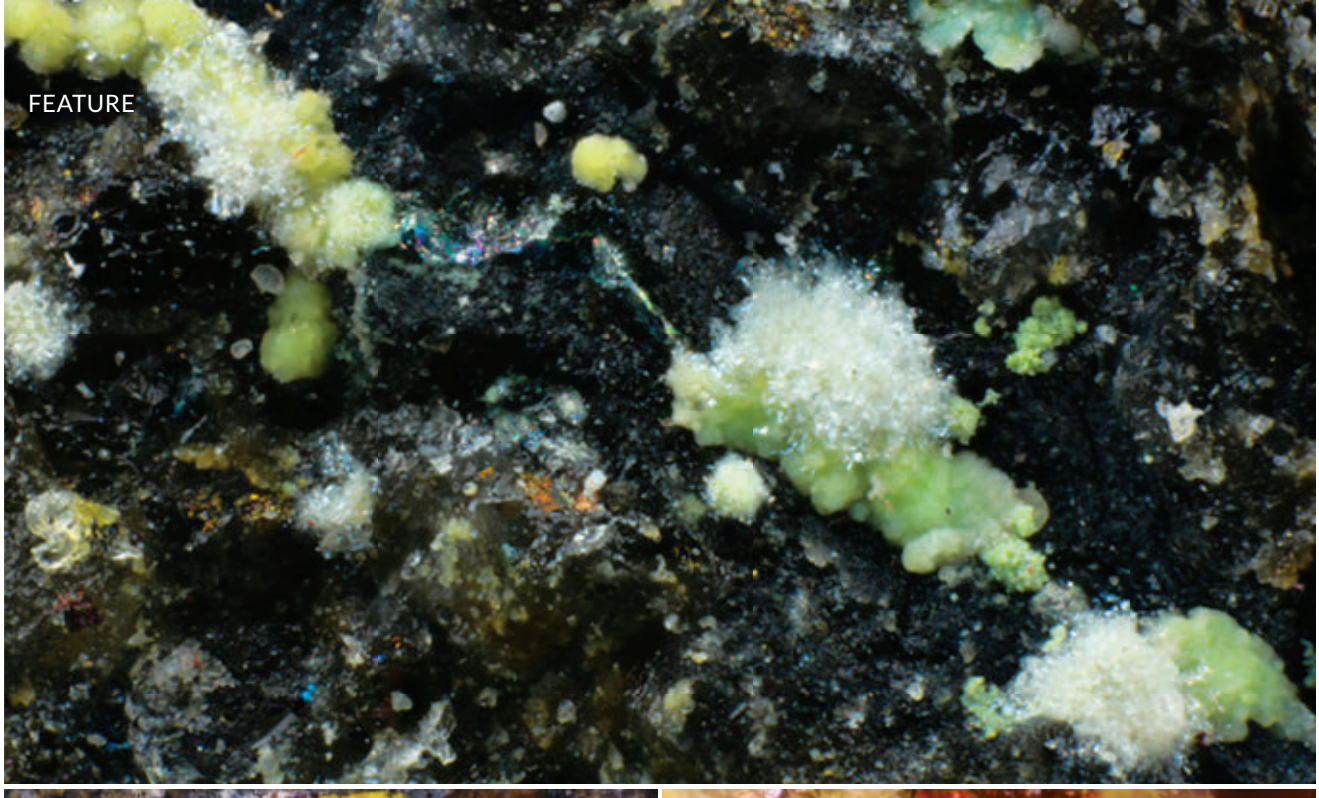
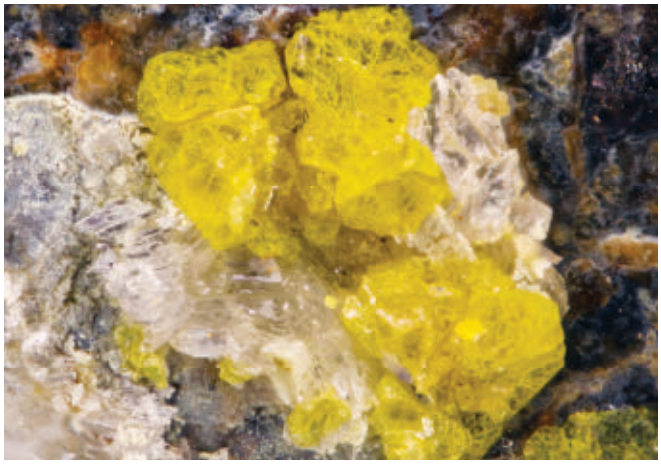
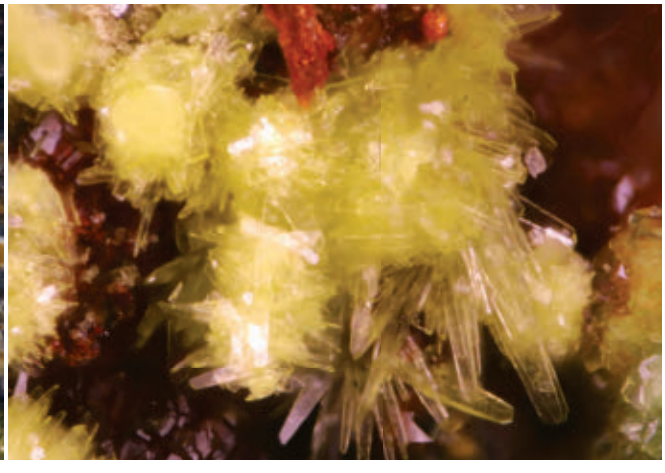






Digging Carbon

A new challenge has scientists searching for dozens of unknown, beguiling crystals

By Sid Perkins

Abellaite, leószilárdite and ewingite (clockwise from top) are three of the seven carbon-bearing minerals recognized by the International Mineralogical Association in the past year. A search is on to find dozens more undiscovered carbon minerals.

Like many abandoned mines, the Eureka uranium mine in northern Spain is a maze of long, dank tunnels. Water seeping down the walls carries dissolved substances that percolated through rocks overhead. As the water evaporates into the tunnels' cool air, some of those dissolved ingredients combine to make new substances in solid form.

"The mine is a crystallization factory of weird minerals," says Jordi Ibáñez-Insa, a physicist at the Institute of Earth Sciences Jaume Almera in Barcelona.

Including the uranium-bearing ores that attracted miners to Eureka in the first place, scientists visiting the mine have cataloged 61 different minerals — solids that have a distinct chemical recipe and arrangement of atoms. The latest find, called abellaite, is a rarity that grows in small pincushions of tiny crystalline needles about 40 to 50 micrometers long. Discovered in

TOP: MATTEO CHINELLATO; BOTTOM ROW: TRAVIS OLDS

July 2010, the mineral has been found only on the walls of a 3-meter-long stretch of one tunnel, says Ibáñez-Insa.

Abellaite is uncommon in another sense: It contains carbon. Of the 5,161 minerals characterized by scientists and recognized by the International Mineralogical Association, just 8 percent, or 416, include carbon.

The Carbon Mineral Challenge, launched last December and running until September 2019, exhorts researchers to scour the landscape — and their museum drawers — for unknown carbon-bearing minerals. In a recent analysis, scientists estimate that there are at least 548 carbon minerals on Earth. That means well over 100 are waiting to be noticed.

The analysis, published in the April *American Mineralogist*, even provides clues about where scientists and rock hounds should look and what recipes and atomic arrangements such minerals might have.

The hunt for carbon minerals is much more than stamp (or rock) collecting. The challenge aims to identify minerals that could help tell the story of the planet's carbon and water cycles — past and present. Besides having a specific recipe and structure, minerals form only in certain conditions (on Earth and elsewhere), making them keen chroniclers of the environments that existed at the time and place they formed, as well as the conditions since then (see Page 21).

A census of minerals

A few minerals are, forgive the phrase, as common as dirt. Of the more than 5,000 recognized minerals, about 100 have been reported by geologists and amateur collectors at more than 1,000 sites worldwide. Many more are very rare: At least 1,000 minerals have been found in only one locale, says Robert Hazen, a geophysicist at the Carnegie Institution for Science in Washington, D.C. More than half of the world's minerals have been found at five or fewer locations.

Not every mineral on Earth has been discovered, of course. But by analyzing a massive database of known minerals and how common or rare they are, scientists can use a standard statistical tool to estimate the number of minerals yet to be uncovered. Hazen and his colleagues suggest in the August 2015 issue of *Mathematical Geosciences* that there are at least 1,500 undiscovered minerals out there. About 140 of those minerals contain carbon, the team predicted in the follow-on analysis published in April.

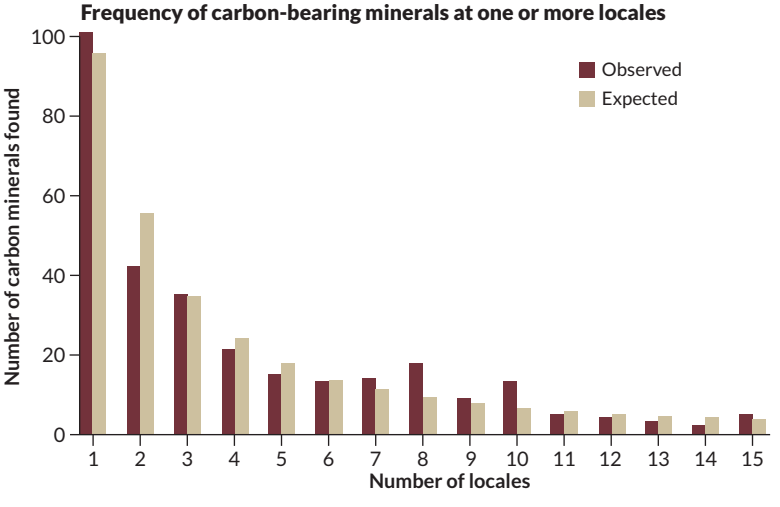
Both professional mineralogists and amateur collectors can participate in the Carbon Mineral Challenge, but any potential discoveries have to survive the strict screening process of the International Mineralogical Association, which Ibáñez-Insa and a raft of colleagues navigated for abellaite. (The mineral was approved in December 2015.) The researchers submitted a portfolio of data — the sample's appearance, chemical makeup, arrangement of atoms, color, hardness, transparency, fluorescence, a proposed name and more — to the IMA's Commission on New Minerals, Nomenclature and Classification.

A few dozen new minerals are recognized each year, says Hans-Peter Schertl, a mineralogist at Ruhr University in Bochum, Germany, and an IMA officer. Approval can be straightforward, or it can drag out for months or longer, especially if additional data are required, Schertl says. One strict requirement is that a sample be natural, not lab-made or a result of human interference. Thus, any unusual crystals that grow on the surfaces of rocks that were pulled from a mine and then dumped nearby and exposed to the elements wouldn't qualify as a mineral, he notes, "Those would just be pretty crystals."

Oddly, the "natural sample" requirement long prevented official recognition of what is purported to be the most common mineral on Earth. Bridgmanite, an iron- and magnesium-rich silicate, received the IMA seal of approval only in 2014 (*SN: 1/10/15, p. 4*). Estimated to make up a whopping 38 percent of the planet's volume,

Survey says The number of minerals found at only one locale is expected to decrease as more minerals are found. But of all known carbon-bearing minerals (maroon bars), most have been found in only a handful of places. Anticipated finds (tan bars) based on statistical analyses, offer hope of yet-to-be-found minerals.

SOURCE: R. HAZEN *ET AL/AMERICAN MINERALOGIST* 2016



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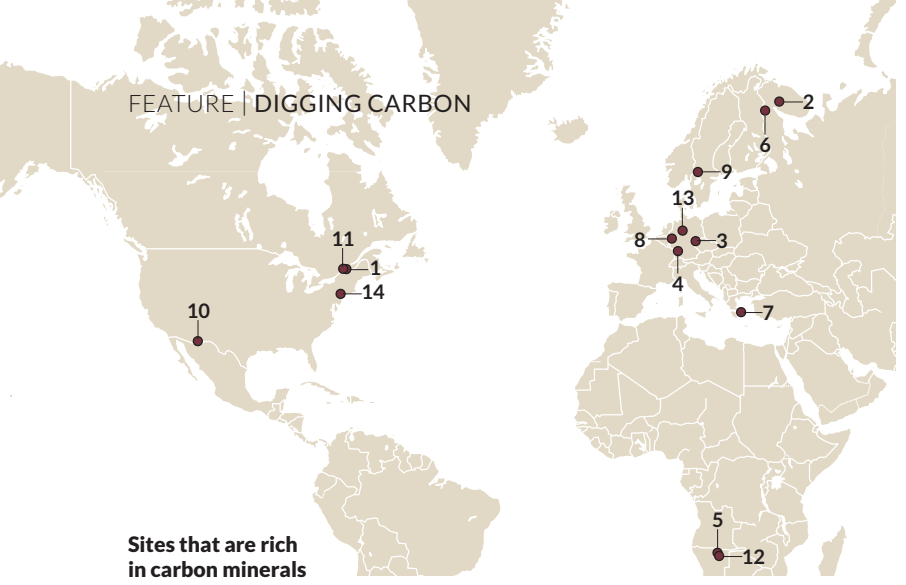

Sites that are rich in carbon minerals

	Location	Number of minerals*
1	Poudrette Quarry, Mont-Saint-Hilaire, Quebec, Canada	78
2	Kukisvumchorr Mt., Khibiny Massif, Kola Peninsula, Russia	45
3	Jáchymov, Karlovy Vary Region, Bohemia, Czech Republic	38
4	Clara Mine, Wolfach, Baden-Württemberg, Germany	37
5	Tsumeb Mine, Tsumeb, Namibia	29
6	Vuoriyarvi Massif, Northern Karelia, Russia	25
7	Sounion Mine No. 19, Attikí Prefecture, Greece	24
8	Friedrichssegen Mine, Rhineland-Palatinate, Germany	23
9	Långban, Filipstad, Värmland, Sweden	22
10	Bisbee, Warren District, Mule Mtns., Cochise County, Arizona	22
11	Francon Quarry, Montreal, Quebec, Canada	21
12	Kombat Mine, Grootfontein District, Namibia	21
13	Glücksrad Mine, Oberschulenberg, Harz, Germany	20
14	Sterling Mine, Sussex County, New Jersey	20

**Number of known carbon-bearing minerals discovered at these sites as of September 2016*

Promising places
In the search for hidden carbon-bearing minerals, scientists and rock hounds aspiring to geologic fame should visit these locales (or analyze samples already collected there).

SOURCE: D. HUMMER/SOUTHERN ILLINOIS UNIV.

bridgmanite can exist only at the high pressures found between 660 and 2,900 kilometers below Earth's surface — too deep to dig up. Scientists had long studied lab-made samples but hadn't found a natural bit of the mineral until earlier this decade in a meteorite that landed in Australia in 1879.

Where to look

In their analysis published in April, Hazen and colleagues included general recipes for a variety of Earth's yet-to-be-discovered carbon minerals. One formula — a complex mix of sodium, lead and carbonate and hydroxyl ions, written scientifically as $NaPb_2(CO_3)_2(OH)$ — matches abellaite from the Spanish mine. Bingo. One more carbon mineral in the bag.

Many of those "missing" minerals will be very similar to known forms, with combinations that differ by only a single element — swapping out a magnesium atom for a calcium atom in the recipe for a known mineral, for example, or a sodium atom for a potassium atom.

"The chemical formula tells you a lot about the conditions that a mineral forms in," says Daniel Hummer, a geochemist at Southern Illinois University in Carbondale and lead scientist for the Carbon Mineral Challenge. It also suggests that existing minerals that have a very similar formula can, in many cases, serve as a guide for what the missing minerals might look like, in terms of the colors or shapes of their crystals.

In fact, similarities could be so strong that a mineral might be overlooked because it looks so much like a known, or even common, mineral. "It's possible that some of these missing minerals are hiding in plain sight," Hummer notes.

If not camouflaged, some carbon minerals may simply be so scarce that they've never been encountered. In June in *American Mineralogist*, Hazen and environmental scientist Jesse Ausubel of Rockefeller University in New York City discuss several reasons why minerals can be rare — so rare, in fact, that the entire world's supply might fit into a thimble, Hazen says.

First, a mineral might form or remain stable only in extremely unusual combinations of temperature, pressure and pH. The mineral hatrurite (Ca_3SiO_5), for example, forms only at temperatures above 1,250° Celsius and only in the absence of aluminum, the third most common element in Earth's crust. Hatrurite was first found in Israel, in an ancient limestone deposit that was probably exposed to intense heat generated when hydrocarbons in nearby sediments burned.

Second, a mineral might include chemical elements that are rare to begin with and even rarer in combination. Examples include swedenborgite (which contains the scarce combination of beryllium and antimony) and any mineral that includes tellurium, which on average is found in Earth's crust at concentrations of 5 parts per billion.

Third, a mineral may be exceptionally ephemeral. Some are so hygroscopic, or humidity-absorbing, that they pull moisture from the air and dissolve themselves, Hazen says. Hygroscopic minerals have to be collected or observed in the field as they form and before they disappear. Then there are the minerals that form in conditions so remote or harsh that scientists hardly ever get near them (think deep-sea hydrothermal vents or active volcanoes).

Some minerals present more than one of these challenges. Consider fingerite, $Cu_{11}O_2(VO_4)_6$, an unstable shiny black mineral that forms only at high temperatures and includes the rare combination of copper and vanadium. This exceedingly

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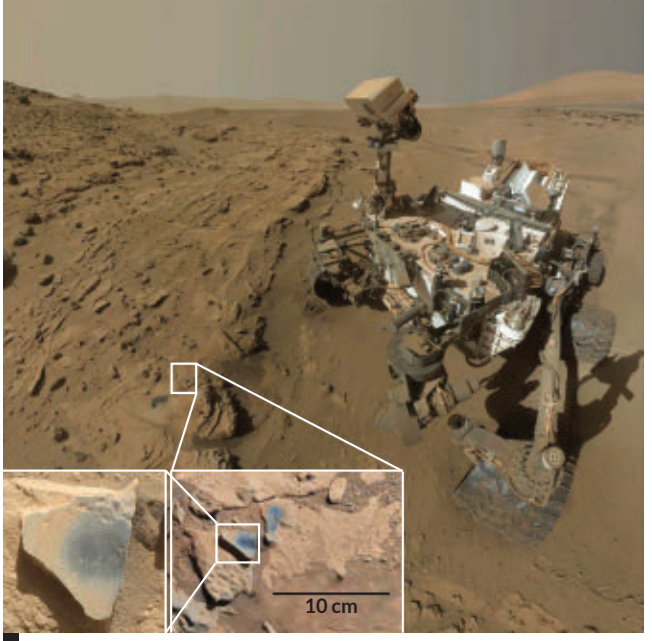


Curious about Martian minerals

The latest discoveries of carbon-bearing minerals haven't yet led to revelations about Earth's history. But some new mineral finds by NASA's Curiosity rover (above) suggest that Mars' past may have been different than thought.

In 2014, Curiosity drilled into layered sediments with veins of hard, black, manganese-rich minerals within softer strata of sandstone and siltstone (inset), says Nina Lanza, a planetary scientist at Los Alamos National Laboratory in New Mexico. A dearth of chlorine or sulfur atoms (two plausible chemical partners for manganese) plus a lack of carbon above levels normally seen in the Martian atmosphere strongly suggests that the minerals are manganese oxides, she and colleagues reported July 28 in *Geophysical Research Letters*.

But Mars' oxygen levels are too low for such minerals to form; on Earth, manganese oxides formed only after atmospheric concentrations of oxygen rose above 1 percent. (On Earth today, oxygen levels in the air are just below 21 percent. On Mars, levels are only about 0.15 percent.)

So where did Mars' ancient wealth of oxygen come from? Probably not from oxygen-making microorganisms, Lanza says. Since Mars has no protective magnetic field (*SN: 9/19/15, p. 5*), the oxygen might have come from radiation-triggered breakdown of water vapor in the air; perhaps lighter hydrogen molecules were lost to space while the slower, heavier oxygen molecules accumulated.

The new results, Lanza says, also suggest that finding signs of oxygen on planets around distant suns wouldn't be a slam dunk sign of life there.

At another site, Curiosity found tridymite, a silicon dioxide that forms above 870° Celsius, where flows of silica-rich lava cool, says Richard Morris, a geochemist at NASA's Johnson Space Center in Houston. The Red Planet may have had a much more violent volcanic history than suspected, he and colleagues reported June 28 in the *Proceedings of the National Academy of Sciences*. — *Sid Perkins*

FROM TOP: NASA/JPL-CALTECH/MSSS; PANDA3800/ISTOCKPHOTO

rare mineral is known only from samples recovered from rocks near heat-belching fissures and holes atop El Salvador's Izalco volcano.

There are less hostile places to search for new minerals, though. Fourteen sites worldwide, including mines, have each given up 20 or more carbon minerals, Hazen says. Scientists could revisit those 14 sites and look for more unrecognized minerals, he notes. Or they could simply take a closer look at or perform additional tests on samples already collected from such locales.

Or researchers could target areas where ephemeral minerals could be expected to form, if ever so briefly. For example, calcium carbide — a substance produced on an industrial scale to create acetylene for miner's lamps — reacts so quickly with water that it hasn't been found in a natural setting. But small, short-lived quantities might be produced when lightning strikes near rocks containing both limestone and coal (admittedly, a pretty hostile situation).

There's no reason to be limited by the 14 promising locations. Scientists found the yellowish-white crystals of tinnunculite ($C_5H_4N_4O_3 \cdot 2H_2O$), a mineral just recognized in December, in an unexpected milieu: inside the residue of bird poop that had landed on extremely hot rocks overlying an underground coal fire in northwestern Russia. The elevated temperatures drive the crystallization of uric acid in the excrement, the researchers say.

The exotic mineral was dubbed tinnunculite to honor the European kestrel (*Falco tinnunculus*), whose indispensable contribution to mineralogy cannot be denied.

For his part, Ibáñez-Insa plans to spend more time at Spain's Eureka mine. Although the site's uranium ores are no longer worth extracting, scientific treasures akin to abellaite may still lie undiscovered. "I'm pretty sure," he says, "we'll find some more new minerals there." ■

Explore more

- The Carbon Mineral Challenge: mineralchallenge.net

Sid Perkins is a freelance science writer based in Crossville, Tenn.

Tinnunculite, a mineral first recognized in December, crystallized within globs of excrement from the European kestrel (*Falco tinnunculus*) heated by an underground coal fire.

THE HYBRID FACTOR

The physical effects of interbreeding among animals may offer clues to Neandertals' genetic mark on humans

By Bruce Bower

Neandertals are the comeback kids of human evolution. A mere decade ago, the burly, jut-jawed crowd was known as a dead-end species that lost out to us, *Homo sapiens*.

But once geneticists began extracting Neandertal DNA from fossils and comparing it with DNA from present-day folks, the story changed. Long-gone Neandertals rode the double helix express back to evolutionary relevance as bits of their DNA turned up in the genomes of living people. A molecular window into interbreeding between Neandertals and ancient humans suddenly flung open.

Thanks to ancient hookups, between 20 and 35 percent of Neandertals' genes live on in various combinations from one person to another. About 1.5 to 4 percent of DNA in modern-day non-Africans' genomes comes from Neandertals, a population that died out around 40,000 years ago.

Even more surprising, *H. sapiens'* Stone Age dalliances outside their own kind weren't limited to Neandertals. Ancient DNA shows signs of interbreeding between now-extinct Neandertal relatives known as Denisovans and ancient humans. Denisovans' DNA legacy still runs through native populations in Asia and the Oceanic islands. Between 1.9 and 3.4 percent of present-day Melanesians' genes can be traced to Denisovans (*SN Online: 3/17/16*). Other DNA studies finger unknown, distant relatives of Denisovans as having interbred with ancestors of native Australians and Papuans (see Page 6). Genetic clues also suggest that Denisovans mated with European Neandertals.

These findings have renewed decades-old debates about the evolutionary relationship between humans and extinct members of our evolutionary family, collectively known as hominids. Conventional wisdom that ancient hominid species living at the same time never interbred or, if they did, produced infertile offspring no longer holds up.

But there is only so much that can be inferred from the handful of genomes that have been retrieved from Stone Age

JAMES CAREY

individuals so far. DNA from eons ago offers little insight into how well the offspring of cross-species flings survived and reproduced or what the children of, say, a Neandertal mother and a human father looked like.

Those who suspect that Neandertals and other Stone Age hominid species had a big evolutionary impact say that ancient DNA represents the first step to understanding the power of interbreeding in human evolution. But it's not enough.

Accumulating evidence of the physical effects of interbreeding, or hybridization, in nonhuman animals may offer some answers. Skeletal studies of living hybrid offspring — for example, in wolves and monkeys — may tell scientists where to look for signs of interbreeding on ancient hominid fossils.

Scientists presented findings on hybridization's physical effects in a variety of animals in April at the annual meeting of the American Association of Physical Anthropologists in Atlanta. Biological anthropologist Rebecca Ackermann of the University of Cape Town in South Africa co-organized the session to introduce researchers steeped in human evolution to the ins and outs of hybridization in animals and its potential for helping to identify signs of interbreeding on fossils typically regarded as either *H. sapiens* or Neandertals.

"I was astonished by the number of people who came up to me after the session and said that they hadn't even thought about this issue before," Ackermann says.

Streaming evolution

Interbreeding is no rare event. Genome comparisons have uncovered unexpectedly high levels of hybridization among related species of fungi, plants, rodents, birds, bears and baboons, to name a few. Species often don't fit the traditional concept of populations that exist in a reproductive vacuum, where mating happens only between card-carrying species members.

Evolutionary biologists increasingly view species that have diverged from a common ancestor within the last few million years as being biologically alike enough to interbreed successfully and evolve as interconnected populations. These cross-species collaborations break from the metaphor of an evolutionary tree sprouting species on separate branches. Think instead of a braided stream, with related species flowing into and out of genetic exchanges, while still retaining their own distinctive looks and behaviors.

Research now suggests that hybridization sometimes ignites helpful evolutionary changes. An initial round of interbreeding — followed by hybrid offspring mating among themselves and with members of parent species — can result in animals with a far greater array of physical traits than observed in either original species. Physical variety in a population provides fuel for natural selection, the process by which individuals with genetic traits best suited to their environment tend to survive longer and produce more offspring.

Working in concert with natural selection and random genetic changes over time, hybridization influences evolution in other ways as well. Depending on available resources and climate shifts, among other factors, interbreeding may stimulate the merger of previously separate species or, conversely, prompt one of those species to die out while another carries on. The birth of new species also becomes possible. In hybrid zones where the ranges of related species overlap, interbreeding regularly occurs.

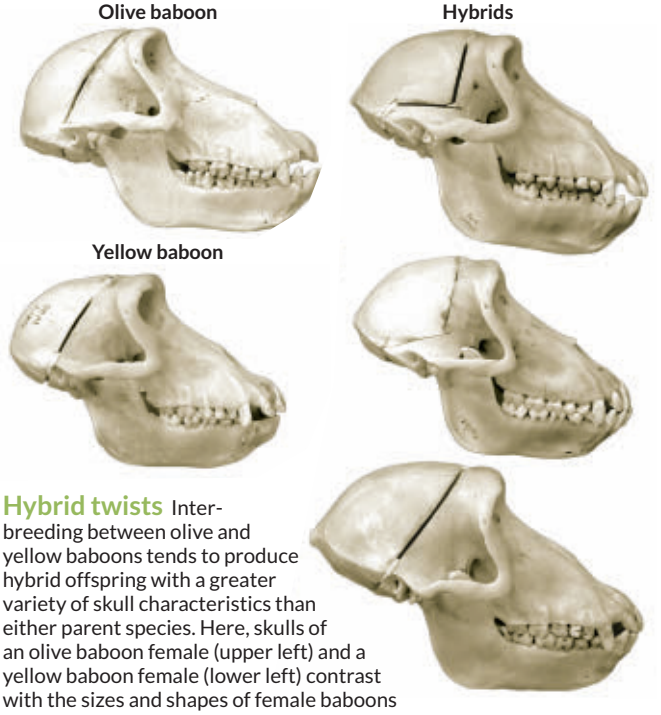
"Current evidence for hybridization in human evolution suggests not only that it was important, but that it was an essential creative force in the emergence of our species," Ackermann says.

Hybrid faces

A vocal minority of researchers have argued for decades that signs of interbreeding with Neandertals appear in ancient human fossils. In their view, *H. sapiens* interbred with Asian and European Neandertals after leaving Africa at least 60,000 years ago (*SN: 8/25/12, p. 22*). They point to some Stone Age skeletons, widely regarded as *H. sapiens*, that display unusually thick bones and other Neandertal-like features.

Critics of that view counter that such fossils probably come from particularly stocky humans or individuals who happened to develop a few unusual traits. Interbreeding with Neandertals occurred too rarely to make a dent on human anatomy, the critics say.

One proposed hybrid fossil has gained credibility because of ancient DNA (*SN: 6/13/15, p. 11*). A 37,000- to 42,000-year-old human jawbone found in Romania's Oase Cave contains genetic fingerprints of a Neandertal ancestor that had lived only four to six generations earlier than the Oase individual.



Hybrid twists Interbreeding between olive and yellow baboons tends to produce hybrid offspring with a greater variety of skull characteristics than either parent species. Here, skulls of an olive baboon female (upper left) and a yellow baboon female (lower left) contrast with the sizes and shapes of female baboons produced by interbreeding of olive and yellow baboons (right).

R. ACKERMANN, J. ROGERS AND J.M. CHEVERUD/*J. HUMAN EVOL.* 2006

Since the fossil's discovery in 2002, paleoanthropologist Erik Trinkaus of Washington University in St. Louis has argued that it displays signs of Neandertal influence, including a wide jaw and large teeth that get bigger toward the back of the mouth. In other ways, such as a distinct chin and narrow, high-set nose, a skull later found in Oase Cave looks more like that of a late Stone Age human than a Neandertal.

Roughly 6 to 9 percent of DNA extracted from the Romanian jaw comes from Neandertals, the team found.

"That study gave me great happiness," Ackermann says. Genetic evidence of hybridization finally appeared in a fossil that had already been proposed as an example of what happened when humans dallied with Neandertals.

Hybridization clues such as those seen in the Oase fossil may dot the skulls of living animals as well. Skull changes in mouse hybrids, for instance, parallel those observed on the Romanian fossil, Ackermann's Cape Town colleague Kerryn Warren reported at the anthropology meeting in April. Warren and her colleagues arranged laboratory liaisons between three closely related house mouse species.

A mouse hybrid's skull, shown from above and right side, is larger than skulls of the two species from which it derived.

First-generation mouse hybrids generally displayed larger heads and jaws and a greater variety of skull shapes than their purebred parents. In later generations, differences between hybrid and purebred mice began to blur. More than 80 percent of second-generation hybrids had head sizes and shapes that fell in between those of their hybrid parents and purebred grandparents. Ensuing generations, including offspring of hybrid-purebred matches, sported skulls that generally looked like those of a purebred species with a few traits borrowed from another species or a hybrid line. Borrowed traits by themselves offered no clear road map for retracing an animal's hybrid pedigree.

There's a lesson here for hominid researchers, Ackermann warns: Assign fossils to one species or another at your own risk. Ancient individuals defined as *H. sapiens* or Neandertals or anything else may pull an Oase and reveal a hybrid face.

Shape-shifting

Part of the reason for Ackermann's caution stems from evidence that hybridization tends to loosen genetic constraints on how bodies develop. That's the implication of studies among baboons, a primate viewed as a potential model for hybridization in human evolution.

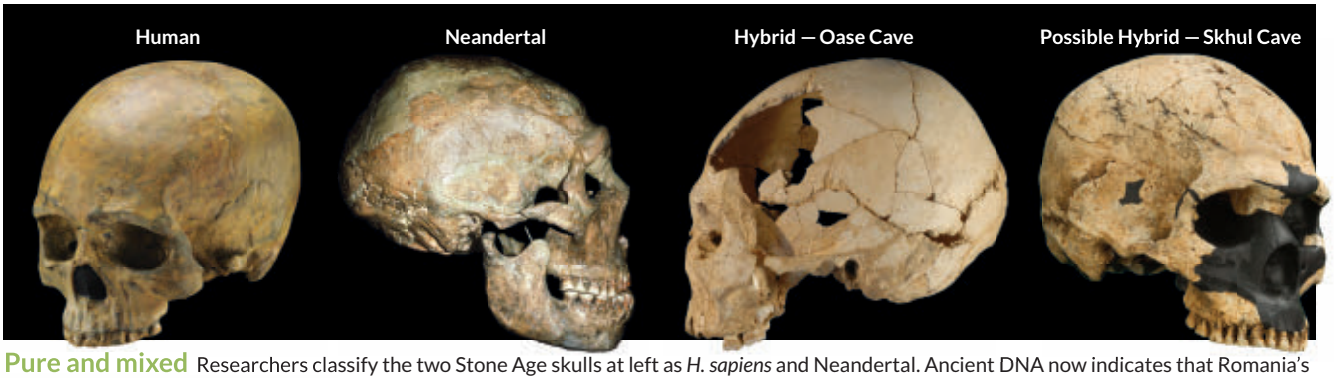
Six species of African baboons currently interbreed in three known regions, or hybrid zones. These monkeys evolved over the last several million years in the same shifting habitats as African hominids. At least two baboon species have inherited nearly 25 percent of their DNA from a now-extinct baboon species that inhabited northern Africa, according to preliminary studies reported at the anthropology meeting by evolutionary biologist Dietmar Zinner of the German Primate Center in Göttingen.

Unusual arrangements of 32 bony landmarks on the braincase appear in second-generation baboon hybrids, Cape Town physical anthropologist Terrence Ritzman said in another meeting presentation. Such alterations indicate that interbreeding relaxes evolved biological limits on how skulls grow and take shape in baboon species, he concluded.

In line with that proposal, hybridization in baboons and many other animals results in smaller canine teeth and the rotation of other teeth in their sockets relative to parent species. Changes in the nasal cavity of baboons showed up as another telltale sign of hybridization in a recent study by Ackermann and Kaleigh Anne Eichel of the University of Waterloo, Canada.

The researchers examined 171 skulls from a captive population of yellow baboons, olive baboons and hybrid offspring of the two species. Skulls were collected when animals died of natural causes at a primate research center in San Antonio. Scientists there tracked the purebred or hybrid backgrounds of each animal.

First-generation hybrids from the Texas baboon facility, especially males, possessed larger nasal cavities with a greater variety of shapes, on average, than either parent species,



Pure and mixed Researchers classify the two Stone Age skulls at left as *H. sapiens* and Neandertal. Ancient DNA now indicates that Romania's Oase skull, second from right, belonged to a *H. sapiens* with recent Neandertal ancestry. Some scientists think an 80,000- to 120,000-year-old *H. sapiens*, whose remains were found at Israel's Skhul Cave, skull at far right, also interbred with Neandertals.

MOUSE: K. WARREN/UNIV. OF CAPE TOWN; HUMAN AND SKHUL CAVE SKULLS: HUMAN ORIGINS PROGRAM, SMITHSONIAN INSTITUTION; NEANDERTAL: MILFORD WOLPOFF/UNIV. MICHIGAN; OASE SKULL: E. TRINKAUS/WASHINGTON UNIV.

Skeletal signs

Monkeys living in half-acre, fenced spaces at the California National Primate Research Center in Davis may have a lot to teach scientists about recognizing hybrid hominids in the fossil record.

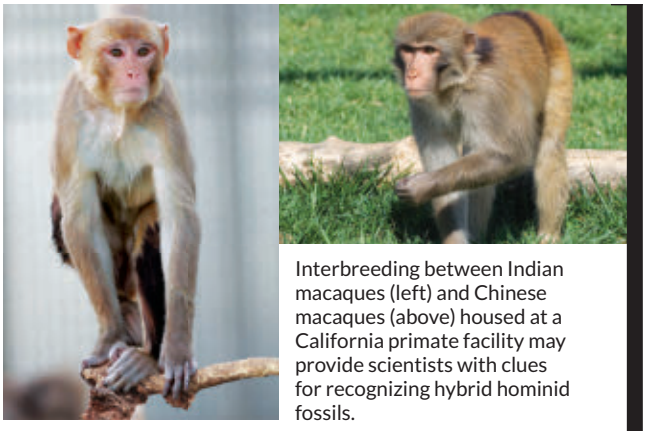
Indian and Chinese rhesus macaques have been interbreeding at the West Coast facility since the mid-1980s. Most of the more than 5,000 monkeys housed at the center are rhesus macaques. To boost genetic diversity in what was an exclusively Indian rhesus colony, researchers introduced Chinese rhesus DNA into the mix. The two populations are classified as subspecies that occasionally mate in the wild and mate frequently when kept in common enclosures. Offspring of Indian-Chinese unions, and of hybrid macaques that mate with members of either parent population, have been tracked since the Chinese monkeys arrived in Davis.

UC Davis anthropologists David Katz and Timothy Weaver, anthropologist Rebecca Ackermann of the University of Cape Town in South Africa and geneticist Sree Kanthaswamy of Arizona State University in Tempe are studying the effects of different amounts of hybridization on the monkeys' bodies.

So far, full-body CT scans and DNA have been obtained from nearly 70 animals. The scientists plan to study more than 200. The researchers will look closely for skeletal signs of hybridization in the animals, which might include changes in the shape of the nose and braincase.

The Davis macaque colony is a promising model for interbreeding between humans and Neandertals, Katz says, even if subspecies are not as genetically distinct as species. First, he says, roughly 14,000 generations passed between the two macaque subspecies diverging from a common ancestor and interbreeding in captivity. That's not too far off from the approximately 18,000 generations that passed between *H. sapiens* and Neandertals splitting from a common ancestor and interbreeding in the wild.

Second, Indian macaques and present-day people display comparable levels of genetic diversity across individuals. And most monkey hybrids are essentially Indian macaques that carry a small DNA contribution from Chinese macaques, about 3 to 6 percent. That's closely in line with the average amount of Neandertal DNA inherited by present-day non-Africans. — *Bruce Bower*



Interbreeding between Indian macaques (left) and Chinese macaques (above) housed at a California primate facility may provide scientists with clues for recognizing hybrid hominid fossils.

BOTH: KATHY WEST/UC DAVIS

Ackermann and Eichel reported in the May *Journal of Human Evolution*. Male hybrid baboons, in general, have large faces and boxy snouts.

Similarly, sizes and shapes of the mid-face vary greatly from one Eurasian fossil hominid group to another starting around 126,000 years ago, says paleoanthropologist Fred Smith of Loyola University Chicago. Mating between humans and Neandertals could have produced at least some of those fossils, he says. One example: A shift toward smaller, humanlike facial features on Neandertal skulls from Croatia's Vindija Cave. Neandertals lived there between 32,000 and 45,000 years ago. Smith has long argued that ancient humans interbred with Neandertals at Vindija Cave and elsewhere.

Ackermann agrees. Ancient human skulls with especially large nasal cavities and unusually shaped braincases actually represent human-Neandertal hybrids, she suggests. She points to fossils, dating to between 80,000 and 120,000 years ago, found at the Skhul and Qafzeh caves in Israel.

Eurasian Neandertals mated with members of much larger *H. sapiens* groups before getting swamped by the African newcomers' overwhelming numbers, Smith suspects. He calls it "extinction by hybridization." Despite disappearing physically, "Neandertals left a genetic and biological mark on humans," he says.

Some Neandertal genes eluded extinction, he suspects, because they were a help to humans. Several genetic studies suggest that present-day humans inherited genes from both Neandertals and Denisovans that assist in fighting infections (*SN: 3/5/16, p. 18*).

Helpful blends

One physical characteristic of hybridization in North American gray wolves is also a sign of interbreeding's health benefits. Genetic exchanges with coyotes and dogs have helped wolves withstand diseases in new settings, says UCLA evolutionary biologist Robert Wayne.

"There are few examples of hybridization leading to new mammal species," Wayne says. "It's more common for hybridization to enhance a species' ability to survive in certain environments."

Despite their name, North American gray wolves often have black fur. Wayne and his colleagues reported in 2009 that black coat color in North American wolves stems from a gene variant that evolved in dogs. Interbreeding with Native American dogs led to the spread of that gene among gray wolves, the researchers proposed. The wolves kept their species identity, but their

coats darkened with health benefits, the scientists suspect. Rather than offer camouflage in dark forests, the black-coat gene appears to come with resistance to disease, Wayne said at the anthropology meeting. Black wolves survive distemper and mange better than their gray-haired counterparts, he said.

Similarly, DNA comparisons indicate that Tibetan gray wolves acquired a gene that helps them survive at high altitudes by interbreeding with mastiffs that are native to lofty northern Asian locales. Intriguingly, genetic evidence also suggests that present-day Tibetans inherited a high-altitude gene from Denisovans or a closely related ancient population that lived in northeast Asia.

Labeling gray wolf hybrids as separate wolf species is a mistake, Wayne and colleagues contend (*SN: 9/3/16, p. 7*). Hybrids smudge the lines that scientists like to draw between living species as well as fossil hominid species, Wayne says.

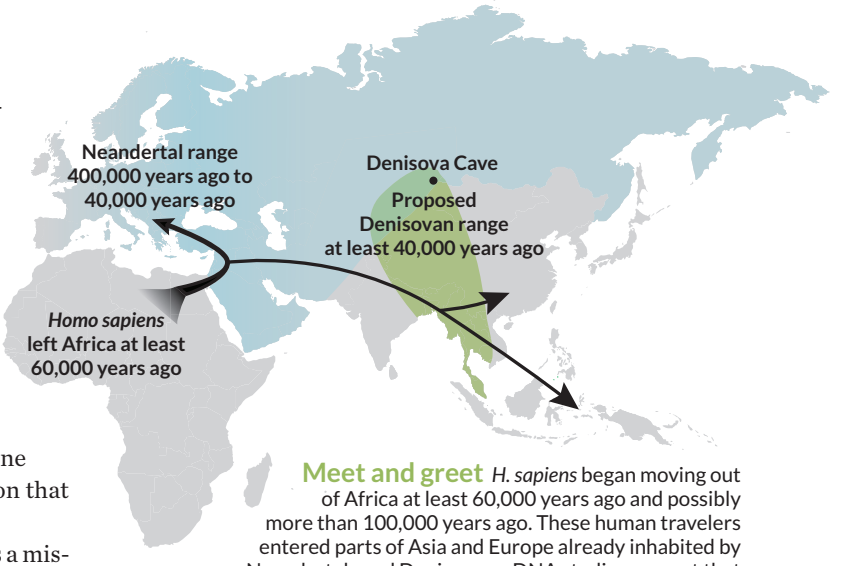
Making contact

Like wolves, ancient hominids were medium-sized mammals that traveled great distances. It's possible that an ability to roam enabled humans, Neandertals and Denisovans to cross paths in more populated areas, resulting in hybrid zones, paleoanthropologist John Hawks of the University of Wisconsin–Madison suggests.

Hominids may have evolved traits suited to particular climates or regions. If so, populations may have rapidly dispersed when their home areas underwent dramatic temperature and habitat changes.

Instead of slowly moving across the landscape and stopping at many points along the way, hominid groups could have trekked a long way before establishing camps in areas where other hominids had long hunted and foraged. Perhaps these camps served as beachheads from which newcomers ventured out to meet and mate with the natives, Hawks says.

Hybridization of North American gray wolves with Native American dogs may have endowed some wolves with an immunity-boosting gene and a black coat.



Meet and greet *H. sapiens* began moving out of Africa at least 60,000 years ago and possibly more than 100,000 years ago. These human travelers entered parts of Asia and Europe already inhabited by Neandertals and Denisovans. DNA studies suggest that interbreeding followed, leaving a genetic and biological mark on people today. SOURCE: S. VATTATHIL AND J.M. AKEY/*CELL* 2016

All ancient hominid populations were genetically alike enough, based on ancient DNA studies, to have been capable of interbreeding, Hawks said at the anthropology meeting. Specific parts of Asia and Europe could have periodically become contact areas for humans, Neandertals, Denisovans and other hominids. Beneficial genes would have passed back and forth, and then into future generations.

Ackermann sees merit in that proposal. Hominid hybrid territories would have hosted cultural as well as genetic exchanges among populations, she says, leading to new tool-making styles, social rituals and other innovations.

"These weren't necessarily friendly exchanges," Ackermann says. Many historical examples describe cultural exchange involving populations that succumb to invaders but end up transforming their conquerors' way of life.

However genes, behaviors and beliefs got divvied up in the Stone Age, a mix of regional populations — including Neandertals and Denisovans — can be considered human ancestors, she theorizes. They all contributed to human evolution's braided stream.

That's a controversial view. Neandertals and Denisovans lived in relatively isolated areas where contact with other hominid populations was probably rare, says paleoanthropologist Matthew Tocheri of Lakehead University in Thunder Bay, Canada. Random DNA alterations, leading to the spread of genes that happened to promote survival in specific environments, played far more important roles in human evolution than occasional hybridization did, Tocheri predicts.

Neandertals and Denisovans can't yet boast of being undisputed hybrid powers behind humankind's rise. But a gallery of interbreeding animals could well help detect hybrid hominids hiding in plain sight in the fossil record. ■

Explore more

■ Rebecca Ackermann *et al.* "The hybrid origin of 'modern' humans." *Evolutionary Biology*. March 2016.

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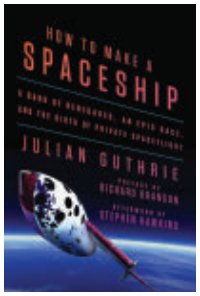


How to Make a Spaceship
Julian Guthrie
PENGUIN PRESS, $28

BOOKSHELF

XPRIZE launched new kind of space race

On the 47th anniversary of Sputnik's launch, former Navy pilot Brian Binnie flew a rocket-powered ship past the brink of outer space.

Named *SpaceShipOne*, the ship cruised up 112 kilometers, then plunged back to Earth, wings flared like a shuttlecock to slow its descent. *SpaceShipOne*'s October 4, 2004, flight, the second in two weeks, earned its makers fame and the Ansari XPRIZE.

The $10 million prize, created in 1996, aimed to spawn a fantastical new kind of tourism. One day, perhaps, ordinary people could book a ride on a rocket and gaze down on Earth from the blackness of space.

It was a prize to ignite the private space industry and to "bring about change in the stagnant aerospace world," said XPRIZE founder Peter Diamandis. To win, contestants had to build a fully reusable manned spacecraft — something not even NASA has achieved (though the space shuttle came close).

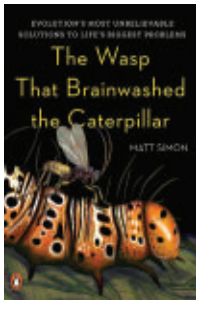
In *How to Make a Spaceship*, journalist Julian Guthrie follows a handful of teams from around the world on the race to win the prize. She gives readers a front-row seat to a rocket launch in Romania, a crash landing in Texas and spaceship building in California's Mojave Desert.

Guthrie introduces the people behind the tech stuff, too. They're engineers, pilots, airplane designers and more, and they're so fired up about getting to space that they tap savings accounts, pull all-nighters and strap themselves into carbon fiber cockpits for test flights. These characters give Guthrie's story lift, offering examples of inventiveness and drive as inspiring as the idea of spaceflight itself.

But frustration ensues, felt most keenly by Diamandis. The real challenge seems to be money. Diamandis, a doctor, entrepreneur and space aficionado, spent years securing the prize's funding, knocking on the doors of nearly every famous billionaire around, including Richard Branson, Jeff Bezos and Elon Musk. (Eventually, the Ansari family, which earned its fortune in telecommunications, stepped in to sponsor the prize.)

But today the future of private spaceflight remains uncertain. *SpaceShipOne* now hangs in a museum, and *SpaceShipTwo* (known as *VSS Enterprise*) tore apart during a 2014 test flight. And despite successes, in September, a rocket from Musk's aerospace company, SpaceX, burst into flames during a prelaunch test.

A second version of *SpaceShipTwo*, *VSS Unity*, may begin test flights this fall. Owned by Virgin Galactic, *VSS Unity* could be the first to offer spaceflights to paying customers. Making a spaceship is a dangerous business to be sure, but as Guthrie so vividly shows, some people will risk anything to reach the stars. — *Meghan Rosen*



The Wasp That Brainwashed the Caterpillar
Matt Simon
PENGUIN BOOKS, $20

BOOKSHELF

Meet Earth's most fanciful creatures

Writer Matt Simon begins his new book with a bleak outlook on life: "In the animal kingdom, life sucks and then you die." But thanks to evolution — which Simon calls "the most majestic problem-solving force on planet Earth" — some critters have peculiar adaptations that make life suck a little less (though sometimes at the expense of other species).

From mustachioed toads to pink fairy armadillos, Simon's debut book, *The Wasp That Brainwashed the Caterpillar*, recounts an eclectic cadre of animals that use creative and often bizarre solutions to find love, a babysitter, a meal or a place to crash.

Take, for instance, the book's title characters. Technically, it's the wasp larvae that brainwash the caterpillar. Once a female *Glyptapanteles* wasp deposits eggs into a living caterpillar, she takes off, leaving the oblivious host to babysit her young. After hatching, some larvae stay behind to release chemicals that manipulate the caterpillar's brain. Once their siblings erupt from the poor creature's body, the caterpillar mindlessly protects the youngsters from predators.

Mind control isn't unique to wasps — flies and even fungi do it, too. But the book is about more than just the seemingly diabolical tactics of parasites. Prey species also have skin, or in some cases snot, in the game.

Hagfish, eel-like fish that scavenge the seafloor, eject thick, slimy mucus to clog the gills of sharks that try to make a meal of the hagfish. And the East African crested rat protects itself from dogs and other predators by slathering its fur with the chewed-up bark of the *Acokanthera* tree, traditionally used by indigenous hunters to make poison arrows. "A species may gain an edge, but any sort of edge is answered," Simon writes. And so marches on the arms race of natural selection.

The author never dives deeply into exactly how these creatures evolved. The book is a quick, fun read that's light on science and heavy on snark (not to mention a lot of anthropomorphizing). Readers familiar with Simon's column for *Wired*, "Absurd Creature of the Week," may already be acquainted with some of these animals. But the book is packed full of even more fascinating facts that will both impress and creep out. — *Cassie Martin*

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Science News for Students

***Science News for Students* (sciencenewsforstudents.org)** is an award-winning, free online magazine that reports on research and new developments across scientific disciplines for inquiring minds of every age from middle school on up.

Science News for Students highlights women in STEM

Not that long ago, girls were actively discouraged from careers in science, technology, engineering and math. And women's representation in STEM fields reflected this. In the 1960s, for instance, just one in every 100 engineers was a woman. The situation has improved, but today, women still make up only 27 percent of people working in science and engineering.

Science News for Students attempts to shed some light on this underrepresentation in a feature story reported by award-winning writer Stephen Ornes. In it, he delves into the many challenges that girls and women can face when pursuing an education or career in STEM. One is the misguided stereotype that boys are naturally better than girls in these subjects. That idea, though completely untrue, is deeply ingrained in society and can have a range of effects. In another article, "Adults can sabotage a student's path in science or math," Sarah Zielinski, *SNS*' managing editor, describes how parents, teachers and other adults can turn kids away from STEM through seemingly innocent activities, such as helping children with their homework. So *Science News for Students* gathered some advice that women in STEM have for girls who also want to pursue careers in these areas: Follow your passion, work hard, ignore the doubters and find peers who are just as into STEM as you are.

Illustrating the feature story are images and videos of women currently working in STEM fields. These women submitted their stories to *Science News for Students* in response to a request by Bethany Brookshire on the *Eureka! Lab* blog. Brookshire expected to receive 10 or 20 responses. Instead, more than 150 women got back to her from across STEM and around the world. They submitted images, audio and video from 18 countries and all seven continents — even Antarctica. All of these women are being featured in a series on *Eureka! Lab*, where their stories can inspire the next generation of scientists, engineers and mathematicians.

TABIA SANTOS (above) was a research assistant in a neuroscience lab at the Columbia University Medical Center. Now she is using what she has learned as she trains to be a surgeon at the Hofstra School of Medicine in Hempstead, N.Y. (where she is student body president). VANESSA LUCIEER (top right) works at the University of Tasmania in Australia as a marine spatial analyst at the Institute for Marine and Antarctic Studies. She studies acoustic data to map the seafloor. ANNE GALYEAN (bottom right) develops sensors to discover where chemicals are or aren't present. To study how chemicals affect the environment, researchers have to first be able to find them. She's a scientist at the Colorado School of Mines in Golden.

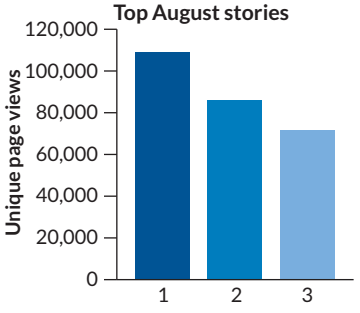
CLOCKWISE FROM LEFT: JULIE THOMPSON; IMAS; MATTHEW DELORME

Read more: www.sciencenewsforstudents.org/article/women-in-STEM

AUGUST 20, 2016

Readers' choice

Science News loves data and so do our readers. Take a look at the stats for three online-only stories that resonated with readers in August.



1. A new 'Einstein' equation suggests wormholes hold key to quantum gravity, by Tom Siegfried (*SN Online: 8/17/16*).
2. A prayer for Archimedes, by Julie Rehmeyer (*SN Online: 10/03/07*).
3. Backwash from nursing babies may trigger infection fighters, by Laura Sanders (*SN Online: 9/15/15*).

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Metallic odyssey

Scientists are getting closer to turning hydrogen into a solid metal, ***Emily Conover*** *reported in "Chasing a devious metal" (SN: 8/20/16, p. 18).*

"If, as some scientists think, [metallic hydrogen] formed under intense pressure remains solid at room temperature, why don't we find any on our planet?" asked **Michael Brostek**. "If formed in a star that subsequently explodes, wouldn't some make its way to us like other elements we have that were formed within stars?"

"We do not believe that conditions exist in stars for solid metallic hydrogen to form," says Harvard University physicist **Isaac Silvera**. "The temperatures are too high." Above a certain temperature, solid metallic hydrogen would convert to a more stable phase. If that transition temperature is low enough, it could explain why we don't see metallic hydrogen on Earth.

The relationship between metallic hydrogen and everyday hydrogen is similar to the relationship between diamond and graphite, a more stable phase. "If diamond is heated to a few thousand degrees Kelvin, it will convert to graphite," **Silvera** says. "I do not recommend experimenting with a valuable stone!"

Pass the salt

In "Quenching society's thirst" (SN: 8/20/16, p. 22), ***Thomas Sumner*** *reported on next-generation desalination technologies that use improved and energy-efficient materials. Desalination efforts could help meet the world's growing need for freshwater.*

Reader **Sallie Reynolds** wondered what happens to the salt left behind.

Most desalination plants end up with briny leftover water that they pump deep underground (away from sources of drinking water) or dilute into a nearby water source, such as the ocean. But some facilities extract salt crystals from the desalination leftovers using evaporation ponds. In solid form, the salt can be stored, transported or dumped at landfills. "This salt could potentially be used for industrial purposes, such as glassmaking, tanning, metal refining and cement manufacturing," **Sumner** says. "The downside of evaporation ponds is that you need a lot of available space and a relatively warm, dry climate."

Sun spotting

The sun's magnetic field rises to the surface no faster than about 500 kilometers per hour — the same speed that gas rises and falls within the sun. Moving gas may help guide the field, ***Christopher Crockett*** *reported in "Gas steers sun's magnetic fields" (SN: 8/20/16, p. 5).*

Mary Jane Knox wondered whether planets, moons and other celestial bodies in the solar system might contribute to the formation of sunspots and other solar activity: "Could they be reflecting the sun's rays back on it causing hot spots which might allow the eruption of the magnetic fields?"

Planets don't have anything to do with dark spots on our sun, **Crockett** says. Sunspots, which are cooler than the surrounding gas, are caused by strong magnetic fields that prevent hot gas from bubbling up to the surface. "Planets were once considered culprits," he notes. In 1972, aerospace engineer Karl Wood calculated that periodic planetary alignments seemed to correspond to upticks in sunspot activity. But later work showed no link.

For other stars, planets may play a role in boosting solar activity. Some stars host planets roughly the size of Jupiter on very tight orbits. Magnetic fields from a few of these worlds appear to trigger hot spots on their parent stars.

Correction

"Quenching society's thirst" (*SN: 8/20/16, p. 22*) states that a floating desalination farm would cover three-tenths of a square kilometer of ocean. In fact, each floating farm would stretch 300 meters long by 100 meters wide, covering only three-hundredths of a square kilometer of ocean. This area could provide about a square kilometer's worth of stacked cultivable surfaces, depending on the crop.

A 19th versus 21st century peek inside a child mummy

X-rays were the iPhone 7 of the 1890s. Months after X-rays were discovered in late 1895, German physicist Walter Koenig put the latest in tech gadgetry to the test by scanning 14 objects, including the mummified remains of an ancient Egyptian child (above, right). Koenig's image of the child's knees (above, left) represented the first radiographic investigation of a mummy.

Originally collected by explorer-naturalist Eduard Rueppell in 1817, the specimen lacked any sort of decoration that might link it to a particular dynasty or time period. Now, biological anthropologist and Egyptologist Stephanie Zesch of the Reiss Engelhorn Museum in Mannheim, Germany, and colleagues have scanned the mummy with modern CT scans (several examples at right) and learned that the child was a boy. His teeth (A) suggest that he was 4 to 5 years old when he died. Radiocarbon dating places him in the Ptolemaic period, between 378 and 235 B.C., the researchers report online July 22 in the *European Journal of Radiology Open*.

The team also diagnosed a slew of health conditions: a common chest wall deformity called pectus excavatum, or sunken chest (B); bone density marks called Harris lines in his leg bones that indicate physiological stress (C) and an enlarged liver (D). The team attributes the distended liver to a parasitic infection like schistosomiasis, which is common in Egypt and sometimes lethal. Without any obvious signs of trauma, however, "it's impossible to determine cause of death," Zesch says. Even with the all-seeing power of today's CT scans, the culprit behind the boy's demise remains under wraps. *— Helen Thompson*

1896 X-RAY: © GERMAN RÖNTGEN MUSEUM; ALL OTHER IMAGES: S. ZESCH *ET AL/EURO. J. RADIOL. OPEN* 2016

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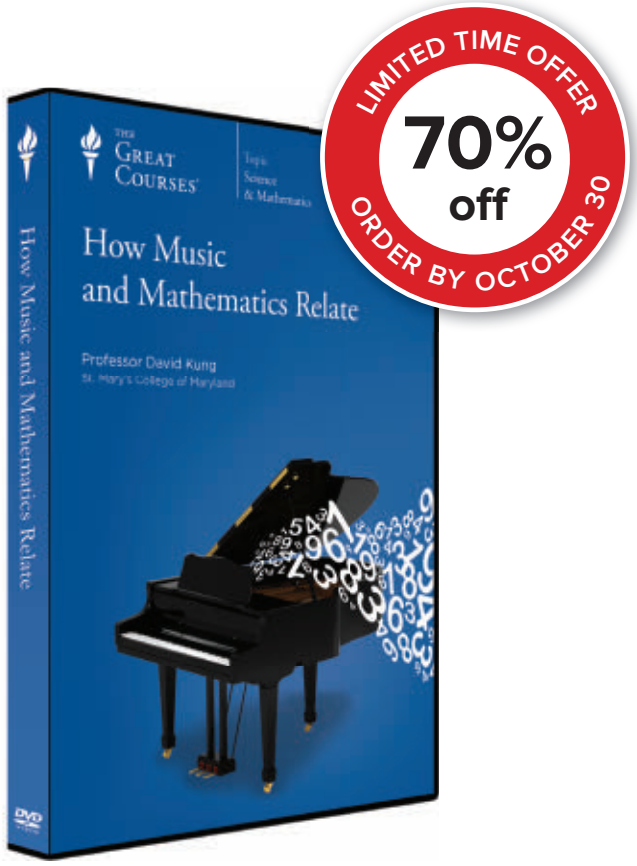

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