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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
AUGUST 6, 2016

Incredible Shrinking Telescopes

Zika May Be Peaking

Spiders Bearing Gifts

Farming's Origins Revisited

Rare HISTORY

What gold and other iron-loving metals reveal about early Earth

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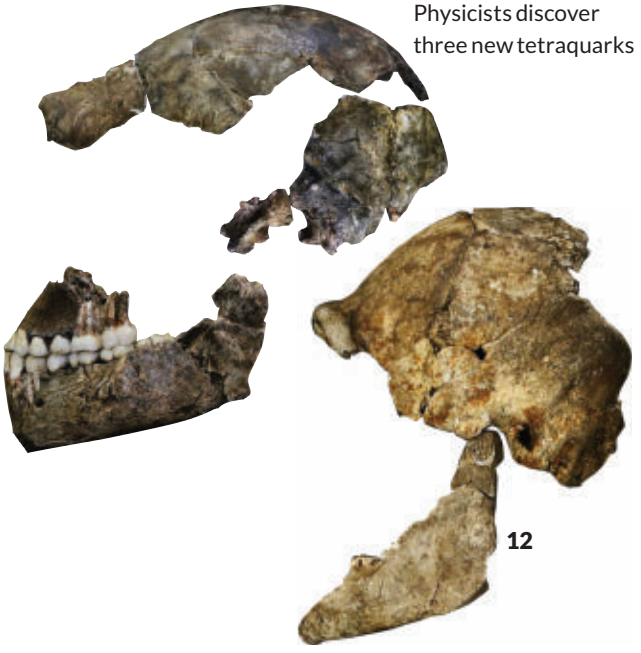
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SOCIETY UPDATE
Exciting stories from *Science News for Students*

COVER There's a reason gold and other iron-lovers are rare and precious: They were pulled deep into Earth's core long ago. *Albert Russ/Shutterstock*

CLOCKWISE FROM TOP LEFT: LOCKHEED MARTIN; KAREN M. WARKENTIN; CC JOHN HAWKS_WITS UNIVERSITY

Science finds many tricks for traveling to the past

Talking about her cover story on what iron-loving elements are telling geologists about the Earth's deep past, Alexandra Witze likens these rare metals to time travelers. They can tell you, she says, what was happening more than 4.5 billion years ago, during the first 50 million years of our planet's existence. By then the Earth's molten interior had begun to settle into its current layer cake form: a dense, solid inner core surrounded by an outer liquid core — both rich in iron and metals such as gold, platinum, ruthenium and others that tend to form alloys with iron. The scarcity of these metals in the outer layers of the planet — the mantle and crust — make them precious to us.

Their high melting points and other properties help them resist change, allowing geoscientists to use them as fingerprints that mark events in the distant past. With new, more precise analytic techniques, scientists can now measure the amounts of these iron-loving metals relative to other elements to deduce what happened to them over eons of time. These traces are found in some very old rocks, Witze reports on Page 22, such as 3.8-billion-year-old deposits in Greenland. But the metals also show up as ancient time capsules in younger rock. Studying these traces reveals the imperfect mixing of the mantle and can provide insight into outstanding questions, such as why amounts of these metals differ in the mantles of the moon and Earth.

Science is surprisingly adept at this type of virtual time travel. Researchers have repeatedly come up with ways to discover facts about the distant past. In this issue of *Science News* alone, several new findings illustrate the ability of science to figure out things that would seem impossibly difficult to know. A black hole in a distant galaxy formed over 13 billion years ago, for example, so long ago that it's hard to even imagine reconstructing the events that led to its birth. But scientists have now pieced together clues, Christopher Crockett reports on Page 7, that it formed by the direct collapse of a massive gas cloud, rather than from the death of a massive star (the more common origin of black holes).

Reconstructing the evolution of the tail has been stymied by a lack of fossils from creatures that led the transition from water to land. But that hasn't stopped scientists eager to explore the biomechanics of fishlike animals attempting to hop out of the water and up a slope. Studies of big-tailed fish called mudskippers highlight the utility of a tail in balancing flipper-hops up a sandy incline, Susan Milius reports on Page 13. To describe the math, scientists built a robot and made it scale an unsteady hill of shifty poppy seeds or plastic bits. Their conclusion: The tail could have been a big assist to flippered creatures emerging on sandy shores several hundred million years ago.

The story on *Homo naledi* by Bruce Bower (Page 12) shows why sometimes scientists might just prefer to actually time travel. Efforts to date the bones of this hominid species have proved frustrating; the latest estimate, 912,000 years old, was deduced from evolutionary trees. Knowing how old *H. naledi* actually is might reveal the diversity of relatively recent hominid species, and perhaps help piece together the story of how *Homo sapiens* became the sole survivors. That's some time travel I'd be interested in booking. — *Eva Emerson, Editor in Chief*

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Customer service: member@societyforscience.org
Editorial/letters: editors@sciencenews.org
Sponsor content: ads@societyforscience.org
Science News (ISSN 0036-8423) is published biweekly by Society for Science & the Public, 1719 N Street, NW, Washington, DC 20036.
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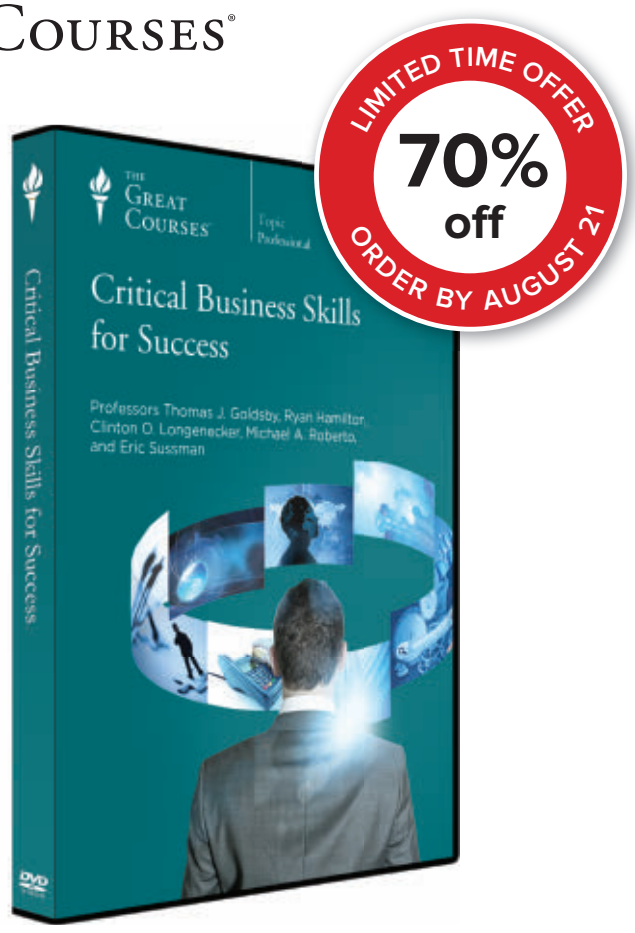

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Excerpt from the August 6, 1966 issue of *Science News*

50 YEARS AGO

Seafood is exhaustible

Man is capable of using up the resources of the ocean ... and if he is going to exploit them intelligently, he has a lot to learn.... The world's annual fish catch went up from 23 million to 46 million tons between 1953 and 1963, and is now estimated at 50 million tons, but scientists do not expect it to double every decade indefinitely.

UPDATE: The fish catch hasn't doubled every decade, but increasing catches still cause concern. The Fisheries and Aquaculture Department of the United Nations reported a worldwide catch of more than 89 million metric tons in 2010 and 93 million tons in 2014. These numbers may be an underestimate, ignoring small-scale fisheries, scientists reported in 2016. While governments set limits on fishing certain species, some critically endangered and threatened species — such as Chinese pufferfish and Pacific bluefin tuna — remain food favorites.

IT'S ALIVE

Self-preservation may mean bringing a gift

Here's another reason to show up with a box of chocolates: It doubles as a shield if she bites.

Edging slowly toward a female, male nursery web spiders clutch in front of their bodies their version of courtship candy: a big dead insect wrapped in white silk. "It's pretty spectacular actually," says Søren Toft of Denmark's Aarhus University. It's also prudent, he and colleague Maria Albo reported in the May *Biology Letters*. Sometimes female *Pisaura mirabilis* spiders just eat males that come calling. In a lab test, however, suitors bearing gifts were almost one-third as likely to be devoured as males that showed up empty-legged.

Males of diverse animal species go wooing with gifts of food or showy things. Biologists have long discussed the evolution of these nuptial gifts, including the possible benefits for male self-defense.

A different lab's experiment with nursery web spiders had failed to find a defensive benefit because so few courtships in this species end in death. But Toft had been watching the spiders for years and had seen enough fatal flirtations to suspect the gifts, in part, function as shields. So he and Albo set up an experiment with enough mating opportunities to see lives lost — and saved. When a female pounced, "she actually hit the gift with her jaws," he says. When that happened, the encounter turned from murder to mating.

Nursery web spiders — most of the time — are more likely to pounce on flies and other yummies than on each other. But dates do go wrong.

Pouncing females are rare in this species. Typically, a female grabs the present and punches in her mouthparts to eat. The male then releases his grip and, while the female feeds, transfers sperm using organs near his mouth. The mating lasts, Toft says, "as long as it takes [her] to eat the fly."

In observations of nursery web spiders in the wild, "30 percent of males have a worthless gift," reports Albo, now at Clemente Estable Institute of Biological Research in Montevideo, Uruguay. These sneaks have sucked the innards out of prey and packaged the inedible remains or some other debris into a silk-wrapped lump. Cheating doesn't pay much: These matings last only as long as it takes the female to discover her pretty present is no gift. — *Susan Milius*

It's an iffy moment when a male nursery web spider (left), bearing a gift wrapped in white silk, makes his move toward a female. She may bite the offering and accept him, grab the present and run or skip the gift and eat him instead. For mating males, gift-giving may be a smart move.

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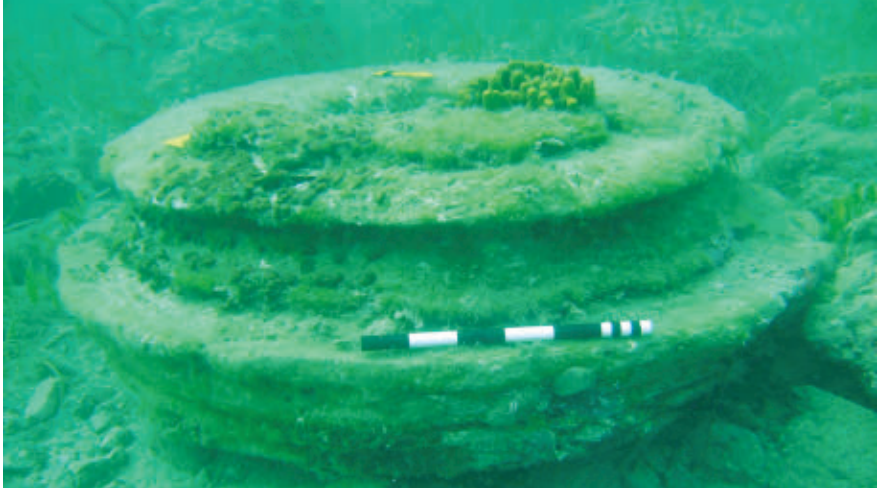
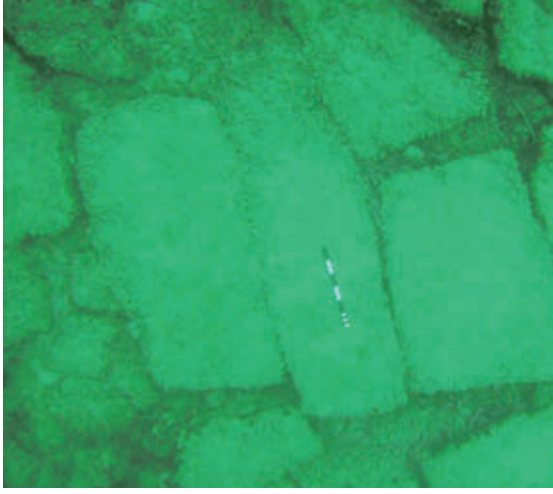




WHAT WERE THEY THINKING?

Underwater city built by microbes, not people

When divers discovered what appeared to be ancient stonework off the coast of the Greek island of Zakynthos in 2013, archaeologists thought the odd rocks might be the ruins of an ancient city. But among the columns, bagel-shaped rings and paving stone–like rocks, they found no telltale pottery shards or other artifacts. Soon after, geochemist Julian Andrews of England's University of East Anglia and colleagues dove down to the supposed ruins and collected samples.

Turns out, the so-called Lost City of Zakynthos was built by microbes, not by ancient Greeks. What appear to be submerged Greek ruins are actually the fossilized remains of sediments laid down by methane-chomping microbes millions of years ago, the researchers report in the September *Marine and Petroleum Geology*.

The formations are the creation of microbes living in vents below the seafloor where methane-rich fluids seeped toward the seafloor surface around 3 million to 4 million years ago, the researchers' analysis suggests. As those microbes feasted on the methane, their excretions produced carbonate minerals that formed large hollow structures. Over time, erosion exposed those structures on the seafloor. While not an archaeological treasure trove, the finding could help scientists learn more about the region's geologic past.

The researchers even penned a helpful maxim to mark their find: "Columns and pavements in the sea, not always antiquities will be." *—Thomas Sumner*

Methane-eating bacteria helped form these formations in the Mediterranean Sea. The odd structures, in a range of shapes, were originally misidentified as Greek ruins.

ALL: UNIV. OF ATHENS

SCIENCE STATS

U.S. still leads in fatal motor vehicle crashes

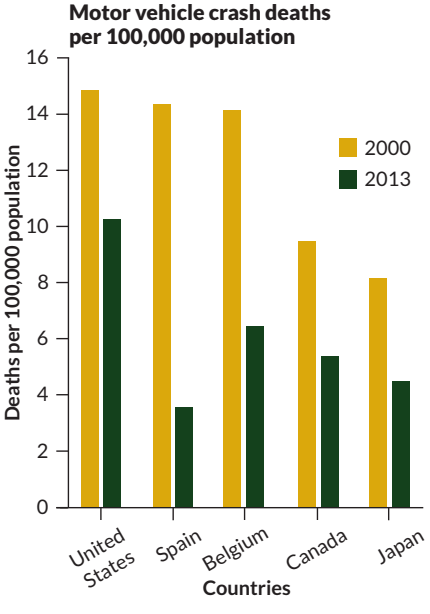
U.S. drivers love to hit the road. The problem is doing so safely.

In 2013, 32,894 people in the United States died in motor vehicle crashes. Although down since 2000, the overall death rate — 10.3 per 100,000 people — tops 19 other high-income countries, the U.S. Centers for Disease Control and Prevention reported July 6. Belgium is a distant second with 6.5 deaths per 100,000. Researchers reviewed World Health Organization and other data on vehicle crash deaths, seat belt use and alcohol-impaired driving in 2000 and 2013.

Canada had the highest percentage of fatal crashes caused by drunk drivers: 33.6 percent. New Zealand and the United States tied for second at 31 percent. But Canada and 16 other countries outperformed the United States on seat belt use — even though, in 2013, 87 percent of people in the United States reported wearing safety belts while riding in the front seat.

Spain saw the biggest drop — 75 percent — in its crash death rate. That country improved nearly all aspects of road safety, including decreasing alcohol-impaired driving and increasing seat belt use, the researchers say. *—Alex Maddon*

SOURCE: E.K. SAUBER-SCHATZ *ET AL*/*MMWR* 2016



HUMANS & SOCIETY

Farming spread from two groups

Separate Near East cultures took agriculture east, west

BY AMY MCDERMOTT

The cradle of agricultural civilization was culturally diverse.

Two societies lived side-by-side 10,000 years ago in the Near East, where humans first learned to farm, a new study finds. Over time, one group expanded west, carrying agriculture into Europe. The other spread east, taking its traditions to South Asia, scientists report online July 14 in *Science*.

"We thought the people of the Fertile Crescent were one group genetically and culturally, but in fact they were probably two or more," says paleogeneticist Joachim Burger of the University of Mainz in Germany, who led the study. It's time to rethink the textbook idea that modern Europeans and South Asians descend from a single Stone Age people, he says.

This year, Burger's team reported in the *Proceedings of the National Academy of Sciences* that the first European farmers came from western Anatolia near present-day Istanbul. Scientists suspected that the Anatolians had started out farther east, at sites in Iran, Iraq, Syria and southeastern Turkey, where farming began about 10,000 years ago.

DNA in a bone fragment, discovered in this cave in the Zagros region of Iran, is from a 7,000-year-old farmer — evidence that two different groups practiced early farming.

Fertile fields A new study analyzed remains of ancient Iranian farmers from two sites, Wezmeh Cave and Abdul Hosein, in the Fertile Crescent (shaded). Their descendants spread to southern Asia; descendants of Anatolian farmers from sites like Barcin Höyük went to Europe.

But DNA from 7,000- to 10,000-year-old remains, found at two ancient Iranian settlements, told a different story. Carbon and nitrogen ratios in bones showed that people there ate more cultivated cereals than meat. They farmed and lived several thousand years before the Anatolians, but genetic analysis showed that the two bloodlines were not closely related.

In fact, the two groups had probably separated more than 45,000 years earlier, just after humans left Africa, says statistical geneticist Garrett Hellenthal of University College London, a coauthor of the new study. Even 10,000 years ago, the ancestors of Iranians and Anatolians had already been isolated for 36,000 to 67,000 years.

Evidence of Anatolian farming is a few thousand years younger than the Iranian remains, but both cultures "must have known each other to some extent," Burger says.

People in the two groups probably looked different and spoke separate languages, Burger says. They didn't intermarry, but undoubtedly shared the ideas of early agriculture. It would have taken centuries to convert from hunting and gathering to an agrarian way of life.

"Domestication of wild beasts is nothing you do over the weekend," Burger says. And "you don't invent something crazy and complicated like farming coincidently at the same time."

Not everyone agrees. "The change from hunting to farming happened probably several times," says archaeologist Roger Matthews of the University of Reading in England. While both the Anatolians and Iranians were farmers, "it's not actually the same idea they're coming up with," he says. In the east, early agrarians focused on goats as well as barley and wheat, while in the west, shepherds raised sheep and other foods. Both probably took separate steps toward farming, Matthews says.

Sometime after farming was developed, the two cultures began to move apart. Why they spread so differently is still a mystery. More DNA from ancient people east of the Fertile Crescent is needed to confirm that people spread from Iran eastward, says anthropologist Christina Papageorgopoulou of the Democritus University of Thrace in Greece. She coauthored the Anatolian study but wasn't involved in the new work.

More DNA from the Fertile Crescent could also reveal a border between ancient Anatolians and Iranians. "I cannot imagine there was a connection," she says. If there had been, scientists would have seen it in the DNA. "I think there is some kind of barrier there." ■

FROM TOP: J. BURGER; FEREIDOUN BIGLARI

ATOM & COSMOS

Black hole born without stellar parent

Direct collapse of gas may explain observations in remote galaxy

BY CHRISTOPHER CROCKETT

A remote galaxy might harbor a type of black hole that arises directly from a massive cloud of gas rather than forming after the death of a star. This rare specimen could explain how some galaxies built gargantuan black holes in the first billion years or so after the Big Bang.

The galaxy, known as CR7, is unusual (*SN: 7/25/15, p. 8*). It blasts out more ultraviolet radiation than other galaxies that lived at the same time, roughly 13 billion years ago (about 800 million years after the Big Bang). The gas in CR7 also appears to lack elements such as carbon and oxygen, which are forged within stars and then ejected into space. One idea is that CR7 is giving birth to first-generation stars, similar to the first stars ever created in the universe. Another hypothesis is that CR7 harbors the first known "direct collapse" black hole, one that forms when a blob of interstellar gas collapses under its own weight without first forming stars.

Galaxy CR7 (illustrated) could harbor an unusual black hole that formed directly from a massive gas cloud, a new study suggests.

A black hole is more likely, Aaron Smith of the University of Texas at Austin and colleagues suggest in the Aug. 11 *Monthly Notices of the Royal Astronomical Society*. They developed computer simulations that explore how interstellar gas interacts with the harsh radiation from primordial stars or with a large black hole. Smith and colleagues found that the light from a cache of hot, young stars can't explain why a parcel of gas is racing away from CR7 at about 580,000 kilometers per hour. What can push the gas is radiation from a superheated disk of debris swirling around a black hole about 100,000 times the mass of the sun.

If CR7 does host a black hole, it would be the first evidence of one forming from clouds that haven't given birth to stars yet. Astronomers struggle to explain how some supermassive black holes could have formed in about 1 billion years out of only smaller black holes merging. "There's just not enough time to do that," Smith says. A direct-collapse black hole, however, creates a massive seed all in one go, jump-starting the growth of a behemoth that will eventually weigh as much as several billion suns.

"This is definitely a good step forward," says David Sobral, an astrophysicist at Lancaster University in England who discovered CR7 in 2015. But it's too early to say whether a black hole or a group of stars is powering CR7, he says. "I've tried to stay a bit away from it and argue that what we need is new observations instead of taking sides." With the available data, he says, it's hard to distinguish between stars or a black hole. ■

M. KORNMESSER/ESO

BODY & BRAIN

Gut bacteria boost risk after stroke

Mouse study suggests fecal transplants as countermeasure

BY RACHEL EHRENBERG

When mice have a stroke, their gut reaction can amp up brain damage.

A series of new experiments reveals a surprising back-and-forth between the brain and the gut in the aftermath of a stroke. In mice, this dickering includes changes to the gut microbial population that ultimately lead to even more inflammation in the brain.

There is much work to be done to determine whether the results apply to humans. But the research, published in the July 13 *Journal of Neuroscience*, hints that poop pills laden with healthy microbes could one day be part of post-stroke therapy.

The work also highlights a connection between gut microbes and brain function that scientists are only just beginning to understand, says Ted Dinan of the Microbiome Institute at University College Cork, Ireland. There's growing evidence that gut microbes can influence how people experience stress or depression, for example (*SN: 4/2/16, p. 23*).

"It's a fascinating study" says Dinan, who was not involved with the work. "It raises almost as many questions as it answers, which is what good studies do."

Following a stroke, the mouse gut becomes temporarily paralyzed, leading to a shift in the microbial community, neurologist Arthur Liesz of the Institute for Stroke and Dementia Research in Munich and colleagues found. This altered, less diverse microbial ecosystem appears to interact with immune system cells called T cells that reside in the gut. These T cells can either dampen inflammation or dial it up, leading to more damage, says Liesz. Whether the T cells further damage the brain after a stroke rather than soothe it seems to be determined by the immune system cells' interaction with the gut microbes.

Transplanting microbe-laden fecal matter from healthy mice into mice who had strokes curbed brain damage, the researchers found. But transplanting fecal matter from mice that had strokes into stroke-free mice spurred a fourfold increase in immune cells known to exacerbate inflammation in the brain.

Learning more about this interaction between the gut's immune cell and microbial populations will be key to developing therapies, says Liesz. "We basically have no clue what's going on there." ■

EARTH & ENVIRONMENT

Phytoplankton shells get acid test

Initial calcification gains with elevated CO_2 don't persist

BY THOMAS SUMNER

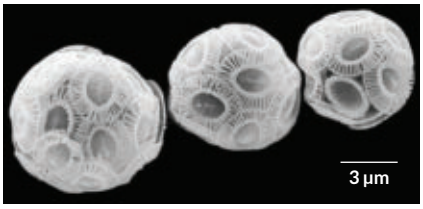
Armor-plated marine microbes surprised scientists a few years ago by recovering their shell-building prowess in the more acidic ocean conditions expected under future climate change. But those gains were short-lived, new research shows.

For four years, marine ecologist Lothar Schlüter and colleagues steeped successive generations of *Emiliania huxleyi* phytoplankton in seawater acidified by carbon dioxide. After an initial drop in shell calcification — a process that helps sequester CO_2 from the atmosphere — the microbes mostly restored their calcification activities within a year, the researchers had reported.

But as the experiment continued, the phytoplankton began making less and less shell material. By the end of the experiment, the phytoplankton in the acidified water were calcifying less than a population that hadn't been exposed to such harsh conditions, the researchers report July 8 in *Science Advances*.

"One year just isn't long enough to tell us something about how evolutionary adaptation will play out," says study coauthor Thorsten Reusch, a marine ecologist who works with Schlüter at the GEOMAR Helmholtz Center for Ocean Research in Kiel, Germany. In the future, the shell-making phytoplankton "may calcify even less than we assume today based on short-term experiments."

While ocean phytoplankton may ultimately follow a different evolutionary path than those in the lab, the work shows that the response to climate change is more complex than previously thought, Reusch says. There is a silver lining, though: When returned to present-day conditions, the phytoplankton bounced back to their original calcification rates. So even if acidification continues, the phytoplankton could quickly restart calcifying if conditions improved. "This isn't a case of 'use it or lose it,'" Reusch says.



In an experiment simulating expected ocean acidification conditions, shell-building rates of *Emiliania huxleyi* phytoplankton (shown) dropped, rebounded and then dropped again.

Photosynthetic plankton produce about half of Earth's oxygen and their sinking carcasses transport carbon from the ocean surface to the seafloor — key steps in the temperature-regulating carbon cycle. The weight of *E. huxleyi*'s shells serves as ballast during the descent, accelerating the carbon drawdown.

The shell-making process requires *E. huxleyi* to lower its own acidity by pushing protons out through its cell wall. But as the ocean becomes more acidic, that pushing requires more energy to overcome the increased acidity outside the cell. Many scientists worry that the energy cost could cause calcifying phytoplankton such as *E. huxleyi* to ultimately

GENES & CELLS

Donor mitochondria could alter aging

Mouse DNA study may have implications for 3-parent babies

BY AMY MCDERMOTT

For a "three-parent baby," getting disease-free mitochondrial DNA from a surrogate may do more than just avert disease: For better or for worse, a donor's mitochondria could also affect the course of aging, new research shows.

Two strains of mice — genetically identical except for the source of their mitochondria, the energy centers of cells — aged very differently, researchers report online July 6 in *Nature*. Even though both mouse strains had healthy mitochondrial DNA, the mice with mitochondria that did not come from the same source as the rest of their DNA fared better later in life. After two years, these mice showed fewer signs of aging and had a lower incidence of tumors.

The results don't necessarily mean that a mitochondrial transplant leads to a healthier life. This is just one case, researchers caution. Other DNA mixes and matches could turn out differently. But the study's finding does point to a larger relationship between mitochondrial DNA and aging and raises new questions about the long-term effects of creating three-parent babies.

What the new results mean for people is still unclear, says Michio Hirano, a neurologist at Columbia University Medical Center who was not involved in the study. But if the findings are true in humans, he says, "you can blame your mother for how you age."

Mitochondrial DNA is passed down from mother to child. Three-parent babies are created through an in vitro fertilization technique that substitutes a mother's diseased mitochondria for the healthy mitochondria of a surrogate (*SN: 11/17/12, p. 5*). In the procedure, which is legal in the United Kingdom and was deemed ethical by a U.S. panel of experts this year (*SN Online: 2/3/16*), a baby inherits its nuclear DNA — the majority of its genetic fingerprint — from mom and dad. But a small amount of DNA — just 37 genes — comes from the mitochondria of a second, healthy woman.

Mitochondria do more than just power cells. They also play big roles in cell-to-cell communication and metabolism. Over the last two decades, mitochondria have been implicated in aging but without conclusive evidence. The new research, Hirano says, "adds fuel to this debate."

In the study, José Enríquez of the Spanish National Center for Cardiovascular Research in Madrid and colleagues bred two strains of mice. The original

KAI T. LOHBECK/GEOMAR

give up their shells, slowing the CO_2 drawdown and worsening climate change.

The researchers began their tests with a single cell of *E. huxleyi* collected off the coast of Norway in 2009. Populations grown from this cell lived in containers of acidified seawater about the size of soda cans. Around 2,100 generations later, the acidity-acclimated phytoplankton population calcified about four-fifths as much shell material as a population kept in regular seawater before being plopped into acidified water.

That calcification decline could be an evolutionary trade-off, Reusch says. The shells probably protect *E. huxleyi* from predators and pathogens. But in more acidic waters, the energy cost of building shells may outweigh the benefits. The researchers plan to repeat the experiment, this time introducing predators to see if the added hazard makes the phytoplankton hold on to their shells.

"There are a lot of surprises in store for us in terms of the kinds of evolutionary responses these organisms can have," says oceanographer Tatiana Rynearson of the University of Rhode Island in Kingston. ■

strain was called C57/Black 6. A second strain of C57/Black 6 carried mitochondria from another kind of mouse called NZB. This mismatch mimicked the effects of a mitochondrial transplant. Early in life, normal C57 mice bulked up faster than those carrying NZB mitochondria and had 11 percent longer telomeres (protective caps at the ends of chromosomes that get shorter over time, so are used as a proxy for aging). But later in life, the mice with NZB mitochondria had longer telomeres and less fat in their muscles, and they had a lower risk of liver tumors at the end of their lives.

Young C57 mice "tend to be stronger," Enríquez says, probably because their mitochondrial and nuclear DNA are a good match and make efficient mitochondria. The weaker batteries in the mice with mismatched mitochondria may cause more cellular stress early on, he says, which may toughen up these mice to age more gracefully. ■

KARAGHEN HUDSON, MICHAEL ROSNACH

MATH & TECHNOLOGY

Heart cell stingray driven by light

Engineering feat could pave way for new artificial organs

BY MEGHAN ROSEN

Even robots can use a heart. Or heart cells, at least.

A new stingray bot about the size of a penny relies on light-sensitive heart cells to swim. Zaps of light force the bot's fins to flutter, letting researchers drive it through a watery obstacle course, Kit Parker of Harvard University and colleagues report in the July 8 *Science*.

The new work "extends the state of the art — very much so," says bioengineer Rashid Bashir of the University of Illinois at Urbana-Champaign. "It's the next level of sophistication for swimming devices."

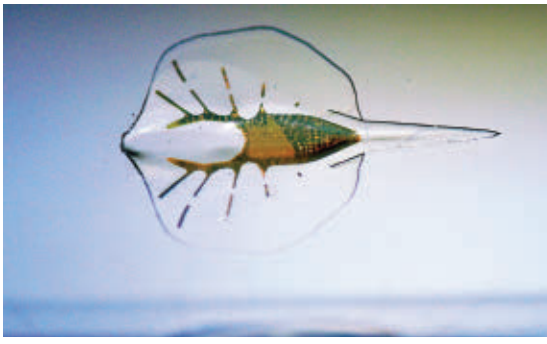
For decades, the field of robotics has been dominated by bulky, rigid machines made mostly of metal or hard plastic. But in recent years, some researchers have turned toward softer, squishier materials, such as silicones and rubbery plastics (*SN: 11/1/14, p. 11*). A small number of scientists have taken the technology one step further: combining soft materials with living cells.

So far, there's just a handful of papers on these hybrid machines, says Bashir, whose lab recently reported the invention of tiny, muscle-wrapped bots that inch along like worms in response to light.

In 2012, Parker's team built a robotic jellyfish out of silicone and heart muscle cells. Electrically stimulating the cells let the jellyfish push itself through water by squeezing its body into a bell shape and then relaxing. But, Parker says, "the jellyfish just swam." He and his colleagues couldn't steer it around a tank. They can, however, steer the stingray bot.

He explains the team's strategy with a story about his daughter. When she was little, Parker would aim his laser pointer at the sidewalk and she'd try to stomp on the dot. He could guide her down a path as she followed the light. "She got to be independent, and I got to make sure she didn't step out into traffic."

Parker guides his stingray bot in a similar way. Layered atop the bot's body — a gold skeleton sandwiched between layers of silicone — lies a serpentine pattern of cells. The pattern is made up of about 200,000 cells, harvested from rat hearts and then genetically engineered to contract when hit with pulses of blue light.



A tiny robotic stingray uses muscles made out of rat heart cells to wiggle its fins.

Flashing the light at the bot sets off a wave of contractions, making the fins undulate like a flag rippling in the wind. To make the stingray turn, the team stimulates the bot's right and left fins separately. Faster flashing on the right side makes the ray turn left and vice versa.

By moving the lights slowly across a fluid-filled chamber, the team led the bot in a curving path around three obstacles.

"It's very impressive," says MIT computer scientist Daniela Rus, a pioneer in the field of robotics. The stingray is "capable of a new type of locomotion that had not been seen before" in robots.

Bashir says he can envision uses for such devices in biomedicine or even environmental cleanup: Perhaps researchers could program cells on a swimming bot to suck toxicants out of lakes or streams.

Parker, a bioengineer interested in cardiac cell biology, has something entirely different in mind. He wants to create a replacement artificial heart for children born with malformed hearts. Like a heart, a stingray's muscular body is a pump, he says, designed to move fluids. "Some engineers build things out of aluminum," he adds. "I build things out of cells." ■

Watch a video of the stingray bot at **bit.ly/SN_stingraybot**

Different methods for measuring the universe's expansion rate disagree — and scientists are struggling to find an explanation. To make one such measurement, scientists observed Cepheid variable stars and a type 1a supernova in the spiral galaxy UGC 9391 (shown), located 130 million light-years away in the constellation Draco.

NASA, ESA, L. FRATTARE/STSCI

ATOM & COSMOS

Debate persists on cosmic expansion

Different methods don't agree on value of Hubble constant

BY EMILY CONOVER

A puzzling mismatch is plaguing two methods for measuring how fast the universe is expanding. When the discrepancy arose a few years ago, scientists suspected it would fade away, a symptom of measurement errors. But the latest, more precise measurements of the expansion rate — a number known as the Hubble constant — have only deepened the mystery.

"There's nothing obvious in the measurements or analyses that have been done that can easily explain this away, which is why I think we are paying attention," says theoretical physicist Marc Kamionkowski of Johns Hopkins University.

If the mismatch persists, it could reveal the existence of stealthy new subatomic particles or illuminate details of the mysterious dark energy that pushes the universe to expand faster and faster.

Measurements based on observations of supernovas, massive stellar explosions, indicate that distantly separated galaxies are spreading apart at 73 kilometers per second for each megaparsec (about 3.3 million light-years) of distance between them. Scientists used data from NASA's Hubble Space Telescope to make their estimate, presented in a paper to be published in the *Astrophysical Journal* and available online at arXiv.org. The analysis pegs the Hubble constant to within experimental errors of just 2.4 percent — more precise than previous estimates using the supernova method.

But another set of measurements, made by the European Space Agency's Planck satellite, puts the figure about 9 percent lower than the supernova measurements, at 67 km/s per megaparsec with an experimental error of less than 1 percent. That puts the two measurements in conflict. Planck's result, reported in a paper published online May 10 at arXiv.org, is based on measurements of the cosmic microwave background radiation, ancient light that originated just 380,000 years after the Big Bang.

And now, another team has weighed in with a measurement of the Hubble constant. The Baryon Oscillation Spectroscopic Survey also reported that the universe is expanding at 67 km/s per megaparsec, with an error of 1.5 percent, in a paper posted online at arXiv.org on July 11. This puts BOSS in conflict with the supernova measurements as well. To make the measurement, BOSS scientists studied patterns in the clustering of 1.2 million galaxies. That clustering is the result of pressure waves in the early universe; analyzing the spacing of those imprints on the sky provides a measure of the universe's expansion.

Although the conflict isn't new (*SN: 4/5/14, p. 18*), the evidence that something is amiss has strengthened as scientists continue to refine their measurements.

The latest results are now precise enough that the discrepancy is unlikely to be a fluke. "It's gone from looking like maybe just bad luck, to — no, this can't be bad luck," says the leader of the supernova measurement team, Adam Riess of Johns Hopkins. But the cause is still unknown, Riess says. "It's kind of a mystery at this point."

Since its birth from a cosmic speck in the Big Bang, the universe has been continually expanding. And that expansion is now accelerating, as galaxy clusters zip away from one another at an ever-increasing rate. The discovery of this acceleration in the 1990s led scientists to conclude that dark energy pervades the universe, pushing it to expand faster and faster.

As the universe expands, supernovas' light is stretched, shifting its frequency. For objects of known distance, that frequency shift can be used to infer the Hubble constant. But measuring distances in the universe is complicated, requiring the construction of a "distance ladder," which combines several methods that build on one another.

To create their distance ladder, Riess and colleagues combined geometrical distance measurements with "standard candles" — objects of known brightness. Since a candle that's farther away is dimmer, if you know its absolute brightness, you can calculate its distance. For standard candles, the team used Cepheid variable stars, which pulsate at a rate that is correlated with their brightness, and type 1a supernovas, whose brightness properties are well-understood.

Scientists on the Planck team, on the other hand, analyzed the cosmic microwave background, using variations in its temperature and polarization to calculate how fast the universe was expanding shortly after the Big Bang. The scientists used that information to predict its current rate of expansion.

As for what might be causing the persistent discrepancy between the two methods, there are no easy answers, Kamionkowski says. "In terms of exotic physics explanations, we've been scratching our heads."

A new type of particle could explain the mismatch. One possibility is an undiscovered variety of neutrino, which would affect the expansion rate in the early universe, says theoretical astrophysicist David Spergel of Princeton University. "But it's hard to fit that to the other data we have." Instead, Spergel favors another explanation: some currently unknown feature of dark energy. "We know so little about dark energy, that would be my guess on where the solution most likely is," he says.

If dark energy is changing with time, pushing the universe to expand faster than predicted, that could explain the discrepancy. "We could be on our way to discovering something nontrivial about the dark energy — that it is an evolving energy field as opposed to just constant," says cosmologist Kevork Abazajian of the University of California, Irvine.

A more likely explanation, some experts say, is that a subtle aspect of one of the measurements is not fully understood. "At this point, I wouldn't say that you would point at either one and say that there are really obvious things wrong," says astronomer Wendy Freedman of the University of Chicago. But, she says, if the Cepheid calibration doesn't work as well as expected, that could slightly shift the measurement of the Hubble constant.

"In order to ascertain if there's a problem, you need to do a completely independent test," says Freedman. Her team is working on a measurement of the Hubble constant without Cepheids, instead using two other types of stars: RR Lyrae variable stars and red giant branch stars.

73
km/s per megaparsec
Rate at which the universe is expanding according to analysis of supernovas

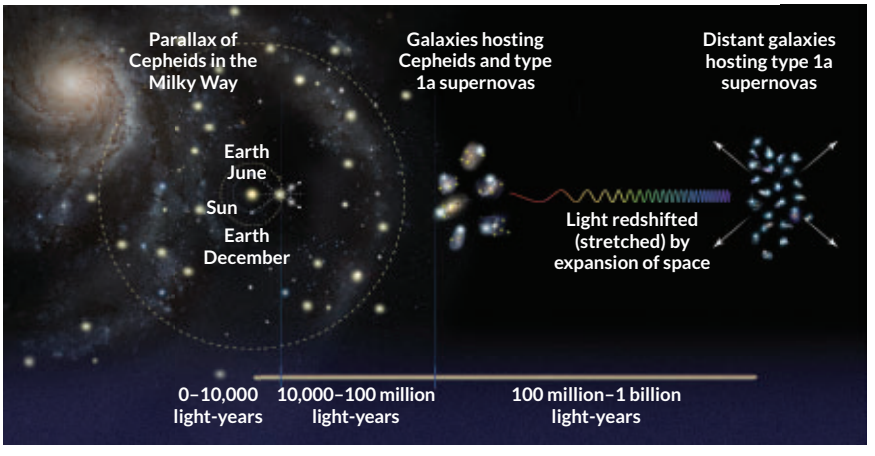
67
km/s per megaparsec
Universe's expansion rate based on analysis of the cosmic microwave background

Another possibility, says Spergel, is that "there's something missing in the Planck results." Planck scientists measure the size of temperature fluctuations between points on the sky. Points separated by larger distances on the sky give a value of the Hubble constant in better agreement with the supernova results. And measurements from a previous cosmic microwave background experiment, WMAP, are also closer to the supernova measurements.

But, says George Efstathiou, an astrophysicist at the University of Cambridge and a Planck collaboration member, "I would say that the Planck results are rock solid." If simple explanations in both analyses are excluded, astronomers may be forced to conclude that something important is missing in scientists' understanding of the universe.

Compared with past disagreements over values of the Hubble constant, the new discrepancy is relatively minor. "Historically, people argued vehemently about whether the Hubble constant was 50 or 100, with the two camps not conceding an inch," says theoretical physicist Katherine Freese of the University of Michigan in Ann Arbor. The current difference between the two measurements is "tiny by the standards of the old days."

Cosmological measurements have only recently become precise enough for a few-percent discrepancy to be an issue. "That it's so difficult to explain is actually an indication of how far we've come in cosmology," Kamionkowski says. "Twenty-five years ago you would wave your hands and make something up." ■



NASA, ESA, A. FIELD/STSCI, A. RIESS/STSCI AND JHU

Measuring the universe To determine the distance of objects in the universe, scientists combine several different measurement methods. They start with parallax — a geometrical method of estimating distances to nearby stars based on their apparent positions as viewed from opposite sides of the Earth's orbit. But the technique works only out to certain distances (large dotted circle). To reach farther, scientists use two types of objects of known brightness: Cepheid variable stars and type 1a supernovas. Their known brightness lets scientists measure greater distances. By calculating the distance of far-off supernovas, and measuring the shift in frequency of their light caused by the universe's expansion, scientists can estimate the expansion rate of the universe.

HUMANS & SOCIETY

New date suggested for *Homo naledi*

South African hominid may have lived only 900,000 years ago

BY BRUCE BOWER

Homo naledi, currently the most mysterious fossil species in the human genus, may be considerably younger than previously thought, a new investigation suggests.

Evolutionary trees of ancient hominids statistically reconstructed from skull and tooth measurements indicate that *H. naledi* lived around 912,000 years ago, say paleoanthropologist Mana Dembo of Simon Fraser University in Burnaby, Canada, and her colleagues. That's a provisional estimate, since researchers have yet to date either *H. naledi*'s bones or the sediment in which some of its remains were excavated.

The new statistical age estimate, described by Dembo's group in the August *Journal of Human Evolution*, challenges proposals that *H. naledi*'s remains come from early in *Homo* evolution. Researchers who first studied *H. naledi* bones retrieved from an underground cave in South Africa noted similarities of the skull and several other body parts to early *Homo* species dating to between 2.5 million and 1.5 million years ago (*SN: 10/3/15, p. 6*).

A comparison of *H. naledi* skull measurements to those of 10 other hominid species, conducted by paleoanthropologist J. Francis Thackeray of the University of the Witwatersrand in Johannesburg, reached the same conclusion. *H. naledi* lived roughly 2 million years ago, Thackeray proposed in the November/December 2015 *South African Journal of Science*.

Dembo disagrees. Her team tested which of 60,000 possible evolutionary trees best fit skull and tooth measurements of *H. naledi*, 20 other hominid species, gorillas and chimpanzees. The new analysis keeps *H. naledi* in the genus *Homo*. But it's still unclear which of several hominid species — including *Homo sapiens*, *Homo floresiensis* (or "hobbits") or *Australopithecus sediba* (*SN: 8/10/13, p. 26*) — is most closely related to the South African species.

Dembo's team found no signs that bones assigned to *H. naledi* represent a variant of *Homo erectus*, as some scientists have argued. *H. erectus* originated about 1.9 million years ago in Africa and rapidly spread to West Asia. But Dembo's statistical model assumes that *H. erectus* skulls and teeth vary in shape throughout Africa and Asia much less than they actually do, says paleoanthropologist Christoph Zollikofer of the University of Zurich. Bones assigned to *H. naledi* most likely represent a form of *H. erectus*, he still contends.

Further statistical comparisons that include measurements of limb and trunk bones may help to clarify *H. naledi's* evolutionary relationships, Dembo says.

Based on geological dates for all hominids except *H. naledi*, the researchers also calculated the rate at which each species' skull and tooth features evolved over time. Those results enabled the researchers to estimate *H. naledi*'s age.

"*Homo naledi* might be less than a million years old," Dembo says. She considers that estimate "reasonably robust," since ages calculated for other hominids in the analysis often fell close to dates gleaned from fossil and sediment studies. In a few cases, though, statistical and geological age estimates differed by 700,000 years or more.

A relatively young age for *H. naledi* expands the number of *Homo* species that survived well into the Stone Age, Dembo says. Small-brained *H. naledi* would have existed at the same time as larger-brained *Homo* species in Africa, just as small-brained *H. floresiensis* lived at the same time as larger-brained *H. sapiens* and *H. erectus* in Southeast Asia (*SN: 7/9/16, p. 6*).

If that scenario holds up, *H. naledi* may have made roughly 1-million-year-old stone tools that have been found in southern Africa, Dembo says.

A new statistical analysis of skulls and teeth suggests that a recently discovered South African hominid dubbed *Homo naledi* lived around 900,000 years ago. That's roughly 1 million years later than estimated by other researchers. *H. naledi* skulls shown here were included in the new study.

"A young date for *Homo naledi* shouldn't be unexpected," says paleoanthropologist Matthew Tocheri of Lakehead University in Thunder Bay, Canada. At least some *H. naledi* bones appear not to have fossilized, he notes, consistent with a more recent age.

While Dembo's statistical approach to hominid evolution shows promise, "a good geological date for *H. naledi* will trump the new date," Tocheri adds.

Paleoanthropologist Bernard Wood of George Washington University in Washington, D.C., doesn't think Dembo's approach can accurately date *H. naledi*. But the humanlike hands, feet and teeth of the South African hominid support the possibility that it lived about 1 million years ago, Wood says.

Two *H. naledi* researchers — John Hawks of the University of Wisconsin–Madison and Witwatersrand's Lee Berger — still suspect that the South African species lived at least 1.8 million years ago, based on its skeletal similarities to *H. erectus*. But a possible age of about 900,000 years for the cave finds, as proposed by Dembo, would be consistent with *H. naledi* or closely related species having survived in Africa for a million years or more, Hawks and Berger write in the current *Transactions of the Royal Society of South Africa*. ■

CC JOHN HAWKS_WITS UNIVERSITY

BODY & BRAIN

Microbes join in oral conspiracy

Benign mouth bacteria provide energy boost for pathogen

BY LAUREL HAMERS

Normally harmless mouth bacteria can be a bad influence. When they pal around with gum-attacking microbes, they can help those pathogens kick into high gear. This teamwork lets infections spread more easily — but also could offer a target for new treatments, scientists report online June 28 in *mBio*.

The way that bacteria interact to cause disease is still poorly understood, says study coauthor Apollo Stacy of the University of Texas at Austin. The new finding suggests that bacteria can change their metabolism in response to the presence or absence of other bacteria. A benign species excretes oxygen, allowing the second species to switch to more efficient aerobic energy production, making it a more robust pathogen.

This is the first time a normally harmless mouth bacterium has been shown to change a pathogen's metabolism to make it more dangerous, says Vanessa Sperandio, a microbiologist at the University of Texas Southwestern Medical Center in Dallas. Similar interactions have been shown between gut bacteria.

Stacy and collaborators examined the relationship between two species of bacteria that tend to grow in the same place in the mouth. One, *Streptococcus gordonii*, is found in healthy mouths and only occasionally causes disease. The other, *Aggregatibacter actinomycetemcomitans*, often causes gum infections.

When *A. actinomycetemcomitans* bacteria grew alone, they produced energy without using oxygen — a slow way to grow. But with *S. gordonii* nearby, the pathogenic bacteria took advantage of the oxygen released by their neighbors and increased their energy production.

In mice, that increased energy let the pathogen grow faster and survive better in a wound.

Stacy plans to test other bacterial pairs to see if other species conspire similarly. Understanding the way bacteria interact with each other could let doctors target infections more efficiently, he says. For instance, if a bacterial infection isn't responding to antibiotic treatment, going after the sidekick bacteria might help take the primary pathogen down. ■

LIFE & EVOLUTION

Hightailing it out of the water

Land-walking fish, robot show value of additional appendage

BY SUSAN MILIUS

Nothing conquers a slippery slope like a good twitch of the tail, say researchers exploring how vertebrates could have taken the first treacherous steps on land.

When early vertebrates invaded land 360 million years or more ago, their tails might have been crucial in helping them climb sloping sand or mud, suggests physicist Daniel Goldman of Georgia Tech in Atlanta. Such surfaces can suddenly shift from a solid heap to a flowing slide that sends climbers flailing. Using a tail the right way in a hop-swing kind of gait, however, lets little fish called mudskippers, as well as a dune-invading robot, get going on slippery slopes, Goldman and collaborators report in the July 8 *Science*.

With a well-timed tail push, "you can then get away with pretty crummy limb use and still get propulsion," Goldman says. A pioneering vertebrate didn't "have to be a ballet dancer."

Studying the function of tails among these early land vertebrates hasn't been simple, partly because of a poor fossil record. Paleontologists have found relatively few complete tail fossils from the transitional creatures, says Stephanie Pierce, curator of vertebrate paleontology at Harvard's Museum of Comparative Zoology. She and her colleagues have proposed that an early land invader called *Ichthyostega* moved right and left forelimbs forward together, similar to the way a person on crutches sweeps the supports forward in unison. So "crutching," as it's called, may have been a form of tetrapod movement.

A small fish called a mudskipper (shown at the Georgia Aquarium in Atlanta) routinely ventures onto land with a hopping gait that inspired a robot study of the motion.

ROB FELT/GEORGIA TECH

Among modern species, little bulging-eyed, big-tailed fish called mudskippers crutch along somewhat like this on their front flippers when venturing onto dry land. Goldman's lab joined forces with mudskipper researchers to see how animals with a crutching gait could cope with changeable materials. On flat surfaces, mudskippers hardly ever do anything special with their tails. On sand tilted up 20 degrees, however, the fish added a tail push with almost every other step.

To analyze the contribution of that tail push, Goldman and colleagues sent a two-limbed robot with a movable tail up slopes of dry plastic particles or poppy seeds. (Sand is dangerous for robot parts.) Positioning the tail to one side and then pushing with it at just the right moment was "critical" on the 20-degree slope, Goldman says. Without that tail power, the robot often stranded itself.

For the research robot, a tail assist "sounds like a very simple maneuver, but to really explain why that works so well on sandy slopes is not trivial," Goldman says. The team was able to come up with a method for mathematically analyzing the first step of the climb. "The amount of physics on the second step is much more terrible to contemplate," Goldman says. ■

Watch a video of the hopping gait at **bit.ly/SN_mudskipper**

GENES & CELLS

‘Junk DNA’ has value for roundworms

Watermarks permit activity for some *C. elegans* germline genes

BY TINA HESMAN SAEY

“Junk DNA” may be an essential part of a worm’s inheritance.

Parts of this not-so-disposable DNA serve as watermarks to authenticate a *Caenorhabditis elegans* roundworm’s own genes and distinguish them from foreign genes that need to be shut down, researchers report in the July 14 *Cell*.

Genes bearing the watermarks — called PATCs — are protected against being shut down. These genes also tend to be active in the germ line (eggs and sperm and the cells that give rise to them). Genes without authentication codes get turned off, especially in the germ line, the researchers discovered. That raises the possibility that other species, perhaps even humans, issue their own germline gene work permits.

> “The general idea that species can mark segments of their genomes and protect them from silencing … could apply to other organisms.”
>
> ANDREW SPENCE

Researchers have known that *C. elegans*’ set of genetic instructions, its genome, is littered with PATCs (short for periodic A_n/T_n clusters), but didn’t know why. PATCs are short stretches of the DNA building blocks adenine or thymine separated by other building blocks, or bases; each run goes about 10 bases on average until the start of the next A or T cluster (for instance, TTTTTaatggAAAA and so on). About 10 percent of the worm’s genome is marked with the A or T clusters, says study coauthor Christian Frøkjær-Jensen, a geneticist at Stanford University.

While other animals don’t seem to have the regular patterns of A’s and T’s exactly like *C. elegans* does, “the general idea that species can mark segments of their genomes and protect them from silencing … could apply to other organisms,” says Andrew Spence, a geneticist at the University of Toronto who was not involved in the study.

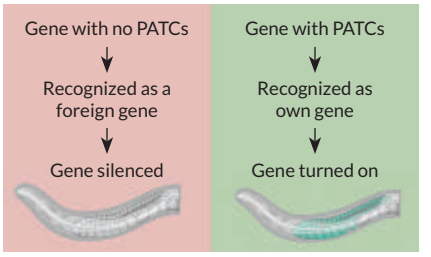
In 2006, Stanford University geneticist Andrew Fire and colleagues pointed out that the A-T tattoos were often associated with genes that are active in the germ line. Those watermarks were found in filler DNA, called introns, sandwiched between the parts of a gene containing the information used to make protein.

Introns are snipped out and thrown away before an RNA copy of a gene is read by protein-building machinery. Introns sometimes contain information about how to regulate gene activity. That seems to be what the PATCs are doing in this case.

Fire and colleagues postulated that the PATCs helped *C. elegans* protect its own genes from being disabled by molecular defense mechanisms that halt the incursion of foreign DNA. (Fire won the 2006 Nobel Prize in physiology or medicine (*SN: 10/7/06, p. 229*) for the discovery of one such mechanism, a gene-silencing system called RNA interference, or RNAi.) Alien DNA from viruses or selfish bits of genetic material known as transposons, or jumping genes, can wreak havoc on a genome, damaging a gene that they hop into. It is important to stop the jumping genes in the germ line because DNA in those cells will be passed on to future generations.

To combat the jumpers, *C. elegans* and other organisms deploy an army of small interfering RNAs that shred RNA copies of foreign genes. Other small RNAs, known as piRNAs, direct cell machinery to stretch molecular hazard tape across DNA where transposons and other aliens settle.

Such off-limits territory is called heterochromatin, and genes there are turned off. Sometimes, though, some important native genes that need to stay on get trapped behind the hazard tape lines. PATCs may be the operating permits that let native genes in heterochromatin remain active.



No aliens allowed Roundworms (*C. elegans*) have to fight off foreign DNA while protecting their own genes that will be passed to the next generation. Some bits of “junk DNA,” known as PATCs, may help by keeping the worms’ own genes active in places where alien genes are turned off.

In 2006, Fire and colleagues could offer no solid data to back up their idea. But the new study puts Fire’s hypothesis to the test. “Oh my gosh, did they test it. It is really a thorough and complete analysis,” says geneticist Susan Strome of the University of California, Santa Cruz.

In the study, Fire, Frøkjær-Jensen and colleagues engineered a gene for a fluorescent jellyfish protein with an intron containing PATC watermarks. When the researchers inserted the PATC-containing gene in a heterochromatin region of the genome, the gene turned on and made the worm’s germline cells glow. But the same jellyfish gene without PATCs was turned off. Those results are evidence that PATCs protect genes against getting turned off. Exactly how that happens isn’t yet known.

Strome isn’t sure that other organisms need DNA certificates to allow their genes to turn on in rough neighborhoods. *C. elegans* worms have unusual chromosomes. Nearly two-thirds of each chromosome is heterochromatin wasteland. The PATC permits may be necessary only in such extreme cases, she says.

Fire says he’s not yet ready to declare that all junk DNA may be useful. “Certainly there is gold in what we see here,” he says, “but the question is whether it is all gold.” ■

C. FRØKJÆR-JENSEN *ET AL*/*CELL* 2016

MATTER & ENERGY

Falling through Earth would be a drag

Air resistance, friction reduce velocity toward planet's core

BY EMILY CONOVER

Falling down a hole through the center of the Earth would be rough — especially if there's friction. A new study reveals what would happen to an intrepid traveler who jumped into a hypothetical tunnel through Earth, propelled by the force of gravity but impeded by air resistance and the friction of the tunnel walls.

Physicists have estimated that if you jumped into a tunnel without such forms of drag, you would reach the other side in less than an hour. But with drag, it could be over a year before you reach Earth's center — and you'd never make it to the other side, scientists report in a paper posted online June 3 at arXiv.org.

"There's a number of assumptions that you have to make to solve this problem," says physicist Alex Klotz of MIT, who was not involved in the new study. To simplify the calculations, scientists have made unrealistic assumptions: that Earth is a sphere of uniform density, that it is not rotating and that there is no drag from friction or air in the tunnel. Including drag, Klotz says, is "a step forward."

If you jumped into such a hole — or rode through it on a futuristic subterranean transit system — gravity would accelerate you downward quickly. After passing Earth's center, you'd keep going, shooting upward. Gravity would gradually slow your rise to the opposite surface. Without air resistance and friction, momentum would carry you to the other side, where you might be able to clamber out of the hole. But drag adds complicating details.

The quandary is fun to think about, say study authors Thomas Concannon and Gerardo Giordano of King's College in Wilkes-Barre, Pa. But, says Giordano, "neither of us think this technology is going to be available" anytime soon. Technical challenges to building such a tunnel would be insurmountable. Instead, the problem is a thought experiment and tool for instructing physics students.

With drag, it would take a vehicle with a profile similar to a large airplane's a whopping 1.8 years to get to Earth's center. But it might not even make it there, because air deep down would be highly pressurized, behaving more like a solid than a gas. The tunnel would have to be emptied of all air to function as intended.

Even in an airless tunnel, friction from the walls or rails directing the shuttle would be in play. In that case, it would take roughly 19 minutes to get to the center. But thanks to the energy lost to friction, you wouldn't be able to make it to the other side. Instead, you would fall back down before reaching the surface and the process would repeat, causing you to oscillate around Earth's core until you slowed to a stop at the center. ■

LIFE & EVOLUTION

Why the turtle got its shell

Digging may have contributed to carapace evolution

BY LAUREL HAMERS

Turtle shells didn't get their start as natural armor, it seems. The reptiles' ancestors might have evolved partial shells for burrowing instead, new research suggests. Only later did the hard body covering become useful for protection.

The findings might help explain how turtle ancestors survived the extinction of most of Earth's plants and animals about 252 million years ago, scientists report online July 14 in *Current Biology*.

Most shelled animals, like armadillos, get their shells by adding bony scales all over their bodies. Turtles, though, form shells by gradually broadening their ribs until the bones fuse together. Fossils from ancient reptiles with partial shells made from thickened ribs suggest that turtles' ancestors started suiting up the same way.

It's an unusual mechanism, says paleontologist Tyler Lyson, who led the study. Thicker ribs don't offer much protection until they're fully fused, as they are in modern turtles. And the modification makes crucial functions like moving and breathing much harder — a steep price for an animal to pay. So Lyson, of the Denver Museum of Nature and Science, suspected there was some advantage other than protection to the partial shells.

He and his colleagues examined fossils from prototurtles, such as a South African reptile called *Eunotosaurus africanus*.

Eunotosaurus africanus, a precursor to today's turtles, had thickened ribs (fossil shown) and powerful forelimbs, possibly to help it dig.

T. LYSON ET AL/CURRENT BIOLOGY 2016

Eunotosaurus shared many features with animals that dig and burrow, the scientists found. It had huge claws and large triceps in addition to thickened ribs. "This animal was very powerful," Lyson says.

Broad ribs provided a strong, stable base for *Eunotosaurus*' powerful digging, Lyson says. Like a backhoe, the reptile could brace itself to burrow into the dirt.

Thanks to a fossil preserving the bones around the eyes, the team was even able to tell that the prototurtle's eyes were well adapted to low light, a feature of animals that spend time underground.

"It's a very plausible idea, although many other animals burrow but don't have these specializations," says paleontologist Hans Sues of the Smithsonian's National Museum of Natural History. He says that it will be important to study other turtle ancestors well-adapted to digging to bolster the explanation.

Lyson thinks the prototurtles' burrowing tendencies might have helped them survive the Permian mass extinction 252 million years ago (*SN: 9/19/15, p. 10*). ■

BODY & BRAIN

Zika peaking in Latin America

Widespread infections to end soon — but virus will return

BY MEGHAN ROSEN

Zika should soon run its course in Latin America. Within the next couple of years, the epidemic that has battered the region since 2015 will largely be over, researchers estimate online July 14 in *Science*.

"If we're not past the peak already, we're very close to it," says study coauthor Neil Ferguson of Imperial College London. After this outbreak winds down, it may be at least a decade before another large-scale Zika epidemic hits the region.

The new timeline could help vaccine researchers get a jump on future outbreaks, and might make health officials rethink advice to pregnant women trying to avoid Zika-related birth defects. Ferguson's work also suggests something counterintuitive: Current efforts to kill Zika-carrying mosquitoes might actually make it easier for the virus to reemerge.

"It's an important and timely analysis," says infectious disease researcher Oliver Pybus of the University of Oxford. "Policy makers would be wise to read it carefully."

Brazil reported the first cases of Zika in May 2015. Since then, the mosquito-borne virus has spread to 48 countries. Scientists have widely accepted Zika as a cause of microcephaly, a devastating birth defect that leaves babies with shrunken heads and brains, as well as other serious problems (*SN Online: 6/28/16*).

Scientists and health officials have hustled to fight Zika, but they've had trouble keeping up. Mosquito-control efforts haven't helped much, says Ferguson, and a safe, effective vaccine could still be years away. What's more, postponing pregnancy isn't always realistic, he says.

Predicting the epidemic's course could refine current Zika-fighting strategies.

Ferguson and colleagues made a computer simulation of Zika transmission within Latin America, using data from 35 countries that have reported cases. The team factored in such variables as seasonal climate variation, the ease with which Zika jumps from person to mosquito to person, and human travel patterns between countries.

After the current outbreak ends, simulations show that some 30 years could pass before Zika transmission picks up again. Once infected with Zika, people are immune to the virus, capping an epidemic's length and buying some time before a resurgence. Ferguson can't say for sure that another major outbreak is still three decades away — but he suspects a lull could last at least a decade.

Zika has "been burning through the population," he says. "Sooner or later, it starts to run out of people to infect."

The virus doesn't need to infect everybody to peter out — just enough to generate herd immunity. At that point, so many people are immune that Zika can't easily spread, protecting those still uninfected.

Killing mosquitoes — a strategy some countries have used to try to curb Zika's reach — could actually hinder herd immunity, letting the next epidemic strike sooner, the team's simulations suggest. With only marginally effective mosquito control, a second wave of Zika hits about five years earlier than with no mosquito control at all, the simulations indicate.

"It makes sense theoretically," says epidemiologist Mikkel Quam of Umeå University in Sweden. But considering that the cost of herd immunity might be more babies born with birth defects, he says, "any way to reduce infection is worth doing now, even if it means potentially more epidemics in years to come."

Immunity to Zika could pose problems for vaccine development, Ferguson says. By the time researchers have something safe, it will be hard to find a group of people to test. "This was a problem at the end of the Ebola epidemic as well," he says.

Still, Ferguson says, it's an opportunity to think creatively. In the future, researchers could prequalify trial sites and get clinicians on the ground early, so when (and if) Zika hits somewhere else, say Southeast Asia, they're ready to go.

He also thinks his simulation could help officials more clearly lay out the risks to pregnant women. Though the epidemic in Latin America will last roughly three years total, his team estimates, individual outbreaks within the region can taper off after three to six months. By tailoring recommendations by location, officials could limit the time they advise women to delay pregnancy. ■

JPL-CALTECH/NASA, SWRI, MSSS

ATOM & COSMOS

Juno snaps its first pic of Jupiter

NASA's Juno spacecraft has sent back its first picture of Jupiter since arriving July 4. The image, taken July 10 when Juno was 4.3 million kilometers from Jupiter, shows the planet's clouds, its Great Red Spot and three of its moons (from left, Io, Europa and Ganymede). Juno's science instruments were turned off while it made its first dive through the planet's harsh radiation belts; this first image indicates that Juno is in good health. The probe is the ninth to visit Jupiter and the second to stay in orbit. For the next 20 months, Juno will investigate what lurks beneath Jupiter's opaque clouds (*SN: 6/25/16, p. 16*). The spacecraft will take its first intimate pictures of Jupiter August 27, from within 5,000 kilometers of the cloud tops. — *Christopher Crockett*

LIFE & EVOLUTION

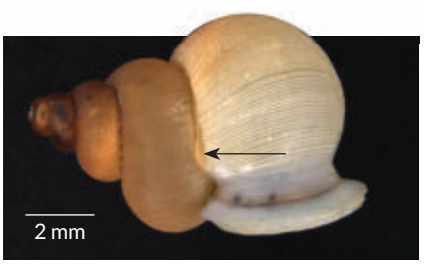
How snails breathe with snorkels

Microscope work may have solved the puzzle of Asian snails' "useless" snorkels.

The small Alycaeidae land snails of Asia grow what looks like a tiny breathing tube curling partway along the outside of their shells. Similar tubes let some other land snails breathe when a little blast-door operculum shuts the main opening of their shells. But in the 350 or so Asian species of Alycaeidae, the supposed breathing tube's outside end is sealed.

Researchers decades ago wondered if the tube had teensy pores or if it broke open in the wild. The answer is neither, Barna Páll-Gergely of Shinshu University in Matsumoto, Japan, and colleagues report July 12 in *Biology Letters*. Electron microscope images now reveal tiny feeder channels branching down from the tube to the bottom whorl of the shell, opening in vanishingly small slits to outside air.

The *Alycaeus conformis* snail's roughly 50 air channels each squeeze down to about 16 micrometers in diameter, far too small for parasites such as slug mites to invade, Páll-Gergely says. These micro-channels with slits might minimize water loss during hot weather. Alycaeidae snails, he says, have evolved the "most complex gas-exchange system" yet discovered among snail snorkels. — *Susan Milius*



A tube (arrow) following the crease between whorls lets this *Alycaeus* snail breathe in its shell — although the tube's outside end is sealed.

B. PÁLL-GERGELY

ATOM & COSMOS

Mars once had many moons

Mars' misshapen moons, Phobos and Deimos, might be all that's left of a larger family of moons that arose in the wake of a giant impact on the Red Planet billions of years ago, researchers report July 4 in *Nature Geoscience*.

The origin of the two moons has never been clear. The new study suggests that a ring of rocks blown off the planet by a collision with an asteroid could have been a breeding ground for a set of larger satellites relatively close to the planet. Those moons, long since reclaimed by Mars, could have herded remaining debris in the sparsely populated outer part of the ring to form Phobos and Deimos.

Pascal Rosenblatt of the Royal Observatory of Belgium in Brussels and colleagues ran computer simulations to show how the helper moons formed, did their duty and then fell to Mars, leaving behind a pair of moons similar to Phobos and Deimos. — *Christopher Crockett*

EARTH & ENVIRONMENT

Bomb debris can reveal blast size

A new type of fallout forensics can reconstruct nuclear blasts decades after detonation. By measuring the relative abundance of various elements in debris from nuclear explosions, researchers say, they can estimate the amount of energy released during the initial blast.

As proof of concept, the researchers estimated the yield of the 1945 Trinity nuclear test in New Mexico — the world's first detonation of a nuclear device. The work pegged the explosion as equivalent to 22.1 kilotons of TNT, close to the official estimate of 21 kilotons. Applying the method to modern blasts could help regulators identify nuclear tests long after the fact, the researchers propose in the July 19 *Proceedings of the National Academy of Sciences*.

Regulators currently monitor nuclear tests by detecting tremors and radioactive material emanating from blasts. Those effects are short-lived, so the techniques work only within a few days or weeks of a test.

Susan Hanson and colleagues at New Mexico's Los Alamos National Laboratory looked at the element molybdenum in glassy debris created by the Trinity test. Stable molybdenum forms when zirconium from a bomb's fireball radioactively decays. The relative abundance of different molybdenum isotopes created from this process differs from that found naturally. By measuring the overabundance of certain molybdenum isotopes, researchers can determine the original amount of zirconium created by the explosion. By pairing the amount of remnant plutonium in the debris with the zirconium figure, the researchers can estimate a blast's explosive yield. — *Thomas Sumner*

ATOM & COSMOS

Three cousins join family of four-quark particles

An exotic particle now has three new cousins, making for a happy family of four.

Scientists with the LHCb experiment, located at the Large Hadron Collider near Geneva, announced the discovery of the particle's new cousins in two papers posted online June 25 at arXiv.org. The particles are each made up of four quarks, elementary particles known for their role as the building blocks of protons and neutrons.

The previously known particle, X(4140), and its cousins — X(4274), X(4500) and X(4700) — are composed of two charm quarks and two strange quarks. Each particle's quarks are arranged in configurations of increasingly higher energy, making each particle heftier than the last — thanks to the equivalence of mass and energy expressed by the equation $E=mc^2$.

The particles are probably tetraquarks, which are composed of four quarks tightly bound together, says physicist Tomasz Skwarnicki of Syracuse University in New York, who led the analysis. For decades, scientists thought quarks grouped up only into pairs or triplets, but recent research has unearthed tetraquarks (*SN: 7/27/13, p. 9*) and even pentaquarks (*SN: 8/8/15, p. 8*). A competing explanation, that the particles are molecule-like pairings made up of two quark partners each, has been ruled out, Skwarnicki says.

Even among tetraquarks, the particles are unusual: They are made up solely of heavy, exotic types of quarks that are not found in everyday materials. — *Emily Conover*

Big Dreams for Small SPIDER Scope

A long-shot approach may slash size, weight and power demand in space imaging

By Charles Petit

In the space business, weight and size are what run up the bills. So imagine the appeal of a telescope that's a tenth to as little as a hundredth as heavy, bulky and power hungry as the conventional instruments that NASA and other government agencies now send into space. Especially alluring is the notion of marrying the time-tested technology called interferometry, used in traditional observatories, with the new industrial field of photonics and its almost unimaginably tiny optical circuits.

Say hello to SPIDER, or Segmented Planar Imaging Detector for Electro-optical Reconnaissance.

Some doubt it will ever work.

But its inventors believe that, once demonstrated at full-scale, SPIDER will replace standard telescopes and long-range cameras in settings where room is scarce, such as on planetary probes and reconnaissance satellites.

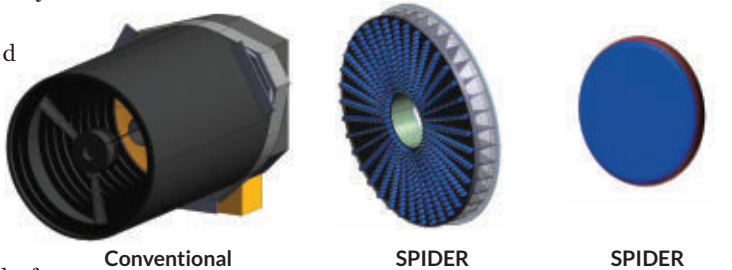
Researchers at the Lockheed Martin Advanced Technology Center in Palo Alto, Calif., with partners in a photonics lab at the University of California, Davis, have described work on SPIDER for several years at specialty conferences. In January, they revealed their progress with a splash to the public in a press release and polished video.

Somewhat like a visible-light version of a vast field of radio telescopes, but at a radically smaller scale, a SPIDER scope's surface would sparkle with hundreds to thousands of lenses about the size found on point-and-shoot cameras. The instrument might be a foot or two across and only as thick as a flat-screen TV.

Transit system for light

SPIDER probably won't be equivalent to a large instrument such as the Hubble Space Telescope, but it could be a smaller, lighter alternative to modest telescopes and long-range cameras. Experts tend to rank telescopes by their aperture — the size of the bucket that catches light or other such radiation. The wider the bucket's mouth, the higher the resolution. Ordinarily, behind the bucket's maw is an extensive framework for massive lenses, mirrors and heating or cooling systems. Hubble's aperture spans 2.4 meters; its power-generating solar panels enlarge it to the size and weight of a winged city bus. Even a compact telescope with a saucer-sized lens might have more than a kilogram of equipment stretched behind its face for a third of a meter or so.

Alan Duncan, a senior fellow at Lockheed Martin's Advanced Technology Center, has devoted much of his career to space and reconnaissance imaging. He often focuses on interferometry, a method astronomers have long used to combine electromagnetic waves — both radio and visible — from several different



Conventional telescope | SPIDER radial blade design | SPIDER single chip design

Shrink it Compared with a conventional reflecting telescope (left), a prototype for a proposed telescope called SPIDER (middle) has a radial design, with spokes of multiple photonic chips. In a farther-out design (right), a single-disk photonic chip has the same diameter and focus as the regular scope, but is much thinner.

FROM TOP: LOCKHEED MARTIN; B. YOO/UC DAVIS

Lockheed Martin imagines a relatively small and light advanced SPIDER telescope with thousands of tiny lenses on one face of a surveillance orbiter.

telescopes. The results, with the help of computers, are images more sharply focused than from any of the smaller telescopes or radio dishes. Yet even with the leverage of conventional interferometry, Duncan struggled to slash the SWaP: size, weight and power demand.

His ambitions leapt at the Photonics West 2010 meeting in San Francisco. He learned that IBM researchers had a supercomputer design that would need relatively little energy to cool its electronic innards. They proposed finely laced channels through which data-filled beams of light would travel to deliver the computer's output data. The setup would require a fraction of the energy of standard, integrated electronic chips that use metal wiring.

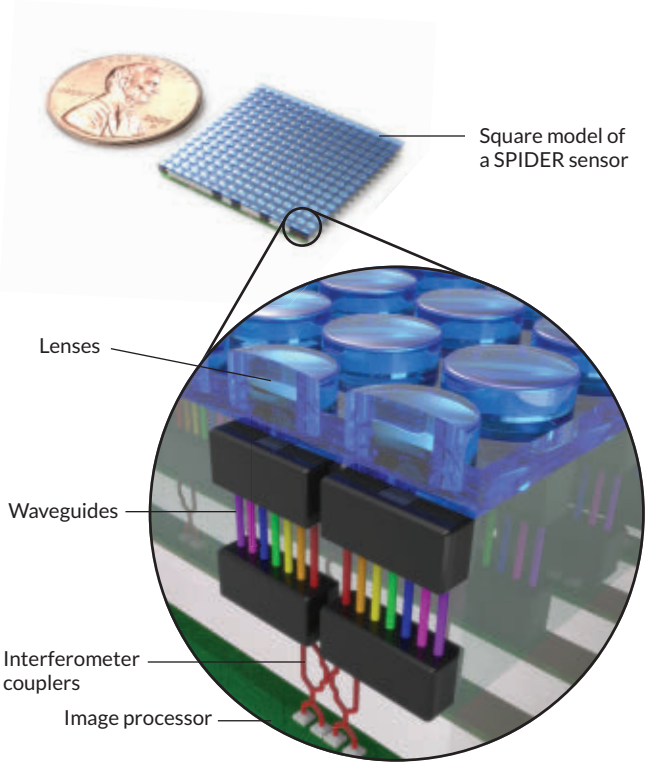
Duncan stared at the skeins of optical channels and the millions of junctions portrayed on the screen during the IBM talk. He recalls seeing "about as many optical interconnects as a digital camera has pixels." (A point-and-shoot camera's pictures can have several megapixels, or millions of individual dots.) He imagined turning IBM's tactic on its head. "They create photons in the chip, impose information on them and send them out to be decoded. What if you captured the light waves on the outside?" Duncan says. "The photons already have the [image] information you want.... You have to decode it inside the device. The decoder is the interferometer."

The IBM people had not designed an interferometer, of course, but their optical circuitry seemed sophisticated enough to be adaptable to interferometry. Duncan figured that the fast-growing photonics industry already had or would soon invent fabrication solutions that his suddenly imagined telescope could use. Already, photonics companies were selling machines to create transparent channels or waveguides only a few millionths of a meter wide.

Considerably smaller than the fibers bundled into fiber-optic cables that carry data across continents and under oceans, photonic waveguides are made by finely focused, pulsating laser beams. As the beams scan along inside silicon-based photonic integrated circuits, or PICs, they leave behind close-packed strings in molten silicon that swiftly merge and cool. The resulting trails of transparency are superb transit systems for light, and they can be laser-incised in any pattern desired. Similar wizardry can shrink the scale of other optical gadgetry, such as filters to sort the signals by color, or the interferometry gadgetry to mix signals from different lenses in a SPIDER scope.

Decoding fringes

Interferometry does not produce pictures the way a conventional telescope does. Telescopes refract a scene's incoming light through lenses or bounce it off of mirrors. The lenses or mirrors are shaped so that light beams, or photons, from a given part of a scene converge on a corresponding place on a photosensitive surface such as an image chip of a digital camera, similar to the retina of an eye.



A future setup A square model of a SPIDER sensor (top) is about the size of a coin. In an upclose view (bottom), an array of aligned lenses take in light from a distant scene and send it through a photonic integrated circuit of waveguides, filters and interferometers to compare the signals' waveforms. The results are sent to a computer to construct an image.

Interferometry, instead, gathers signals from pairs of receivers — sometimes many pairs — all aimed at the same scene. It combines the signals to reveal the slight differences in the phases and strengths of the radio, light or other waves. The separate wave trains, or signals, are projected on a screen in an interferometry chamber as patterns of light and dark fringes where the signals from the paired receivers reinforce or counteract each other. The fringes, somewhat resembling checkout counter bar codes, carry a distinct, encoded hint of the difference in the viewed object as seen from the receivers' offset positions in the aperture. With enough measurements of fringes from enough pairs of waves gathered by enough small receivers, a computer can deduce a picture that is as sharp as from a telescope with a lens as wide as the distance between the most widely spaced lenses, for example, on a SPIDER's face.

Building a tiny version of this using photonics requires separate sets of waveguides for different colors or "spectral bins." The more bins used, the more accurately an object can be portrayed. But each such layer of complexity aggravates the chore of fabrication.

So even a bare-bones SPIDER may need thousands of waveguides. Advanced SPIDERs may have millions of them. As far as Duncan knows, SPIDER would be the most complicated interferometer ever made.

Spycraft and space views

After his epiphany, Duncan began working with Lockheed colleagues, chiefly technology expert Richard L. Kendrick.

LOCKHEED MARTIN

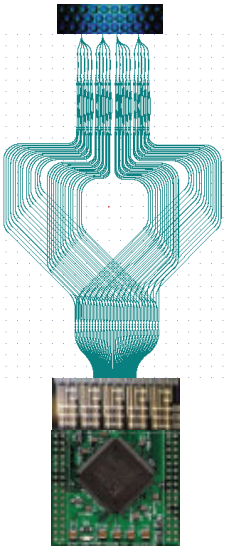
Computed simulations convinced them that their mini-interferometer should work. In 2012, Lockheed Martin filed for a patent — granted in late 2014 — naming the two men as the inventors. Reflecting the company's defense ties, the document provides a hypothetical application: SPIDER in a proposed, high-altitude Pentagon recon drone called Vulture, perhaps built into the curved bottom of a wing.

Initial simulations showed how SPIDER's pictures of one satellite taken from another, or of buildings as seen from space, compare with pictures by standard long-range cameras. Interferometric images, due to the complex calculations using the equations of Fourier transforms, often have extra flares and streaks. Nonetheless, to a layman's eye, the simulated SPIDER images look about the same as equivalent ones from standard lens or mirror telescopes.

If SPIDER pans out, its inventors imagine uses beyond spycraft. NASA is planning a mission to orbit Jupiter's moon Europa (*SN Online: 5/26/15*). The SPIDER team calculates that, given the same space that has already been assigned to a conventional imager, SPIDER's instrument could inspect 10 times the terrain at 17 times better resolution. SPIDER should be able to have a wider array of lenslets — or receivers — take pictures at points farther from Europa on the craft's elliptical orbit and should have a wider field of view.

One proposed design for the first fully operable, but spartan, SPIDER is to have 37 radial blades, each backed by a single photonic chip with 14 lenslets along one edge. The whole model would be about the size of a dinner plate. Eventually, a SPIDER might be built on the face of a single chip of similar or larger size. This would allow more lenslets to be fitted, and permit waveguides to pair them up from anywhere in the aperture. Upshot: more "eyes" packed into the same space.

The Lockheed group has begun to fabricate test components in partnership with a photonics laboratory led by Ben Yoo, professor of electrical and computer engineering at UC Davis. DARPA, the Department of Defense's agency for funding advanced research, granted about $2 million for prototype photonic integrated circuits and other gear to test the idea's feasibility.



Mini guides A photonic waveguide map for just four lenses is connected to a digital chip that calculates the contribution to the ultimate image. Thousands of lenses and waveguides could be combined to make a SPIDER telescope.

The technical challenges are extreme. Each tiny lenslet could need 200 or more separate waveguides leading from its focal area to the interferometers. For a fairly simple SPIDER scope, that would mean tens of thousands of waveguides coursing through the chips' insides — perhaps fabricated many layers deep. So far, the researchers have built prototype components with only four lenslets, too few to get images.

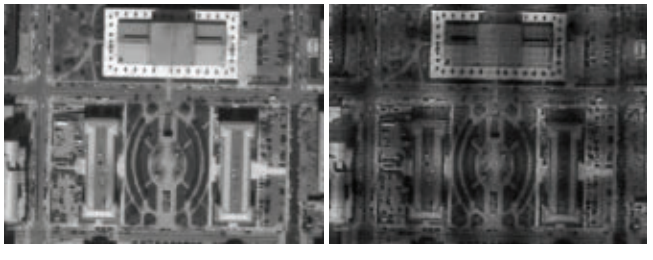
Skeptics and a crusader

At least one top authority says the scheme is nonsense. Others are more amused than critical. Michael Shao, an MIT-trained astronomer and project scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif., has extensive experience with interferometry. He calls the concept of SPIDER "fundamentally sound," but adds that it will require such extensive optical plumbing on a photonic scale that the sheer complexity "would scare a lot of folks away." If the SPIDER team makes it work, great. "But it is a lot of work to save a little space."

Peter Tuthill, an astronomer at the University of Sydney in Australia, leads one of the world's busiest interferometry groups. His team has augmented such large conventional ground-based telescopes as the Keck Observatory in Hawaii with auxiliary interferometers. His group also designed an interferometer to be included on the James Webb Space Telescope, planned successor to the Hubble. After looking over the SPIDER proposal, he declared by e-mail, "I think the argument made that this can be somehow cheaper, simpler, lower mass and higher performance than conventional optics appears not to pass the laugh test."

The extremely large number of waveguides in the SPIDER design, he added, would leave the signal strength per waveguide too feeble — hence vulnerable to swamping by noise in the system. "In short, I don't think (the SPIDER team members) are waiting for technology to enable their platform. I think they are waiting for a miracle that defies physics."

Duncan just smiles when he hears Tuthill's opinion. Even if technical difficulties delay or quash this initial SPIDER project, he is confident somebody will step in and surmount any barriers. "It will happen," he says. ■



SPIDER designers compared an aerial photo (left) of Judiciary Square in Washington, D.C., with how their interferometer of similar aperture would do (right). SPIDER's shot is blotchy, but sharp.

ALL: B. YOO

Explore more

■ Alan L. Duncan *et al.* "SPIDER: next generation chip scale imaging sensor." http://bit.ly/SPIDERscope

Charles Petit is a freelance science writer based in Northern California.

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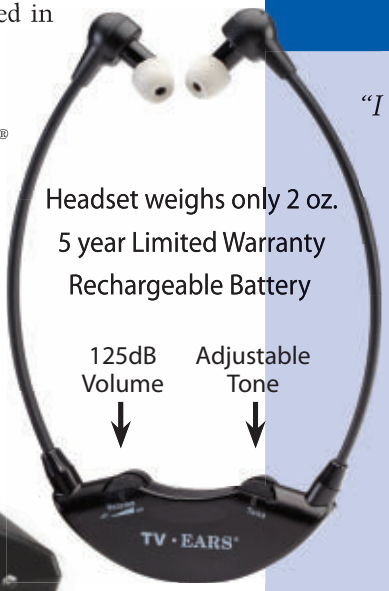

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ADVERTISEMENT

Earth's IRON-LOVERS

Geochemists explore platinum, gold and other rare elements to understand the planet's evolution

By Alexandra Witze

Four and a half billion years ago, after Earth's fiery birth, the infant planet began to radically reshape itself, separating into distinct layers. Metals — mostly iron with a bit of nickel — fell toward the center to form a core. The growing core also vacuumed up other metallic elements, such as platinum, iridium and gold.

By the time the core finished forming, about 30 million years later, it had sequestered more than 98 percent of these precious elements. The outer layers of the planet — the mantle and the crust — had barely any platinum and gold left. That's why these metals are so rare today.

Battles have been fought, and wars won, over the pull of shiny precious metals, which have long symbolized power and influence. But for scientists, the rare metals' lure is less about their shimmering beauty than about the powerful stories they can tell about how the Earth, the moon and other planetary bodies formed and evolved.

By analyzing rare primordial materials, researchers are uncovering geochemical fingerprints that have survived essentially unchanged over billions of years. These fingerprints allow scientists to compare Earth rocks with moon rocks and test ideas about whether giant meteorites once dusted the inner solar system with extraterrestrial platinum and gold. Such research can help scientists learn how volatiles such as water may have spread, leaving some worlds water-rich and others bone-dry.

These explorations, motivated by a growing appreciation of what such rare metals reveal about Earth's history, are now possible thanks to new analytical techniques. "They give us a window into all kinds of processes that we want to understand," says Richard Walker, a geochemist at the University of Maryland in College Park.

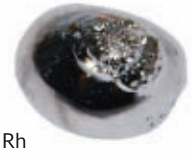
Geochemical memory

Platinum and gold are among eight occupants of the periodic table belonging to the category known as the highly siderophile elements. That name dates back to the 1920s, when

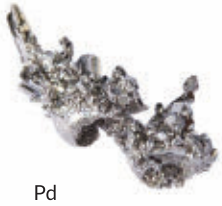
The highly siderophile elements

Eight elements that are very much attracted to iron

Ru
Ruthenium
Atomic number: 44
Atomic mass: 101.07
White metal, used to harden platinum and palladium



Rh
Rhodium
Atomic number: 45
Atomic mass: 102.91
Silvery-white metal, used in industrial catalysts



Pd
Palladium
Atomic number: 46
Atomic mass: 106.42
Steel-white metal, used in catalytic converters

Re
Rhenium
Atomic number: 75
Atomic mass: 186.21
Silvery-white metal, used to produce high-octane gasoline

TOP: CIOANA/ISTOCKPHOTO; FROM LEFT: DAISUKE NISHIO-HAMANE/FLICKR (CC BY-NC-SA 2.0); IMAGES-OF-ELEMENTS.COM/WIKIMEDIA COMMONS (CC BY 3.0); JURI1/WIKIMEDIA COMMONS (CC BY 3.0); UCLA/WIKIMEDIA COMMONS

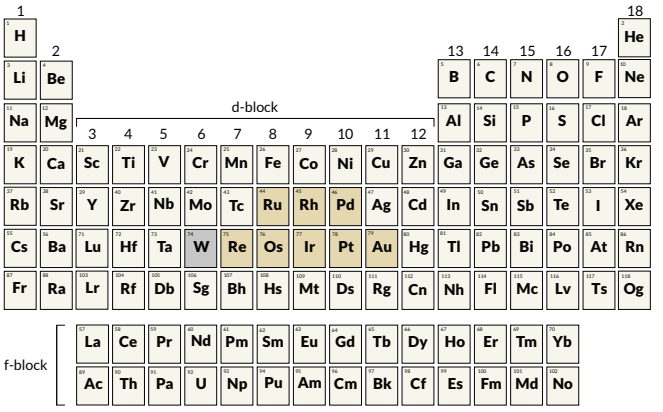
Victor Goldschmidt, a mineralogist at the University of Oslo, divided the elements into groups depending on what they liked to combine with in nature. His four classifications are still used today: the lithophiles (rock-lovers), the chalcophiles (ore- or sulfur-lovers), the atmophiles (gas-lovers) and siderophiles, the iron-lovers.

The siderophile elements tend not to ally themselves with the oxygen- and silicon-based compounds that form the bulk of Earth's crust. They form dense alloys with iron instead. One such element, tungsten (symbolized by W in the periodic table), is an iron-lover that has been important in recent scientific studies of Earth's geologic history. A step beyond tungsten are those highly siderophile elements, which are even bigger fans of iron. They are ruthenium, rhodium, palladium, rhenium, osmium and iridium along with platinum and gold.

Because highly siderophile elements are relatively abundant in the core and scarce in the mantle and crust, they help scientists trace how Earth's insides have evolved over time. Dig up a rock from deep within a mine, or pick up one from a freshly erupted volcano, and you can measure the siderophile elements within. The measurements might show whether a radioactive version of one such element has decayed into another, or whether the rock has higher amounts of one particular variety of siderophile. In turn, that information can reveal how material has shifted around and been chemically processed deep within the planet.

By analyzing the iron-lovers within each rock, scientists can probe what the rock has been doing for billions of years. "We can trace the entire evolutionary process of how a planet formed," says James Day, a geochemist at the Scripps Institution of Oceanography in La Jolla, Calif. "That's why someone like me is interested."

For instance, Walker and his colleagues have explored siderophile elements in some of the oldest rocks on Earth. Through the process of plate tectonics, in which plates of Earth's crust grind against, pull apart from and occasionally dive beneath one another, most ancient rocks have been dragged back into the planet and destroyed by melting. But in southwestern Greenland, in a place called Isua, a chunk of ancient crust never got pulled down by plate tectonics (*SN: 3/24/07, p. 179*). Walker and colleagues, led by Hanika Rizo of the University of Quebec in Montreal, recently studied siderophile elements in these 3.3-billion- to 3.8-billion-year-old rocks.

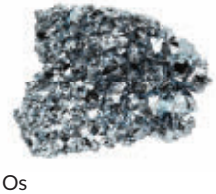


Fans of Fe Eight chemical elements, known as the highly siderophile elements, are preferentially drawn to iron when molten. Most of them have relatively high melting points and resist being corroded or oxidized. Along with the siderophile tungsten, they serve as powerful tracers for how Earth's interior separated into layers billions of years ago.

The scientists looked at the abundance of highly siderophile elements in the Greenland rocks but found that, in this case, the biggest clues came from the slightly less iron-loving tungsten. The rocks contain more of one variety of tungsten, known as tungsten-182, than expected. That isotope forms from the radioactive decay of hafnium-182, which existed only during Earth's first 50 million years. The Greenland rocks thus serve as a sort of time capsule that helps reveal the history of the early solar system, Rizo, Walker and colleagues wrote in February in *Geochimica et Cosmochimica Acta*.

"We believe we are accessing parts of Earth's mantle that formed and took on some of their chemical characteristics while the Earth was still growing," Walker says. "You can call it accessing a building block of the Earth."

Studies of these remnants of the ancient planet suggest that Earth's mantle has remained chemically patchy. Like lumps of flour in poorly mixed cake batter, clumps of primordial material, with higher amounts of tungsten-182, are studded throughout a smoother, more evenly mixed matrix. That's surprising because researchers thought that the hot, churning



Os
Osmium
Atomic number: 76
Atomic mass: 190.23
Lustrous, bluish-white metal, used in some alloys and as a catalyst

Ir
Iridium
Atomic number: 77
Atomic mass: 192.22
Brittle, whitish metal, used to make equipment for high-temperature experiments

Pt
Platinum
Atomic number: 78
Atomic mass: 195.08
Silver-white metal, used in jewelry, catalytic converters and for high-temperature industrial processes

Au
Gold
Atomic number: 79
Atomic mass: 196.97
Yellow metal, used in jewelry and as an industrial catalyst

TOP: E. OTWELL; FROM LEFT: HEINRICH PNIOK/WIKIMEDIA COMMONS, FREE ART LICENSE; IMAGES-OF-ELEMENTS.COM/WIKIMEDIA COMMONS (CC BY 1.0); HEINRICH PNIOK/WIKIMEDIA COMMONS, FREE ART LICENSE; ROB LAVINSKY, IROCKS.COM/WIKIMEDIA COMMONS (CC BY-SA 3.0)

insides of the Earth would have stirred everything around over the course of billions of years. Somehow portions of the mantle resisted the planet's best blending efforts, Walker reported in June at the Goldschmidt geochemistry meeting in Yokohama, Japan.

By studying where those patches are and what they are made of, researchers can investigate such questions as how much convection there was inside the early Earth, and whether any volcanoes today tap into this primordial material. In May, for instance, Walker's team reported that it had used siderophile elements to identify geochemically primitive lavas in Canada's Baffin Bay and in the South Pacific (*SN: 6/11/16, p. 13*).

Like the ancient Greenland crust, these rocks also had an overabundance of tungsten-182. Apparently the Canadian and Pacific volcanoes tapped into a deep reservoir of primordial material, which flowed up through the throat of a volcano and out onto the surface. Studying the iron-loving elements in those rocks is like taking a siderophile time machine into the past and seeing what the Earth was like 4.5 billion years ago.

"It never ceases to amaze me what the rocks can tell," says Amy Riches, a geochemist at Durham University in England.

A dusting from space

Highly siderophile elements can teach about more than just the planet Earth. They can reveal secrets about the history of the moon, Mars and other nearby planetary bodies. That's because all the worlds in the inner solar system apparently got a dusting of gold, platinum and other highly siderophile elements during meteorite bombardments around 4 billion years ago.

The early solar system was something of a cosmic shooting gallery. After the planets coalesced, there were still a lot of leftover space rocks careening around. One enormous impact is thought to have smashed the Earth and spalled off enough debris to form the moon. Other, smaller impacts continued to pummel the inner planets for the first half-billion years or so of their existence. Each collision would have brought a little more fresh material to each world.

On Earth, meteorite impacts could have delivered half a percent to 1 percent of the planet's total mass. Many meteorites that fall to Earth and are analyzed contain relatively high amounts of highly siderophile elements, which suggests that meteorites hitting the early Earth would have carried a lot of them, too. If so, then the cosmic smashups regularly showered Earth with a fresh coating of gold, platinum and other precious elements. By this time, Earth had already finished forming its core, so the highly siderophile elements remained sprinkled throughout its upper layers rather than being vacuumed into its depths.

Ancient rocks in Isua, Greenland, date back to more than 3.8 billion years ago. Siderophile elements in these rocks bear witness to geological processes in the planet's first 50 million years.

This "late accretion" of fresh material could help explain a long-standing puzzle. The amounts of highly siderophile elements in Earth's mantle are higher than predicted, according to laboratory experiments that try to mimic how molten metal separated from rock as Earth was forming. But a shower of meteorites hitting soon after core formation stopped could have done the trick, a process that Day, Walker and Alan Brandon of the University of Houston discuss in the January *Reviews in Mineralogy & Geochemistry*.

Not everyone accepts the late accretion idea. Some scientists, including Kevin Righter at NASA's Johnson Space Center in Houston, note that siderophile elements become less iron-loving when squeezed at high pressures and temperatures. That could mean fewer of them dived deep into Earth's core, and more of them would be left behind for the mantle and the crust. No need for an express meteorite delivery.

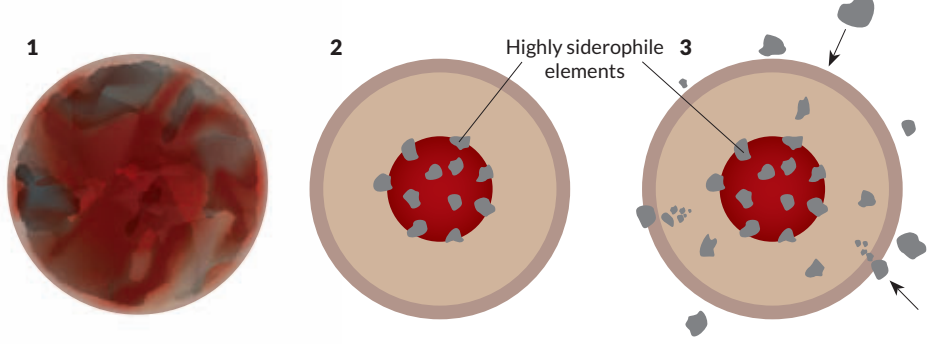
Debate probably won't end anytime soon, as various laboratory experiments seem to support both conclusions. "People are still hacking away at trying to understand this," says James Brenan, a geochemist at Dalhousie University in Halifax, Canada. Clarity is important for getting to the heart of what the highly siderophile elements can tell scientists — where they came from, how they separated out within the primordial Earth, and what they have been doing since then.

Less precious moon

Another big unanswered question is why the Earth and the moon seem to be so different from each other when it comes to highly siderophile elements.

A fresh dusting

Some 4.5 billion years ago, as Earth's core was solidifying within the newborn molten planet (1), the highly siderophile elements were drawn in to the iron-rich core (2). Later, meteorites pummeling the planet may have brought a fresh dusting of these rare metals (3).



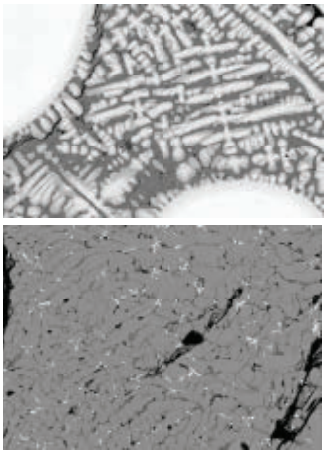
FROM TOP: JONATHAN O'NEIL/UNIV. OF OTTAWA; E. OTWELL

Researchers have a very limited sample of moon rocks to study — just those brought back by the Apollo astronauts, and a few lunar meteorites that happened to fall on Earth and were picked up. None of these samples come from the moon's deep interior. But by extrapolating from the chemistry of the rocks they have in hand, researchers have calculated that the moon's mantle has surprisingly lower amounts of the highly siderophile elements than Earth's mantle — just about 2 percent as much.

If the late-accretion idea is right, then both Earth and the moon should have been dusted by the same meteoritic bombardment of gold, platinum and other elements, and they should have similar amounts of highly siderophile elements in their mantles. That doesn't seem to be the case. The explanation may lie partly in the fact that the moon is a lot smaller than the Earth, Day and Walker noted last year in *Earth and Planetary Science Letters*.

Think of the meteorite bombardment as someone throwing snowballs at a pair of very different-sized dogs, Day says. "The statistical chance of these snowballs colliding with a Rottweiler are much higher than with a Chihuahua," he says. In other words, Earth acquired more platinum and gold simply because it is so much larger than the moon. Both went through the same snowball bombardment, but the bigger object collected more snow coating.

As with most things geochemical, there is another possible explanation. The moon does not have a core that would have sucked highly siderophile elements into its interior. But it's possible that something else could be holding the gold and platinum deep within the moon, Brenan says. That something is sulfur.



Lab experiments at high pressures, meant to simulate the moon's interior, show different patterns of iron sulfide crystals in mixtures rich and poor in iron (top, 96 percent iron; bottom, 25 percent iron). Iron sulfide could have trapped siderophile elements deep within the moon, explaining why their lunar abundance differs from Earth's.

J.M. BRENAN

The iron-lovers are also sulfur-likers. In the absence of metal, highly siderophile elements tend to clump with sulfur instead. By studying the interplay between the two, geochemists can start to tease out how the various elements behave as rocks are squeezed, melted and otherwise altered over billions of years of geologic history.

In recent laboratory experiments, Brenan mixed up a recipe of rock meant to simulate the lunar mantle. Earlier work had suggested that there was simply not enough sulfur deep in the moon for iron sulfide to be present. But his work, which used a more realistic representation of the lunar mantle, suggests that iron sulfide can indeed exist and be stable there. That iron sulfide would have kept the iron-lovers deep inside the moon — trapping the highly siderophile elements out of sight.

The sulfur work may have even broader implications for understanding how the Earth, moon and other worlds in the inner solar system got their water. Both sulfur and water are relatively volatile compounds that often appear together. Researchers thought both had been lost from the moon long ago. After all, the lunar surface today is dry and barren. But in recent years, scientists have been analyzing droplets of melt in lunar rocks and have found surprisingly high amounts of sulfur and water. That indicates that the moon may once have been wetter than thought. "That has really changed our thinking," Brenan says.

By looking at the concentration of these elements in lunar rocks, geochemists can cross-check their measurements of sulfur and water — and begin to understand the differences between Earth and the moon.

Still searching

At the University of Münster in Germany, geochemist Mario Fischer-Gödde has been working to pull together the various threads of what highly siderophile elements can reveal. Many researchers have suggested that Earth may have gotten much of its water and other volatile elements during the meteorite bombardment of the late accretion. So Fischer-Gödde is systematically analyzing different types of meteorites found on Earth to see if they could have actually delivered these volatiles.

He focuses on the element ruthenium. Like the other highly siderophile elements, it probably arrived on Earth aboard meteorites during the late accretion. Weirdly, though, none of the dozens of meteorites Fischer-Gödde has analyzed contain ruthenium isotopes that match those found in the mantle. He concludes that none of the meteorite types found on Earth so far could be the source of the late accretion materials. Some other source — maybe other rocky bits that were flying around the inner solar system — must have brought ruthenium and other siderophiles to Earth, he reported at the Durham workshop.

And that means the highly siderophile elements still have many mysteries to reveal, and there's plenty of work to be done. With new ever-more-sensitive techniques under development — such as scans that reveal individual atoms of highly siderophile elements within small grains of metal — researchers are pushing forward in their efforts to analyze the siderophile elements, hoping to squeeze more stories of Earth's beginning from the discreet iron-lovers. ■

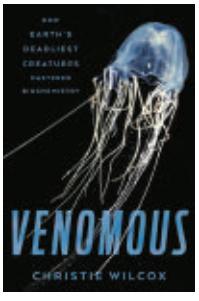
Explore more

- 4th International HSE Geochemistry Workshop. Durham, England. July 2016. http://www.hseworkshop.co.uk/
- *Reviews in Mineralogy & Geochemistry*, special issue on the highly siderophile elements. January 2016. http://rimg.geoscienceworld.org/content/81/1

BOOKSHELF

Scientists deliver a double dose of venomous animal facts

The Sting of the Wild
Justin O. Schmidt
JOHNS HOPKINS UNIV., $24.95



Venomous
Christie Wilcox
SCIENTIFIC AMERICAN/ FARRAR, STRAUS AND GIROUX, $26

In the arms race of life, a number of animals use venom as a weapon to paralyze prey and jump-start digestion. Meanwhile, venom also helps a variety of other seemingly defenseless creatures improve their odds against larger, stronger or more aggressive foes.

In *Venomous*, molecular biologist Christie Wilcox surveys the animal kingdom's wide array of biochemical warriors, from spiders and snakes to sea urchins and centipedes. In *The Sting of the Wild*, entomologist Justin O. Schmidt takes a more focused approach, zooming in on stinging insects such as ants, wasps and bees. Both books recount the origins and effects of venom in wonderful detail, as well as relating the fascinating tales of the researchers who study these noxious and sometimes fatal cocktails.

Male platypuses have venomous spurs on their hind legs that they use in competition with other males during mating season and, when needed, for self-defense. But, Wilcox notes, this is a rare exception. Venoms generally fall into offensive or defensive categories. Venoms for offense tend to be fast-acting and fatal; defensive venoms usually just serve as a warning. The neurotoxins in these defensive venoms often cause great pain but typically aren't lethal (unless the victim happens to be allergic to one or more of a venom's many components).

In the case of insects, venom has done much more than help protect individuals from harm, Schmidt points out: Venom actually helped set the stage for the evolution of ants, wasps, bees and other social insects. While a single insect might not be worth a large predator's attention, an entire colony of defenseless insects — including their high-protein larvae — would be attractive indeed. Venom enables the members of a species to aggregate in large numbers, with many individuals contributing to the common defense.

As both books point out, researchers are still teasing out the secrets of venom. In addition to trying to develop better antivenoms for human victims, scientists are looking for individual components of venoms that could be used as painkillers, blood thinners or treatments for everything from epilepsy to erectile dysfunction.

Many of these scientists do their work in labs using test tubes, but Schmidt has gone above and beyond the call of duty. By letting more than 80 different types of stinging insects jab him, he has developed a "pain index" for each sting. Published in full for the first time in this book, Schmidt's index ranges from 1 to 4 for all but a handful of species. His descriptions of the pain are wry and eloquent. While the sting of one bee species merits a mere 0.5 ("Did I just imagine that?"), the pain from a warrior wasp sting scores a 4 ("Torture. You are chained in the flow of an active volcano. Why did I start this list?"). — *Sid Perkins*

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NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY

The restoration of the Starship Enterprise studio model (above) from the original *Star Trek* was completed in May for a National Air & Space Museum exhibit in Washington. At a DARPA exhibit in Chicago, visitors (right) mix and match parts to create virtual robots.

FROM TOP: ERIC LONG/SMITHSONIAN'S NATIONAL AIR AND SPACE MUSEUM; J.B. SPECTOR/MUSEUM OF SCIENCE AND INDUSTRY, CHICAGO

SCREENTIME

No crystal ball? Ask the hive mind

As the saying goes, "It's difficult to make predictions, especially about the future." The website Metaculus.com aims to make this challenging task easier by harnessing collective wisdom.

Metaculus solicits answers to questions about the future — on topics spanning science, politics and economics — and combines these predictions to infer the likely outcomes. Will 2016 be the hottest year yet recorded? Will we find evidence for aliens soon? Will we hail self-driving taxis in the next few years? The hive mind might provide answers.

The website, created by physicists Anthony Aguirre and Gregory Laughlin of the University of California, Santa Cruz, along with former postdoc Max Wainwright, is an experiment to test whether our pooled instincts can produce reliable predictions. The site may also help scientists make informed decisions about which research to prioritize. Organizations funding research on pandemics, for instance, might want to know whether people are more concerned about bioterrorism, powerful germs escaping laboratories or naturally circulating diseases like the flu.

There's a precedent for successful crowdsourcing of predictions. A U.S. government–funded geopolitical forecasting effort, the Good Judgment Project, has found that collective predictions can be remarkably accurate, and that prediction is a skill that can be honed.

After completing a free sign-up process, Metaculus users click through yes-or-no questions and make predictions, moving a slider from zero to 100 percent to indicate their level of certainty. The site provides relevant background information on each question, and additional research is encouraged. Prognosticators can hash things out in the comments section and share resources to help others make their predictions. Users rack up points — and bragging rights — when their predictions turn out to be correct.

The hive mind isn't perfect — Metaculus users pegged the probability that the United Kingdom would vote to leave the European Union at just 32 percent. The United Kingdom did vote to leave, but that doesn't mean the method is flawed. "The point of this is not to get a 'yes' or 'no,'" Aguirre says, "but to get what is the probability." Most events aren't predictable with complete certainty, he says, but attaching a probability to such events can be useful in planning for the future.

So far, Metaculus has about 1,300 registered participants. In a review of more than 2,000 user predictions, the results were about as expected. When users predicted an event would happen with 80 percent certainty, they were correct about eight times out of 10. When many minds join forces, even nonexperts may collectively become capable guesstimators. — *Emily Conover*

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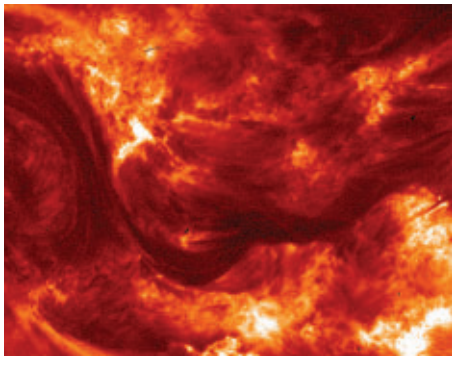
The shocking electric eel!

Philip Stoddard once had a pet named Sparky. The zoologist kept this electric eel in a tank in his lab at Florida International University. "It was so beautiful, I had to pet it," he says. Big mistake. Sparky zapped Stoddard with a memorable 500 volts of electricity. Ken Catania, a biologist at Vanderbilt University in Nashville, discovered that these animals use their electrical bursts to freeze prey in place. The eels can even force hiding fish to reveal their position. Concludes Catania: "Everything I've seen in these animals is amazing." — *Roberta Kwok*

Read more: **sciencenewsforstudents.org/eel**



Cool Jobs: Solar sleuthing

In 1859, a massive burst of energy from the sun slammed into Earth. It caused telegraph wires to explode in sparks, which gave some telegraph operators electric shocks. If such a solar flare hit Earth today, it could zap satellites, fry computer systems and knock out power grids. But there's still a lot that science does not yet know about the star at the center of our solar system. When can we expect the next "super flare" to strike? Why is the sun's atmosphere more than a million degrees hotter than its surface? Our star is full of mysteries. And we meet three scientists working to crack the case.
— *Ilima Loomis*

Read more: **sciencenewsforstudents.org/solar-sleuthing**

Clear, stretchy sensor could lead to wearable electronics

Many electronic parts are made of stiff materials that break easily. That makes them tough to use in products that need to bend. But researchers in South Korea have developed a thin, nearly transparent, flexible mesh (shown on a person's hand, below). It can still conduct electricity after being bent back and forth more than 1,000 times. The mesh even carries a current after being stretched to nearly six times its original length. It could find use in everything from flexible solar cells and the "skin" of robots to sensors applied to the skin of hospital patients. — *Sid Perkins*

Read more: **sciencenewsforstudents.org/sensor**

CLOCKWISE FROM TOP: BRIAN GRATWICKE/FLICKR (CC BY-NC 2.0); S. AN *ET AL/ADVANCED MATERIALS* 2016; HI-C/NASA

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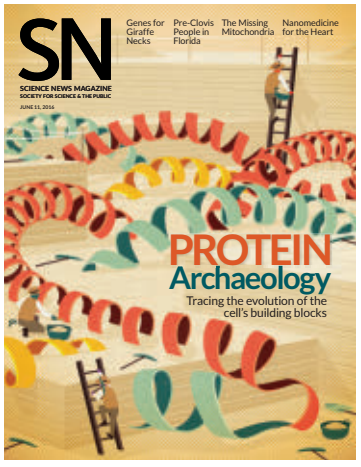

JUNE 11, 2016

Settler surprise

Stone tools discovered in Florida provide evidence that hunter-gatherers inhabited the region at least 1,000 years before the Clovis, once thought to be North America's earliest settlers, **Bruce Bower** reported in "Florida inhabited surprisingly early" (*SN: 6/11/16, p. 8*). Online readers joked back and forth about the relationship between the ancient peoples.

"Now we know where the Clovis people retired."
Gerald Hanweck

"You're not paying attention. These folks preceded the Clovis. Clovis people were the grandchildren that never called."
Jonathan Zingman

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Flightless perks

Galápagos cormorants are the only cormorant species with wings too small to fly, and broken cellular antennae that transmit garbled developmental messages are probably to blame, ***Tina Hesman Saey*** reported *in "How a Galápagos bird got tiny wings"* (SN: 6/11/16, p. 11*).*
Online reader **Mark S.** wondered if the inability to fly conveyed any advantages to the cormorants.

It appears so, says evolutionary biologist **Alejandro Burga** of UCLA. The Galápagos cormorant may be flightless, but it's a great diver. "Shorter wings can be advantageous for diving because they decrease bouyancy by decreasing the number of air bubbles trapped in feathers," **Burga** wrote in an e-mail. Because the birds are flightless, they can allocate the energy they would use flying for other purposes. "In fact, the Galápagos cormorant is larger and heavier than its close relatives. This confers an advantage," he wrote. With increased oxygen storage they can dive for longer.

Butterfly engineering

Scientists re-created a nanostructure found on green hairstreak butterfly wings, ***Emily Conover*** *reported in "Sorting out a butterfly's bright color, with a twist"* (SN: 6/11/16, p. 32*). The bioinspired structure can separate polarized light and may be useful for telecommunications.*
"I'm curious to know what kind of aerodynamic effect those spiral structures have?" asked reader **Daniel Williams**.

The nanostructures themselves may be too small to have an impact on aerodynamics, says **Amy Lang**, an engineer at the University of Alabama in Tuscaloosa. Study coauthor **Min Gu** and colleagues are looking at potential microfluidic applications instead.

Nanostructures may not affect butterflies' flight, but scales do. In a recent experiment, **Lang** and colleagues studied how monarch butterfly scales — just 100 micrometers thick — impact flight. Butterflies with their wing scales removed were less efficient fliers than monarchs with scales intact, she said.

Cold catchers

Children with a defective virus-sensing gene called IFIH1 *may land in intensive care after a cold,* ***Tina Hesman Saey*** *reported in "Faulty gene can turn colds deadly for babies, toddlers"* (SN: 6/11/16, p. 11*).*
Online reader **John Turner** suggested doctors could detect children who carry the gene through newborn screening tests, which are common in many U.S. hospitals. "The blood panel manufacturer could add an *IFIH1* allele indicator to their test, and flag that one-in-a-thousand baby that will need special attention at flu season," he wrote.

An indicator test for the defective gene is possible, but the research is still quite preliminary, **Saey** says. And tests must be carefully validated and undergo a rigorous review process before they can be added to newborn screenings, says computational biologist **Samira Asgari** of the Swiss Federal Institute of Technology in Lausanne. Although an *IFIH1* indicator test "probably will be a good investment given the burden of pneumonia on health care systems," she says, at this point it is unclear if or when such a test would be developed.

Clarification

In "Nano for the heart" (*SN: 6/11/16, p. 22*), freelance writer **Sarah C.P. Williams** describes efforts to develop nanoparticles with and without drugs attached to treat cardiovascular disease. A quote in the article mistakenly implied that **Ira Tabas** of Columbia University was referring to problems with statins. He was instead referring to problems with anti-inflammatories. He is not a critic of statins.

Tabas attaches nanoparticles developed by **Omid Farokhzad** of Harvard University to a small section of a protein called annexin A1. The protein is not a traditional anti-inflammatory agent, as was stated; it is, **Tabas** says, a pro-resolving molecule that dampens inflammation but also helps heal damage.

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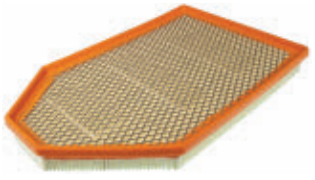

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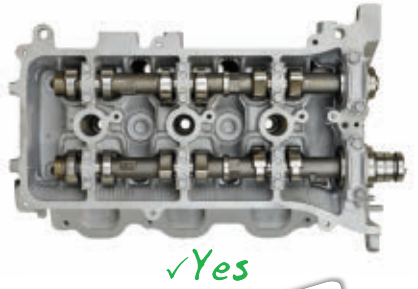

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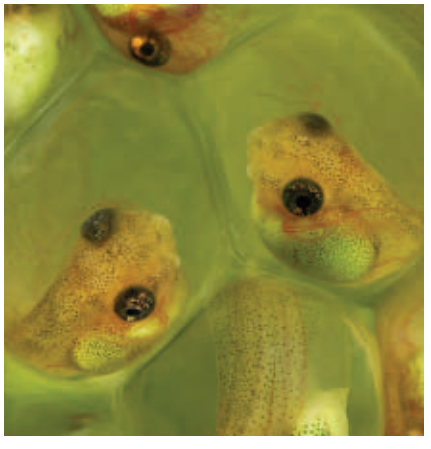

Under threat, tadpoles make early escape

Tree frog tadpoles are the ultimate escape artists. To avoid becoming breakfast, the embryos of red-eyed tree frogs (*Agalychnis callidryas*) prematurely hatch and wriggle away from a snake's jaws in mere seconds, as seen at left. Embryos also use this maneuver to flee from flooding, deadly fungi, egg-eating wasps and other threats. Adding to the drama, red-eyed tree frogs (bottom right) lay their eggs on the undersides of leaves that hang a few inches to several feet above ponds. So the swimmers perform this feat suspended on a leaf, breaking free in midair and cannonballing into the water below.

High-speed video, captured by Kristina Cohen of Boston University and her colleagues, of unhatched eggs (bottom left) collected from Panamanian ponds shows that the embryos' trick plays out in three stages. First, upon sensing a threat, an embryo starts shaking and gaping its mouth to stretch its egg membrane in the spot in front of its snout. Next, a hole forms. (The movement helps tear open the hole, but an embryo's snout probably secretes a chemical that actually does the breaking.) Finally, the embryo thrashes its body about as if swimming and slips out of the egg.

Orientation is key to a hasty escape, the team reports in the June 15 *Journal of Experimental Biology*. An embryo must keep its snout aligned with the hole for a speedy exit. In observations of 62 embryos, the getaway took between six and 50 seconds — 20.6 seconds on average.

Some tadpoles may be leaping out of a cauldron into a fire. "There's a trade-off," Cohen says. "They may have escaped the threat of a snake, but earlier hatchlings fare worse against some aquatic predators." — *Helen Thompson*

ALL: KAREN M. WARKENTIN

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