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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
AUGUST 8, 2015

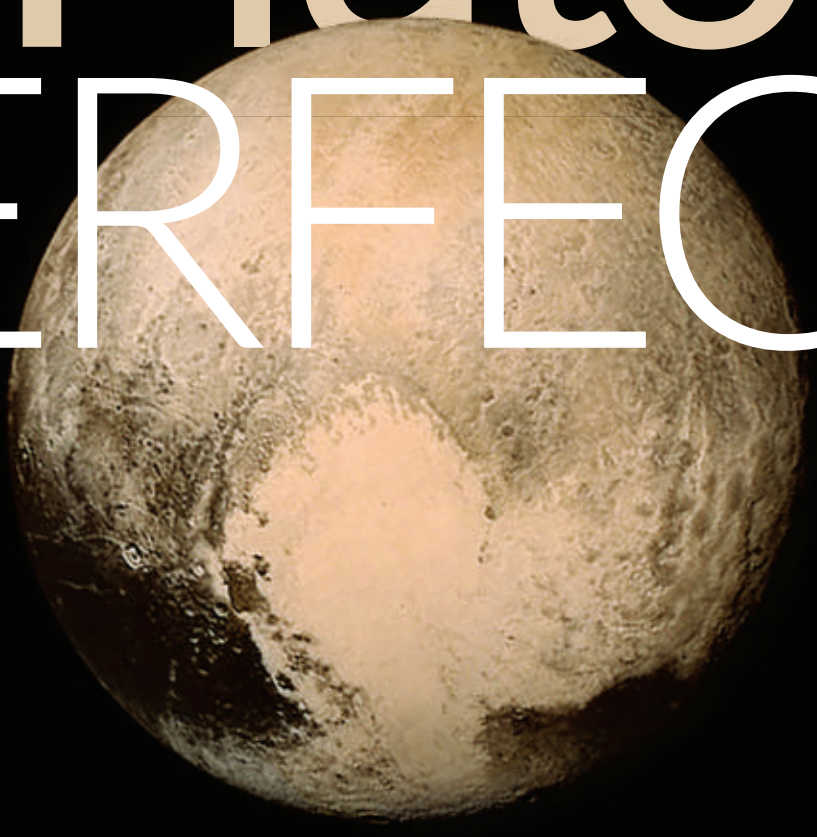
Redrawing the Tree of Life

Trapped Minds

Pentaquark Detection

Neural Speedometer

Pluto PERFECT



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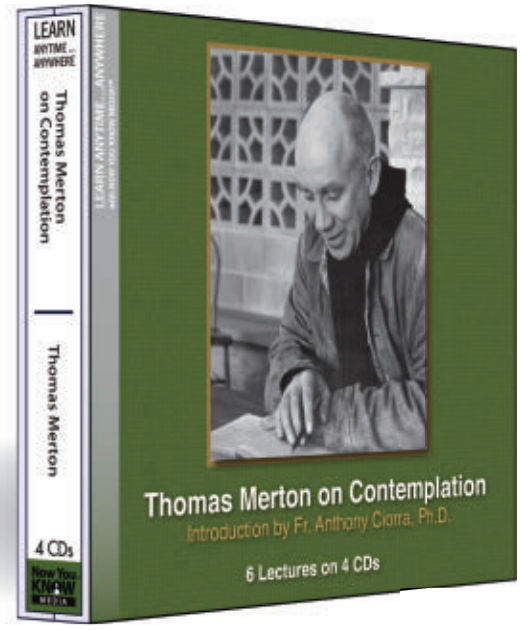

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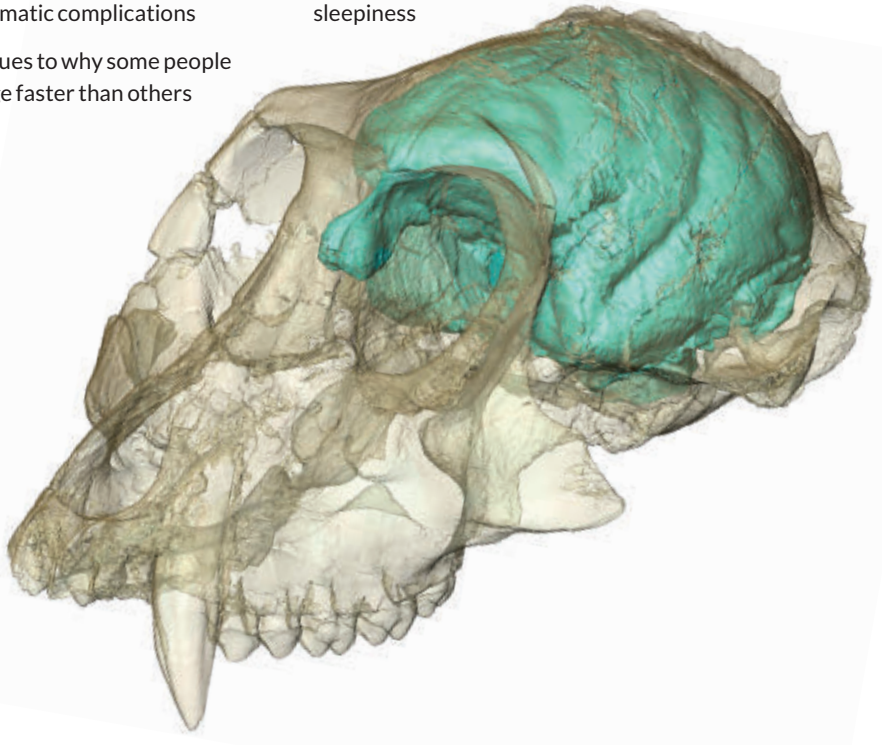
Features

News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Departments

SOCIETY UPDATE
Science fair entries are in

COVER Pluto, the dwarf planet on the outskirts of the solar system, has revealed some surprises to the New Horizons probe. *NASA, JHUAPL, SWRI*

CLOCKWISE FROM TOP: PROYECTO AGUA/FLICKR (CC BY-NC-SA 2.0); SYLKE ROHRLACH/FLICKR (CC BY-SA 2.0); FRED SPOOR/MAX PLANCK INSTITUTE FOR EVOLUTIONARY ANTHROPOLOGY

Encountering an unexpected Pluto and life's complexity

By her own estimate, Susan Milius has considered writing about the downfall of biological kingdoms for some 10 years. That long contemplation made it somewhat difficult to pare all the material down to a six-page feature article. But I think readers will agree that she has succeeded admirably, outlining the shifts in scientific understanding that have uprooted previous notions of the tree of life (Page 22).

Milius describes how genetic tools, which initially led scientists to misconstrue connections, are now beginning to clarify relationships in the panoply of eukaryotic life-forms. It's a fascinating tale of how peering deep into the history of evolution has revealed unexpected richness and complexity, even in the supposedly simple single-celled organisms.

New tools can afford better views not only of the deep past but also the distant present. Just as genetic analyses are revealing details of life's long history, the New Horizons probe is bringing the fuzzy surface of the faraway dwarf planet Pluto into focus. *Science News* wrote about New Horizons (also nearly 10 years in transit) a few issues ago (*SN: 6/27/15, p. 16*), and now reports on the actual flyby of Pluto. The event, which took place while we prepared this issue of the magazine, kept the entire staff rapt.

Christopher Crockett was on the scene July 12–15 at the Applied Physics Laboratory in Laurel, Md., along with about 200 other reporters from around the world. His story on Page 6 began as a series of brief, real-time posts on the *Science News* website while data streamed back from Pluto to the New Horizons team. It was science news at its best. Instead of the dead icy orb people expected, New Horizons revealed a dynamic and varied world unlike any other. Once again, better tools revealed something new, forcing scientists to recast what they thought they knew. It was historic.

At the heart of the excitement in the newsroom was the sense of extending humankind's ability to see more of what's out there, from the details of the surface of a dwarf planet to the incredible diversity of life on Earth. Perhaps even more thrilling was the sense that there are more puzzles to discover, just waiting for the right tools to illuminate them.

—Eva Emerson, Editor in Chief

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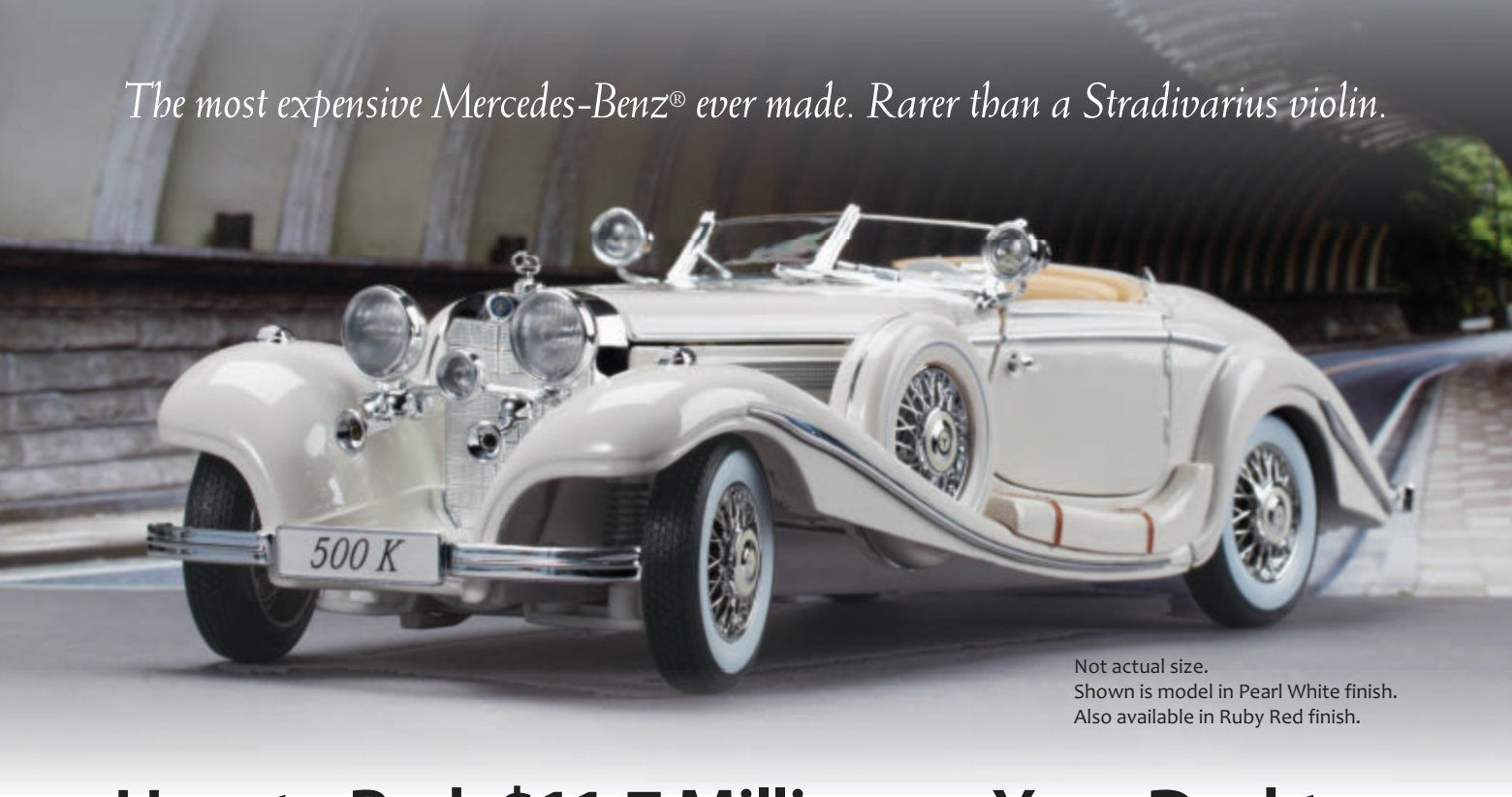

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Shown is model in Pearl White finish.
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Excerpt from the August 7, 1965, issue of *Science News Letter*

50 YEARS AGO

Craters found on Mars

Astronomers are speculating whether the surfaces of other bodies in the solar system, besides Earth's moon and Mars, are covered with craters from meteorite strikes. The surface of Venus may never be revealed because of its cloud cover.... The Mariner 4 photographs of Mars, man's first close-up pictures of another planet, revealed the totally unexpected fact that the Martian surface, like Earth's moon, is peppered with craters.

UPDATE: Earth's moon and Mars are not alone in their pockmarked appearances. Spacecraft have snapped pictures of impact craters on Mercury, Venus and many of the moons of Jupiter, Saturn and Uranus. The gas giants, including Neptune, have no hard surfaces. But Jupiter's gassy body has shown signs of bruising after collisions with comets and other debris (*SN Online: 6/4/10*). The far-flung worlds of Pluto and its largest moon, Charon, have surprisingly few craters, suggesting both are geologically active, or recently were (see Page 6).

IT'S ALIVE

Baby seahorses' toddler phase

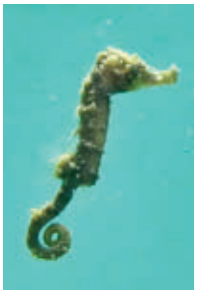
These juvenile seahorses can already grasp with their tails. Babies aren't so coordinated.

Newborn seahorses look like their parents. They deliver beyond-fast strikes at prey. And their tails end with a miniature up-curl like a grown-up's prehensile marvel. But they're babies, and they bumble.

That's the impression of evolutionary morphologist Dominique Adriaens, who has watched *Hippocampus reidi* born in his lab at Ghent University in Belgium. In the seahorse world, it's dad, of course, who's pregnant. "A male gives birth in, let's say, 10 seconds — tops," he says. "You see small white dots squirting out. And five to 10 seconds later, you see hundreds of tiny seahorses floating at the surface of the water."

His lab has found that the rice-grain–sized newborns strike at their prey fast, but not all that accurately. Like adults, they get recoil speed by tensing muscles without moving and building up tension in their tendons. Then they suddenly let fly, and their snouts whip upward to suck in tiny crustaceans. If the rotation continued at strike speed, the heads could spin around more than 80 times in just a second. "They start doing this from the time they are born, only they are very lousy at catching prey with it," Adriaens says.

Nor do babies (one shown below) manage signature seahorse tail grasps, even though they have the basics of the adult shape. As far as Adriaens knows, species in the seahorse family and some small chameleons grow the only prehensile tails that are square in cross section instead of round.



The peculiar seahorse tail shape comes from a flexible, squared-off cage of bony struts that form from skin layers instead of cartilage. The square may be a legacy of ancestral seahorse armor that just happens to work for grasping too, Adriaens and his colleagues propose in the July 3 *Science* (*SN Online: 7/2/15*). Crushing tests on 3-D printed models found that square tails were four times as strong as round versions.

Babies, however, don't get a grip until they're old enough to venture to the sea bottom. There, the fish go prehensile. Out of some 30,000 known kinds of fishes in the world, the seahorse family is the only one to have evolved any form of tail that grasps a perch. — *Susan Milius*

FROM TOP: ZOO BASEL; SYLKE ROHRLACH/FLICKR (CC BY-SA 2.0)

See a slideshow of otherworldly craters at **bit.ly/SN_ETcraters**

MYSTERY SOLVED

Natural concrete keeps lid on volcano

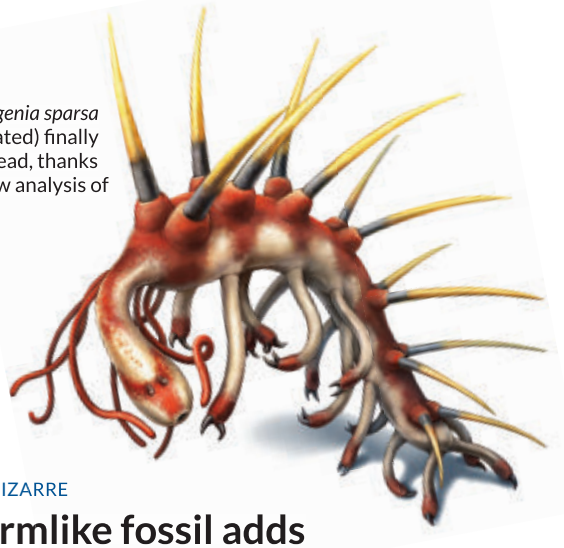
Just west of Naples, Italy, the ground swells and strains around the Campi Flegrei caldera, mythical home of the Roman fire god Vulcan. The volcanic region's most recent rise came between 1982 and 1984, when the ground rose around two meters. Officials evacuated nearly 40,000 people from the nearby town of Pozzuoli in fear of an eruption. It never came.

At the time, Tiziana Vanorio was a teenager in Pozzuoli. Now a geophysicist at Stanford University, Vanorio says she has figured out how the rocks beneath the caldera bulge without breaking.

Examining a rock core drilled from the caldera, Vanorio and Waruntorn Kanitpanyacharoen of Chulalongkorn University in Bangkok discovered a layer of stiff, fibrous rock similar to concrete. This layer, around 1.3 to 1.7 kilometers deep, probably formed over time as rising hydrated lime, one of the main ingredients in manufactured concrete, mixed with volcanic ash. Together, they formed an impenetrable lid that resists fracturing even as the underlying pressure mounts.

This natural engineering could have inspired the ancient Romans to mix their own concrete, the researchers propose online July 9 in *Science*. — *Thomas Sumner*

Naturally occurring concretelike rock allowed the ground around the volcanic Campi Flegrei caldera in Italy to rise without bursting, new research finds. Cracks in the nearby rock (shown) vent gas and heat from deep underground.



Hallucigenia sparsa (illustrated) finally has a head, thanks to a new analysis of fossils.

HOW BIZARRE

Wormlike fossil adds head to its spiny appearance

Whether upside down or right side up, *Hallucigenia sparsa* looks like it wriggled right out of a nightmare. And giving the wormlike creepy-crawly a head hasn't helped.

An analysis of 508-million-year-old *H. sparsa* fossils from the Burgess Shale in Canada revealed that the 10- to 50-millimeter-long critter had a small pair of simple eyes set atop a narrow head. Below the head was a long neck that protruded from a tubular body sporting 10 sets of dangly appendages and seven pairs of spines. Platelike structures surrounded *H. sparsa*'s mouth opening and tiny teeth lined part of its gut, researchers report in the July 2 *Nature*.

Those toothy features are similar to some seen in present-day tardigrades, or water bears (*SN: 7/26/14, p. 4*), hinting at the evolution of such gnarly mouthparts. — *Ashley Yeager*

SCIENCE STATS

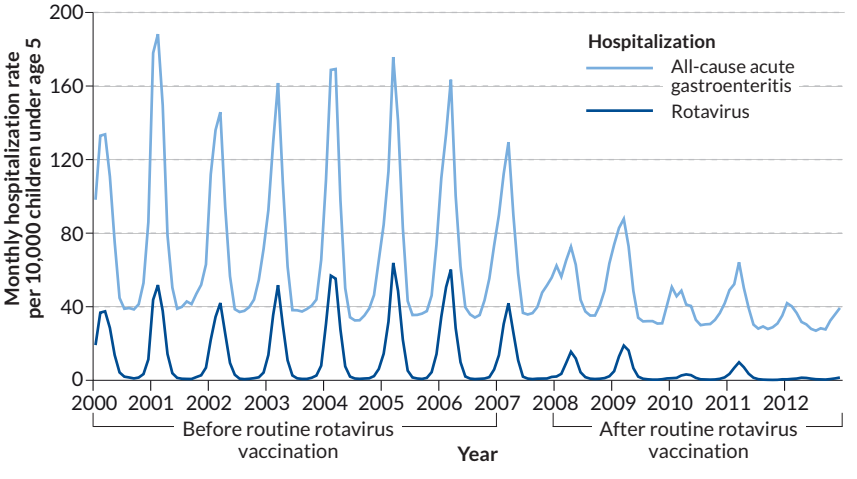
Rotavirus vaccine is proving its worth

Rotavirus vaccination pays off — big time.

The United States began routinely vaccinating babies against the diarrhea-causing virus in 2006. Since then, the number of kids younger than 5 years old hospitalized for intestinal infections has plummeted. In 2012, the hospitalization rate for these children dropped to 45 percent of the prevaccine rate, researchers report in the June 9 *JAMA*.

As of 2013, about 73 percent of U.S. kids ages 19 to 35 months had received the recommended two- or three-dose rotavirus vaccine series. — *Meghan Rosen*

Hospitalization rates for children younger than 5 years old with intestinal infections



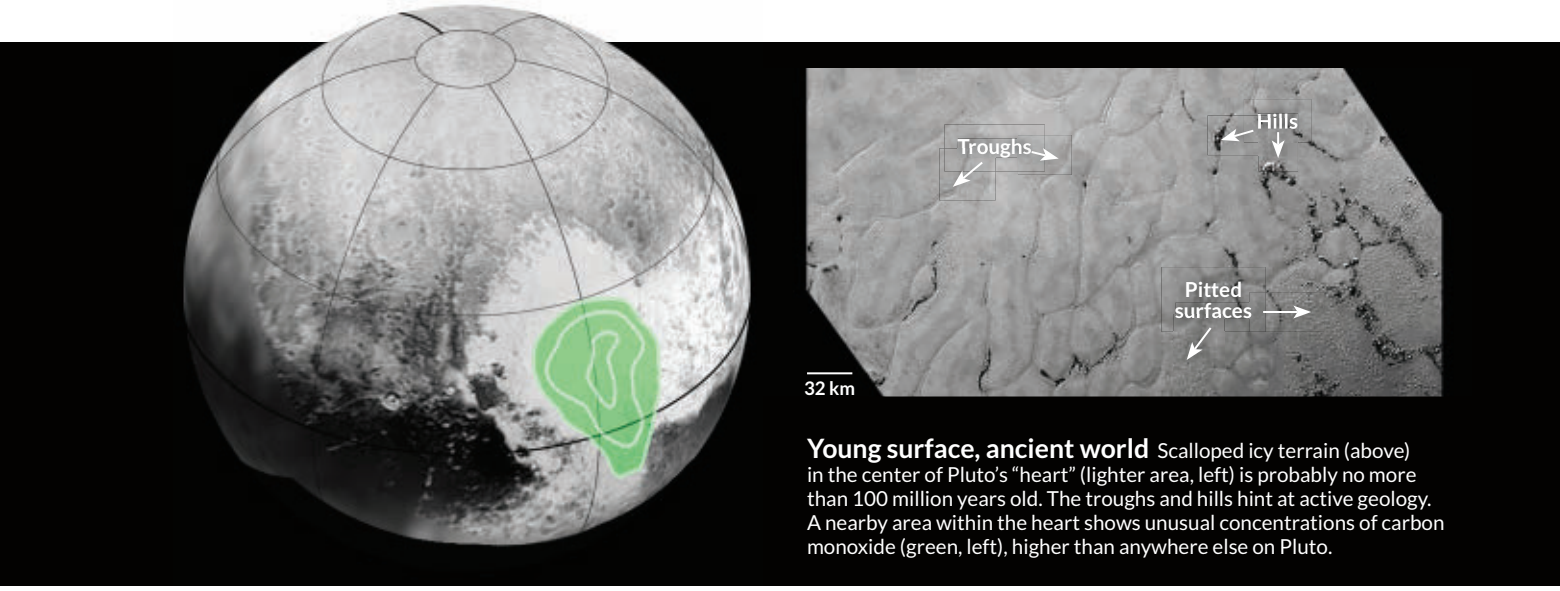
Going down The number of U.S. kids hospitalized for gastroenteritis and rotavirus infection dropped sharply after routine vaccinations began in 2006. Widespread vaccinations blunted the seasonal peak of these cases typically seen in the winter and spring. SOURCE: E. LESHEM *ET AL*/*JAMA* 2015

FROM LEFT: DAMIENOZ/FLICKR (CC BY-ND 2.0); DANIELLE DUFAULT

ATOM & COSMOS

Pluto's icy landscape comes into view

New Horizons reveals varied terrain, evidence of active geology



Young surface, ancient world Scalloped icy terrain (above) in the center of Pluto's "heart" (lighter area, left) is probably no more than 100 million years old. The troughs and hills hint at active geology. A nearby area within the heart shows unusual concentrations of carbon monoxide (green, left), higher than anywhere else on Pluto.

BY CHRISTOPHER CROCKETT

LAUREL, MD. – Alan Stern, head of the New Horizons mission to Pluto, had just three words for the team of scientists and engineers assembled with him on July 14: "We did it."

At 8:52:37 p.m. Eastern time, a radio antenna near Madrid received the first signal from the spacecraft since it buzzed the dwarf planet. After decades of planning and a 9.5-year journey across nearly 5 billion kilometers of interplanetary space (*SN: 6/27/15, p. 16*), the New Horizons probe reported that it was in good health and that the mission was a success. The spacecraft flew within 12,500 kilometers of Pluto, right on schedule.

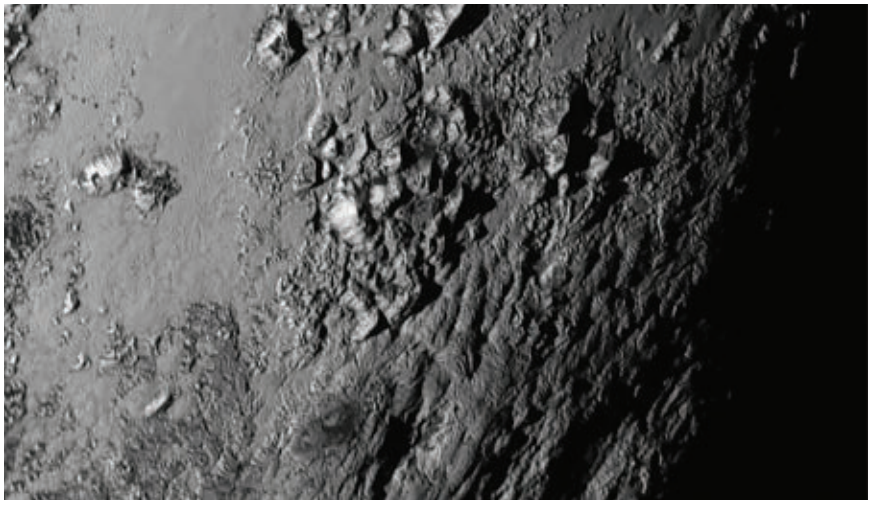
"Our spacecraft did exactly what it was supposed to do," said mission operations manager Alice Bowman. "Just like we planned it, just like we practiced."

From now on, Pluto and its five moons will no longer be abstract points of light, but real worlds with many stories to tell. And even with just a handful of observations retrieved from the hundreds still stored on New Horizons, Pluto and its largest moon, Charon, are already reshaping what astronomers thought they knew about the frigid backwaters of the solar system.

"I expected it would be complicated and amazing," says Will Grundy, a planetary scientist at Lowell Observatory in Flagstaff, Ariz. "But I had no idea it would be this complicated and amazing."

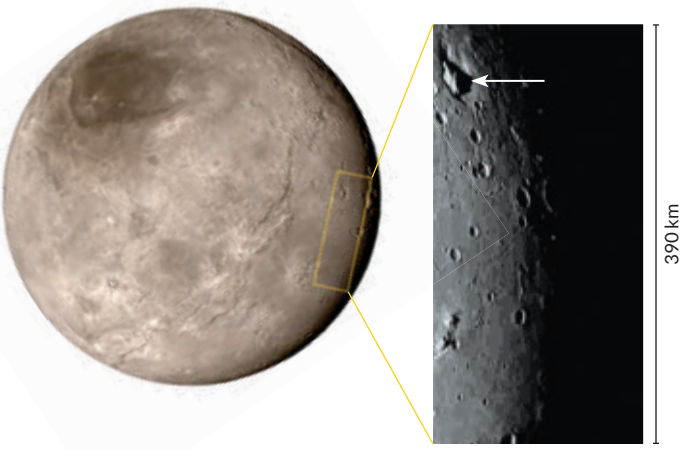
Pluto and Charon are vibrant, diverse worlds. Mountains, canyons, icy bedrock and nitrogen snow are some of the features that shape these worlds, which are unlike any other orbiting the sun. Some terrains have been freshly resurfaced, shaped by internal forces that are not at all understood. Others have stood the test of time, serving as witnesses to most of the solar system's history.

"We're not saying Pluto looks like this world or that world," says planetary scientist Cathy Olkin of the Southwest Research Institute in Boulder, Colo. "There's nothing like it."



Mountains of water ice roughly as tall as the Rockies tower over a young landscape to the south of Pluto's heart-shaped region. Snows of nitrogen and methane blanket the peaks. On the dwarf planet, water ice probably behaves like bedrock on Earth.

ALL: NASA, JHUAPL, SWRI



Pluto's largest moon, Charon, has a dark patch on its north pole, a feature not seen elsewhere in the solar system. Craters dot some of Charon's older terrain (closeup view, far right), including one that appears to house a mountain (arrow).

Ask any scientist on or off the team about how a 4.6-billion-year-old solitary ice world is still actively reworking itself, and the most common response is a long pause followed by a shrug.

"We're like geologists that are just starting out on learning geology," Grundy says. Out there, where temperatures top out at −223° Celsius and bedrock is forged from hardened water ice, planetary scientists are on unfamiliar ground.

Not that the mission scientists have had much time to fully process what they've seen. They had to squeeze in cursory analyses while navigating a circus-like atmosphere at the Johns Hopkins Applied Physics Laboratory in Laurel, Md., home of the mission operations center. Among the spacecraft-shaped hats, Pluto trading cards (collect all nine!), flag-waving and standing ovations, mission control at times felt like a political rally.

But with the celebration behind them, the team can now turn to the fun part: figuring out what Pluto and Charon have to say.

Both worlds already show incredible diversity. Pluto displays a prominent heart-shaped landscape, informally named Tombaugh Regio in honor of the dwarf planet's discoverer. This territory is devoid of craters, which means it's likely young. To the north, the heart gives way to older, pockmarked ground. The heart's "right ventricle" blends into a hummocky, undulating terrain, while the other half runs up against a dark belt that wraps around the equator.

The bright regions appear to be coated in nitrogen, methane and carbon monoxide ice. Darker lands are probably stained by hydrocarbons tarnished by long exposure to the sun's ultraviolet radiation.

To the south of Tombaugh Regio lies what might be the biggest surprise of all: mountains of solid water ice roughly 3,000 meters high. Cover them with pine trees and they wouldn't look out of place in the Rockies. Mission scientists estimate that the surface here is no more than 100 million years old.

"This is a recurring story," says David Jewitt, a planetary scientist at the University of California, Los Angeles who is not part of the New Horizons team. "We've been to a whole bunch of small places that no one expected to be active."

> "I expected it would be complicated and amazing. But I had no idea it would be this complicated and amazing."
> **WILL GRUNDY**

The frozen moons of the giant planets show similar diversity and activity. Water geysers erupt on Saturn's moon Enceladus; the Uranian moon Miranda exhibits towering ice cliffs; and the surface of Triton, Neptune's largest moon, has been resurfaced.

Moons are influenced by the planets they orbit. A planet's gravity stretches and relaxes its moons, which generates heat that can power geologic activity.

But absent a large planet, what's heating Pluto? Planetary scientists have a couple of ideas. Radioactive elements such as thorium and uranium trapped in a rocky core might be heating the surface. Or perhaps a subsurface ocean is freezing, releasing enough heat to power geysers and cryovolcanoes.

Charon, meanwhile, is quite different from Pluto, a mystery given that the duo have lived next to each other for over 4 billion years. Charon's surface is darker, with more craters (though not as many as expected) and less ice. Cliffs 1,000 kilometers long cut across the landscape, while canyons 10 kilometers deep carve notches out of the moon's visible edge.

"Charon looks like an amalgam of some Saturnian and Uranian satellites," says Paul Schenk of the Lunar and Planetary Institute in Houston, "but its dark pole is one of a kind."

Blackened splotches on the moon's north pole are not found anywhere else in the solar system — and Pluto is probably to blame. As Pluto's atmosphere leaks into space, it may carry aloft flecks of darkened hydrocarbons, some of which land on Charon. The pole, which is coming out of a decades-long winter, might be cold enough for a thin veneer of Pluto's effluent to stick to the surface.

Planetary scientists clearly have their work cut out for them. Any conclusions the team comes to now could very well be proved wrong in a month. Only 1 percent of the data are being transmitted right away. The rest of the observations won't finish downloading until late 2016.

As the data trickle in, researchers will study the smaller moons, look for rings encircling Pluto, and try to understand how its atmosphere is escaping and whether it shares that atmosphere with Charon, which would be another solar system first.

At this point, the scientists are struggling to simply identify what they're seeing. "It's like piles of stuff with grooves on it," says planetary scientist John Spencer of the Southwest Research Institute while describing land near the ice mountains. Not very technical, perhaps, but this is an alien environment in an unexplored realm of the solar system.

"It's baffling," Spencer says, "but it's baffling in a very interesting and wonderful way." ■

NASA, JHUAPL, SWRI

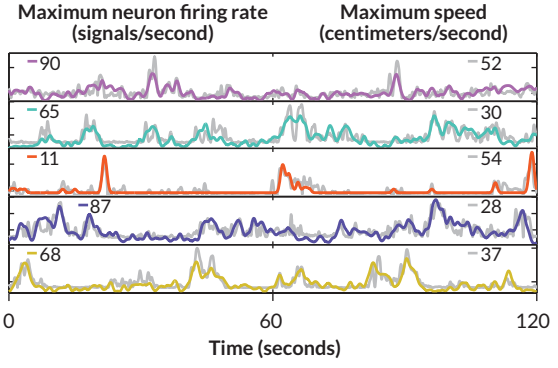
BODY & BRAIN

Rat brains have a speedometer

Specialized nerve cells fire faster when feet are fleet

BY LAURA SANDERS

From a saunter to a sprint, specialized brain cells keep track of a rat's swiftness, scientists report online July 15 in *Nature*. These "speed cells" may be a missing piece in understanding how animals and people navigate the world, says neuroscientist Michael Hausser of University College London.



On the move Speed cells' activity (colored lines) changes with rats' swiftness (gray lines) as they move around an enclosure in search of chocolate crumbs. This graph charts the activity of five different neurons.

Scientists have previously uncovered cadres of brain cells that help an animal constantly calculate its location in space, work that led to Nobel Prizes last year (*SN: 11/1/14, p. 15*). But without information about how fast an animal moves, that calculation was incomplete. "With this discovery," Hausser says, "we now have all of the cellular ingredients we need" to explain how internal maps are drawn.

Navigating in the environment is so basic that most people take it for granted, says Dartmouth College neuroscientist Jeffrey Taube. Without an internal map, people couldn't find a parked car; animals would suffer more dire consequences. "If a small animal turns the wrong way or goes the wrong direction, it's going to be dead meat very quickly," he says.

Speed cells were spotted in the brains of rats as they walked or ran along a track in a bottomless car. Like Fred Flintstone, the rats "drove" the car by moving their paws, but the researchers set the pace. As the rats moved, electrodes picked up signals from nerve cells, or neurons, in the rats' entorhinal cortex, a brain area known to be important for navigation.

When the rats shifted into overdrive, some of these neurons did too, Edvard Moser of the Norwegian University of Science and Technology in Trondheim and colleagues found. In one experiment, researchers toggled the rats between four speeds on the track, from a slow walk at 7 centimeters per second to a jog at 28 centimeters per second. Speed cells kept pace, firing off more signals at faster speeds and fewer at slower speeds.

The speed cells performed just as well off the track, keeping track of swiftness as rats searched for chocolate crumbs. The cells did their job in darkness, too, suggesting that they are all-purpose speedometers for any situation.

Speed cells make up about 15 percent of cells in the entorhinal cortex, which also harbors map-making grid cells. Speed cells seem to be distinct from grid cells, whose discovery led to Nobels for Moser and his wife, May-Britt Moser, coauthor of the new study.

It's not clear how the cells make speed judgments. Seeing scenery fly by probably isn't the most important cue, since the cells can work in darkness. The key signal may come from muscles and so might not work for a rat riding on a fast train. ■

MATTER & ENERGY

LHC reports pentaquark sightings

Collider offers new evidence for elusive five-part particles

BY ANDREW GRANT

Quarks, the elementary units of matter found in every atomic nucleus, are surprisingly comfortable in large crowds.

Two particles discovered at the Large Hadron Collider, or LHC, near Geneva are each composed of five quarks, researchers report online July 13 at arXiv.org. Until recently, quarks had been found only in pairs or trios. Now, in just over a year, an experiment called LHC beauty has exposed a four-quark particle (*SN: 5/17/14, p. 12*) and two five-quark ones.

The fresh evidence for the existence of five-quark particles, or pentaquarks, is "far more compelling" than a claim made a decade ago (*SN: 5/14/05, p. 318*), says Curtis Meyer, a particle physicist at Carnegie Mellon University. He says pentaquarks will help physicists better understand the strong nuclear force.

Physicists had long sought quark-based matter that isn't a three-quark baryon (like protons) or a two-quark meson, although the strong force could seemingly shape larger particles.

Sheldon Stone, a particle physicist at Syracuse University in New York, says he and his LHC beauty experiment colleagues were not seeking pentaquarks. But after analyzing about 26,000 decays of the bottom lambda particle, the team found that roughly 8 percent produced a previously unknown particle nearly 4.7 times as massive as a proton; another 4 percent generated a slightly heftier particle. The particles' masses, decay products and other data indicated a composition of a charm quark, its antimatter counterpart, two up quarks and a down quark.

Stone thinks that the new particles contain five quarks, but it's possible they are "molecules" of tightly packed two- and three-quark clusters. The relatively high mass of the new particles suggests that quarks with more mass are better at binding into big groups, Stone says. ■

E. KROPFF *ET AL*/*NATURE* 2015

EARTH & ENVIRONMENT

Warming shrinks bumblebee territory

As temperatures rise, pollinators lose ground from the south

Rising temperatures are compressing the habitat ranges of bumblebees, such as this rusty-patched bumblebee (*Bombus affinis*).

BY BETH MOLE

As climate change marches on, bumblebees are losing ground.

Rising temperatures are stamping out bumblebees from their southernmost ranges in North America and Europe. Yet surprisingly, many *Bombus* species are holding steady on their northern borders instead of surging into cooler climes, researchers report in the July 10 *Science*.

It's the first time that scientists have firmly fingered climate change as a widespread cause of shrinking bumblebee habitat. The study raises concerns that populations of these pollinators, already declining from pesticides and pathogens, will continue to die out and may even disappear in some areas.

"This is something that is not a problem for the future; it's happening right now and has actually now been going on for decades," says ecologist Jeremy Kerr of the University of Ottawa in Canada.

Mining collections from museums and other places, Kerr and colleagues assembled data on more than 423,000 bumblebees caught from 1901 to 2010 in North America and Europe. The bumblebees represented 67 species, around half of the species that live in those regions.

The records included locations where the bees were caught, allowing the team to assess how ranges changed over time.

From 1974 to 2010, some species' southern borders receded by about 300 kilometers. That's huge, Kerr says. For instance, the rusty-patched bumblebee, *Bombus affinis*, once common in the southern United States, has largely vanished from that area. Some other insects, such as butterflies, aren't losing ground.

During the same time, the bumblebees' native ranges in North America and Europe saw a 2.5 degree Celsius jump in average maximum temperatures, the authors say. Bumblebees, which are very sensitive to heat, seem to be retreating in lockstep with warming, Kerr says.

Yet, along their northern limits, most bumblebees are holding the line. That's "weird," Kerr says, because warming is causing other species to move north.

"The results are both intriguing and concerning," says Scott Hayward, a biologist at the University of Birmingham in England. To understand why bumblebees aren't moving north, researchers will need to focus on their biology, which is still in some ways "a black box," he says. ■

EARTH & ENVIRONMENT

Greenland's out-of-sync climate

Long lag in solar activity's effect portends faster warming ahead

BY THOMAS SUMNER

Scientists think they've figured out why Greenland's climate is out of sync with the rest of the Northern Hemisphere — but they had to go way back in time to find the proposed culprit.

From the 1970s through the early 1990s, Greenland kept its cool even as the Northern Hemisphere warmed. Reconstructing 2,100 years of Greenland temperatures, researchers propose that periodic fluctuations in the sun's activity can desynchronize Greenland's climate and cause changes decades later. The study, to be published in *Geophysical Research Letters*, suggests on the basis of current solar activity that Greenland could warm significantly faster over the coming decades than previously thought.

Whenever seesawing solar activity peaks, as it did in the 1950s, the North Atlantic warms. The researchers postulate that this extra heat slows the ocean current that ferries warm water north from the tropics. The cooling effect of this slowdown wouldn't be felt until 30 to 40 years later, the researchers note. If the sun's activity diminishes as expected in coming decades, this mechanism could reverse — and accelerate warming in Greenland in the 2020s and 2030s, says Takuro Kobashi, a climate scientist at the University of Bern in Switzerland.

Kobashi and colleagues collected a roughly 500-meter-long sample of glacier ice from Greenland and sliced off sections that formed as early as 2,100 years ago. Glacial ice grows under a layer of snow, trapping air pockets. Heavier atoms in the air congregate toward the bottom of the snow when the air is warmer than the ice. As temperatures drop, these atoms rise to the top of the snow layer. Comparing the relative number of heavier atoms in different layers provides a temperature record from when the ice formed.

The record revealed that Greenland warms long after the sun's activity reaches a minimum and cools long after a solar maximum. The temperature change lags 10 to 40 years after the change in solar activity.

Kobashi proposes that rises in solar heating warm the North Atlantic and dump extra rain into the ocean, causing the sea surface to become less dense and slow ocean circulation that carries warm water to Greenland.

Climate scientist Didier Swingedouw of the University of Bordeaux in France says he isn't convinced. In the July 2 *Nature*, Swingedouw and colleagues report that solar variations don't change circulation of North Atlantic currents. ■

GENES & CELLS

Age is more than just a number

Blood protein may explain why rates of growing older differ

BY TINA HESMAN SAEY

Some people age faster than others, a long-term study of New Zealanders reveals. But there's good news for the rapid agers: Studies in mice indicate there may be ways to slow the process down.

Like a class reunion photo, a physiological snapshot of 954 people born in Dunedin, New Zealand, in 1972 and 1973 shows that time has been kinder to some. The calendar indicated that all those people were 38 years old at the time of the study, but their biological ages ranged from 28 to 61, researchers report July 6 in the *Proceedings of the National Academy of Sciences*.

Biological age is based on how healthy a person is compared with the average health of a large number of people of various ages. Biologically older participants were weaker, less coordinated, had more rapidly declining IQs and felt and looked older than their biologically younger counterparts. People with the oldest biological ages had been aging more rapidly at least since they were 26 years old, the study found.

The researchers identified the rapid agers by tracking 18 health measures over time. Those markers included blood sugar and cholesterol levels, lung function, blood pressure, body mass index, waist circumference and the length of telomeres, the protective caps at the ends of chromosomes. Shorter telomeres have been associated with aging (*SN: 12/15/12, p. 13*).

No single factor appeared responsible for rapid aging. There probably isn't just one, says lead author Daniel Belsky, an epidemiologist at Duke University School of Medicine. He and colleagues found that aging affected all organs and body systems at once.

Some researchers think the problems may have started much earlier than age 26. Children who are neglected, abused, living in poverty, malnourished, exposed to hazards such as lead or who live around violence may suffer from poor health (a measure of aging) as adults.

"We see people on the street and we know they age at different rates," says Bruce McEwen, a neuroscientist at Rockefeller University in New York City. But scientists haven't had the data to back up that common wisdom. No one knew for sure that rapid aging started so early in life, either, McEwen says. Measures used in the new study may enable doctors and researchers to determine how fast people are aging and if drugs or lifestyle changes can slow the pace.

Most antiaging therapies have been aimed at people already past retirement age. Belsky thinks such treatments should start much earlier to prevent diseases associated with aging, such as heart problems and Alzheimer's. "Antiaging interventions are going to have a heavier lift if they are only applied to people in their 60s, 70s and 80s," he says.

No effective antiaging therapies have been found yet. But work with mice suggests elixirs of youth may be in the blood. Scientists previously discovered that sewing together the circulatory systems of an old and a young mouse rejuvenates the old mouse, but makes the young mouse age more quickly (*SN: 5/31/14, p. 8*). Researchers have already identified some potential rejuvenation factors in blood.

Now neuroscientist Saul Villeda of the University of California, San Francisco and colleagues think they've discovered a protein in blood that promotes brain aging. Levels of a protein called Beta 2 microglobulin, or B2M, rise as humans and mice age. Young mice injected with B2M developed learning and memory problems, Villeda and colleagues report July 6 in *Nature Medicine*.

Mice loaded up with the protein had trouble associating a foot shock with being in a particular cage, for instance. Fewer new brain cells than usual grew in the hippocampus, an important learning and memory center, when young mice were injected with B2M. The birth of new cells in that part of the brain may be important for forming memories (*SN Online: 5/2/14*).

Young mice could recover from being injected with the protein, indicating that its effects may be reversible. Villeda's team also found that mice genetically engineered to lack the B2M protein continued to have sharp minds as they aged. In comparison, the memories of normal mice got worse. That finding indicates that getting rid of excess B2M in people's blood may improve memory and slow brain aging, Villeda says.

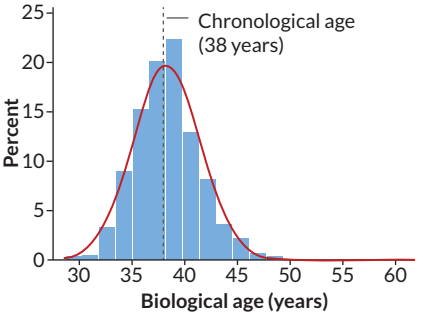
Researchers used to think that cells just wore out with age, but experiments such as Villeda's indicate that factors in the blood may influence how fast someone ages, says Benjamin Alman, a Duke developmental biologist who was not involved in either study.

"The potential exists that if you identify the right factor or group of factors, you can reverse the effects of aging," Alman says.

Far better than fighting aging is preventing the problems that cause it, and for that you have to start very young, says Linda Fried, an epidemiologist and gerontologist at the Columbia University Mailman School of Public Health.

"It's sexy to go after antiaging medicine," Fried says, but improving the social, economic and environmental factors that cause childhood hardship and health damage may be just as important. "How we set our young people up now will influence their life course." ■

Aging snapshot Even though they were all chronologically 38, a group of 954 New Zealanders had a wide variety of biological ages. The finding is evidence that people age at different rates. SOURCE: D. BELSKY *ET AL*/*PNAS* 2015



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MATTER & ENERGY

Superconductivity record challenged

Meissner effect detected in relatively 'warm' hydrogen sulfide

BY ANDREW GRANT

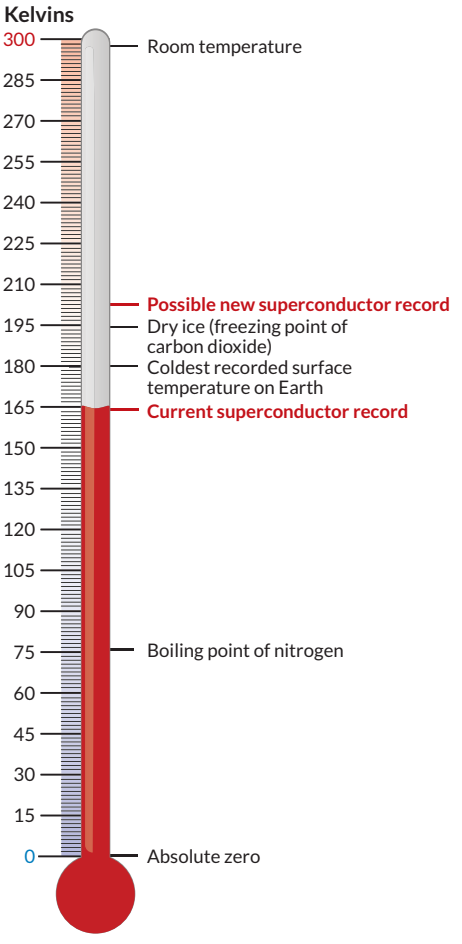
A promising material for conducting electrical current without resistance at a relatively high temperature has passed a crucial test. New magnetic measurements, detailed by German physicists online June 26 at arXiv.org, indicate that pressurized hydrogen sulfide is a superconductor at roughly 200 kelvins.

The fresh data bolster the controversial claim of hydrogen sulfide superconductivity made by the same researchers in December (*SN: 4/4/15, p. 11*). If confirmed, the discovery would nudge physicists closer to their ultimate goal of superconductivity at room temperature (about 300 kelvins). No other known material is superconducting above 164 kelvins.

Mikhail Eremets, a high-pressure physicist at the Max Planck Institute for Chemistry in Mainz, Germany, and colleagues crushed hydrogen sulfide samples between small diamonds at more than 1.5 million times standard atmospheric pressure. The researchers report that at temperatures as high as 203 kelvins, the samples expelled magnetic fields, exhibiting what's known as the Meissner effect. This magnetic evidence is a stronger indicator of superconductivity than the electrical resistance measurements Eremets' team originally used to make the case, says Russell Hemley, a materials chemist at the Carnegie Institution for Science in Washington, D.C.

Ivan Božović, a condensed matter physicist at Brookhaven National Laboratory in Upton, N.Y., wants to see a separate group of physicists replicate the finding. "I think it is still too early to uncork the champagne," he says. Confirmation could take time because there aren't many labs that can perform precision measurements at such high pressures.

Hemley, whose lab is working on related experiments, says the German team's research has sparked physicists to explore the superconducting prospects of other simple hydrogen-containing compounds. Understanding the structure of these compounds under pressure could enable physicists to devise materials that seamlessly shuttle electrons at more reasonable pressures and temperatures, he says. ■



Heating up A new experiment shows that pressurized hydrogen sulfide may be a superconductor at up to 203 kelvins (–70° Celsius), nearly 40 kelvins above the current record.

MATTER & ENERGY

Bacteria eliminate fluid's viscosity

E. coli's synchronized swimming produces superfluid solution

BY ANDREW GRANT

By coaxing billions of *E. coli* to work together, French researchers got a small sample of a bacteria-laden solution to have no resistance to flow, or zero viscosity. Such effortless motion is usually reserved for superfluids like liquid helium that are kept at frigid temperatures.

"The results are pretty compelling," says Raymond Goldstein, a complex systems physicist at the University of Cambridge. The study, in the July 10 *Physical Review Letters*, demonstrates how the motion of microscopic organisms can drive the large-scale behavior of liquids.

Physicists Héctor Matías López and Harold Auradou of Paris-Sud University and colleagues dipped a hanging cylindrical probe into a small cup filled with a solution of water, *E. coli* and enough nutrients for the bacteria to swim but not divide. Then the physicists slowly rotated the cup and measured the torque exerted by the solution on the probe.

A viscous fluid like honey would tug on and spin the probe. But when infused with a strain of very active *E. coli*, the water solution exerted no torque on the probe, indicating zero viscosity. In some trials, the viscosity actually became negative: The solution in the counterclockwise-rotating cup exerted a clockwise torque on the probe.

Before the cup spins, the bacteria swim about randomly. But theoretical studies suggest that once the liquid starts to flow, the *E. coli* coordinate their motion. The rod-shaped bacteria push water in front and behind as they swim. Liquid fills in from the sides, nudging neighboring bacteria closer together and causing them to align and swim in concert.

The bacteria's collective pushing boosts the speed at which adjacent water layers can rush past each other, giving the solution a less viscous flow. Bacteria may help scientists analyze tiny volumes of liquid by ensuring that samples don't get stuck in micro-sized passageways. ■

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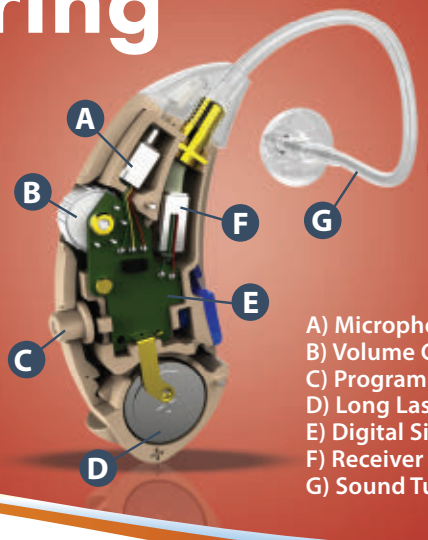

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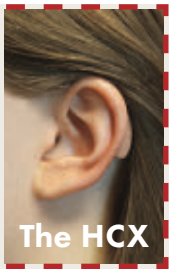
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LIFE & EVOLUTION

Ancient comb jellies maybe not so soft

Chinese fossils hint at rigid framework for filmy sea creatures

BY SUSAN MILIUS

Comb jellies, just globes of shimmering film in today's oceans, may have had rigid skeletons and hard plates millions of years ago.

Fossils about 520 million years old from six species of comb jellies show signs of hard parts, such as rigid spokes and hard plates, says Qiang Ou of China University of Geosciences in Beijing. Ou and colleagues report the finding July 10 in *Science Advances*. Until now, biologists have thought of comb jellies, or ctenophores, as soft bodied, so the fossils reveal an "unexpected lost history," Ou says.

"Exciting," says Stefan Bengtson, a paleontologist at the Swedish Museum of Natural History in Stockholm. The notion of long-ago rigid parts "may help explain why these animals, now represented by forms with flimsy and rapidly degradable bodies, have a fossil record that is comparatively rich in the Ediacaran-Cambrian [periods] but quite depauperate after that."

The skeletons, from the Chengjiang site in China, weren't necessarily bonelike and rich in minerals, says paper coauthor Shuhai Xiao, a geobiologist at Virginia Tech University in Blacksburg. He suspects the hard parts were more like the exoskeletons of today's insects, made of organic molecules.

Part of the evidence for a hardened framework comes from the shapes of the body parts preserved in the fossils. In the 37 specimens, the researchers don't find the jellies' flaps twisted or folded as would be expected from mere filmy structures. Instead, these parts lie flat, as they would if supported by rigid frames or if they were hard plates themselves.

What's known about genes of modern comb jellies (*SN: 5/13/13, p. 20*) makes the idea of a skeleton sound plausible, says Leonid Moroz, an evolutionary neuroscientist and geneticist at the University of Florida in St. Augustine. The jellies have genes for the calcium carbonate needed to make sensory structures called statoliths, as well as other genes for collagen. Using such genes to create rigid supports "is not a big stretch," he says.

The extinct oddball comb jellies with skeletons fit with the idea that early lifeforms may have been unusually diverse, Moroz says. In this interpretation of the story of life, the long-ago period when rigid comb jellies lived was a time of exploding novelty in shapes and lifestyles that has dwindled since. The number of species may have grown but the extent of bizarre differences within groups of organisms has shrunk. ■

A fossil of a newly described species of comb jelly, *Gemmactena actinala*, hints that some rigid spine kept a flap (right side of left image) from twisting and gave the complicated shape (right image) some support.

HUMANS & SOCIETY

Monkey brain's folds surprising

Victoriapithecus fossil may alter primate evolution story

BY BRUCE BOWER

Thanks to modern technology, a 15-million-year-old monkey skull has added surprising new wrinkles to primate brain evolution.

A digital analysis of the fossil finds that this ancient African monkey, from the genus *Victoriapithecus*, possessed a tiny brain that nonetheless was folded in a pattern observed in the much larger brains of its present-day descendants.

Among human ancestors, tissue folding emerged with increases in brain size. But wrinkling developed on its own in the ancient monkey's plum-sized brain, biological anthropologist Lauren Gonzales of Duke University and colleagues report July 3 in *Nature Communications*. Many researchers regard the folds as signs of complex organization within large brains.

"Evidence from the brain of *Victoriapithecus* shows that cerebral complexity and brain size evolved independently in these monkeys," Gonzales says. In short, bigger brains aren't always needed to produce more powerful brains.

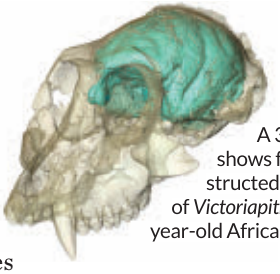
In another surprise, a brain section crucial for detecting smells, the olfactory bulb, was three times as large in the extinct primate as in living monkeys of comparable size. A section of folded tissue linked to color vision in modern macaque monkeys also appears in the fossil monkey's reconstructed brain.

Excavations on an island in Kenya's Lake Victoria in 1997 yielded the *Victoriapithecus* skull. It's the oldest known monkey skull from Africa, Asia or Europe.

Using a high-resolution scanner, the researchers digitally reconstructed the surface of *Victoriapithecus*' brain based on impressions left on the fossil braincase's inner surface.

Skull measurements indicate that *Victoriapithecus* was roughly the size of

FOSSIL: Q. OU ET AL/SCIENCE ADVANCES 2015; ILLUSTRATION: Q. OU ET AL



A 3-D computer image shows folds on the reconstructed brain surface (green) of *Victoriapithecus*, a 15-million-year-old African monkey.

present-day vervet monkeys, Gonzales says. Vervet monkeys' brain volumes range from around 59 cubic centimeters to 71 cubic centimeters. In *Victoriapithecus*, brain volume reaches only 36 cubic centimeters.

The unexpected discovery of an unusually large olfactory bulb in a small brain folded like those of living monkeys "is a really important finding," says Christoph Zollikofer, a paleoanthropologist at the University of Zurich in Switzerland. But it's unclear if the wrinkled brain reflected upgrades in brain organization and thinking abilities, he cautions.

Despite the new evidence, primate evolution remains poorly understood, says Christine Charvet, a neurobiologist at George Washington University in Washington, D.C. It's possible that African monkeys started out with small, *Victoriapithecus*-like brains with large olfactory bulbs and gradually evolved larger brains devoted more to vision than smell. Or, Charvet suggests, a common ancestor of monkeys and apes could have had a small olfactory bulb that expanded and contracted several times over the course of primate evolution.

Gonzales' findings may relate to a major controversy in hominid evolution — the proposed existence of a diminutive *Homo* species known as hobbits. A hobbit's digitally reconstructed brain surface displays folds indicating humanlike mental capacities in a chimp-sized brain (*SN: 4/25/09, p. 9*), says paleoanthropologist Dean Falk of Florida State University in Tallahassee. Evidence from *Victoriapithecus* suggests that neural modifications can boost learning and memory in small-brained primates, Falk adds.

A recent study suggests that surface area and thickness of a brain's outer layer determine whether and how it folds (*SN: 7/25/15, p. 7*). If so, wrinkles in the hobbit brain — and perhaps those in the ancient monkey brain as well — may reflect basic physical forces rather than underlying neural changes, Zollikofer says. In that case, Gonzales' suggestion that brain folding can evolve independently of brain size appears unlikely, remarks behavioral ecologist Robert Barton of Durham University in England. ■

BODY & BRAIN

Sugar may put you to sleep

Glucose triggers nerve cells to spur drowsiness in mice

BY LAURA SANDERS

Contrary to parental belief, sugar may actually cause drowsiness, not hyperactivity. Key brain cells awash in glucose put mice to sleep, scientists report in the July 8 *Journal of Neuroscience*.

"We all experience this strong feeling of sleepiness after a very large meal," says study coauthor Christophe Varin of Lyon Neuroscience Research Center and ESPCI ParisTech in France. Sugar is the reason those postmeal naps are often irresistible, the results suggest.

This study offers hard evidence that sugar promotes sleep, an idea that had been largely anecdotal, says neuroscientist Denis Burdakov of the Francis Crick Institute in London. "It's really great to see it measured properly," he says.

Varin and colleagues injected glucose directly into the brains of mice. Meals, particularly those loaded with carbs, raise sugar levels in the brain, too. This glucose might spur similar brain cells in people to exert sleepy effects.

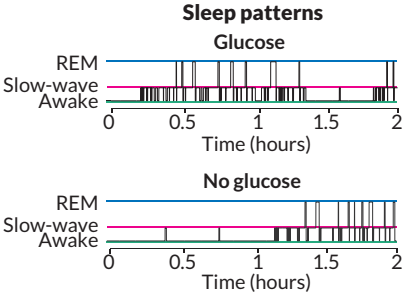
Scientists already knew that specialized nerve cells in the mouse brain are sleep pushers. These neurons, nestled in the ventrolateral preoptic nucleus, or VLPO, tamp down their sleep-inducing activity in response to various brain messengers that promote wakefulness. The new study shows that glucose has the opposite effect — amping up these sleep-promoting cells.

In the first two hours after glucose was injected directly into the VLPO, mice fell into a deep sleep called slow-wave sleep faster and stayed there longer than mice injected with a nonsugar solution. People and mice spend much of their sleeping time in slow-wave sleep as opposed to more active REM sleep.

VLPO neurons can directly sense the glucose in their neighborhood, other experiments revealed. And the more glucose the neurons detected, the more they fired their sleep-inducing signals.

The idea that sugar can lead to drowsiness may not be popular among energy drink manufacturers. It is possible that such drinks, which are often chock-full of sugar, can lead to immediate surges in alertness. But over longer periods of time, high-sugar drinks, at least those with little caffeine, might actually enhance sleepiness, as scientists reported in *Human Psychopharmacology: Clinical and Experimental* in 2006. The new study may help explain why that sugar blast made participants less alert.

Sugar shocker In the two hours after an injection of glucose into the brain, mice fell into slow-wave sleep faster and stayed there longer (top) than mice injected with a non-sugar solution (bottom).



There may be a good reason to sleep after a high-sugar meal, Burdakov says. Sleeping soon after eating ensures that a person or animal sticks close to a good food source, he says. "Moving less when sugar is around makes basic survival sense."

Scientists suspect that human VLPO neurons are similar to those in mice, but more experiments are needed to reveal just how those cells might respond to sugar. ■

FROM TOP: FRED SPOOR/MAX PLANCK INSTITUTE FOR EVOLUTIONARY ANTHROPOLOGY; C. VARIN *ET AL*/*JOURNAL OF NEUROSCIENCE* 2015

Acquiring one gene and one mutation made plague bacteria, *Yersinia pestis* (yellow, in a flea's digestive system in this colored scanning electron micrograph), able to cause deadly pandemics.

GENES & CELLS

Tweak in borrowed gene turned *Y. pestis* deadly

It only took a genetic two-step to turn the plague into a scourge.

The ancestor of the plague-causing bacterium *Yersinia pestis* causes mild stomach disease. Early in its evolution, *Y. pestis* acquired a single gene from another bacterium that allowed it to cause the deadly lung infections of pneumonic plague, scientists report June 30 in *Nature Communications*. Later, one mutation in this gene enabled *Y. pestis* to invade the lymph nodes and blood, creating the bubonic plague that caused pandemics like the 14th century's Black Death.

Microbiologist Wyndham Lathem and colleagues at Northwestern University Feinberg School of Medicine in Chicago tested different strains of *Yersinia* bacteria in mice to determine which genes were needed to make the microbes deadly. The results indicate that *Y. pestis* could cause pneumonic plague very early in its evolution, and that one mutation may have made the difference between isolated disease outbreaks and global epidemics.

Other adaptations also make *Y. pestis* suited to its deadly role, says Lathem, who plans to do further research to look for additional genetic differences that separate the bacterium from its microbial predecessors. — *Sarah Schwartz*

GENES & CELLS

Why mammoths loved the cold

A single genetic change may have made woolly mammoths fat, hairy and cold-loving.

Researchers deciphered the genomes of two woolly mammoths that died about 20,000 and 60,000 years ago. When comparing the mammoths' DNA with that from three Asian elephants, researchers noted that mammoths had different forms of some proteins involved in sensing temperature.

In the lab, the team produced one of the mammoth temperature sensors, a protein called TRPV3. As computer models had predicted, the mammoth protein was 20 percent less active than the elephant version, researchers report in the July 14 *Cell Reports*.

Mice that lack that protein prefer cooler temperatures and have more fat than usual. The mice also have curly whiskers and wavy hair. Reduced activity of TRPV3 may have led to similar temperature tolerance and physical changes in woolly mammoths.

"My wild speculation is that they actually liked the cold," says coauthor Vincent Lynch, an evolutionary geneticist at the University of Chicago. — *Tina Hesman Saey*

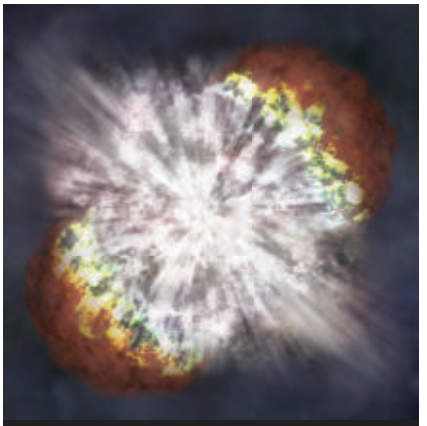
BODY & BRAIN

How screams shatter the brain

Blood-curdling screams pierce the brain. Unlike other vocalizations, screams contain an acoustical signature that alerts the brain to danger, scientists report July 16 in *Current Biology*. The results help explain why screams are such an effective method of communication.

By analyzing the acoustical makeup of sounds, David Poeppel of New York University and the Max Planck Institute for Empirical Aesthetics in Germany and colleagues found that screams scored high on measures of "roughness." That quality features big swings in loudness and an unpleasant perception. Normal speech isn't very rough, but car and house alarms are, the researchers found. Smoothing out the rough signals in screams led people to say the screams weren't as scary.

Rough screams came with more activity in the amygdala, a structure in the brain that helps a person detect threats, functional MRI brain scans revealed. The results help explain why screams are so distinctly alarming. — *Laura Sanders*



An exploding star (illustrated) discovered on June 14 is the most powerful supernova seen to date — 600 billion times as bright as the sun.

ATOM & COSMOS

Brightest supernova breaks record

A stellar explosion that was first detected on June 14 is the brightest one seen so far, researchers report July 8 in the *Astronomer's Telegram*. The supernova briefly shone with the light of roughly 600 billion suns. That makes it about five times as powerful as the previous record holder.

The star actually exploded about 2.8 billion years ago in a galaxy that sits in the constellation Indus — the light is just reaching Earth now. The outburst, designated ASASSN-15lh, appears to be part of a class of "superluminous supernovas," extraordinarily powerful explosions whose origins are still very much a mystery. — *Christopher Crockett*

FROM TOP: NIAID; M. WEISS, CXC/NASA

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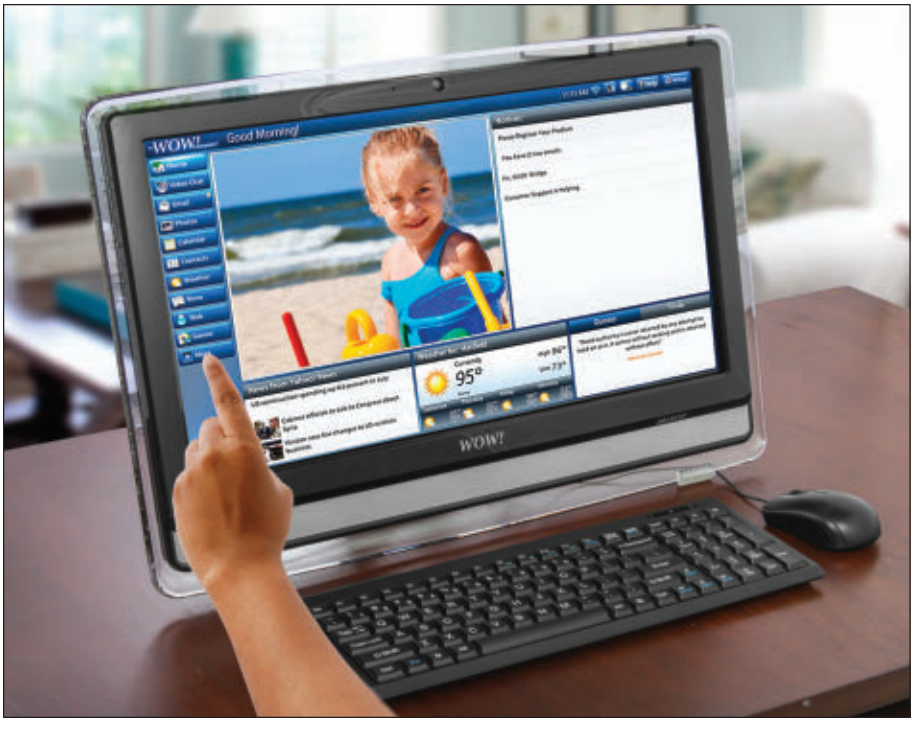

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– Janet F.

Have you ever said to yourself "I'd love to get a computer, if only I could figure out how to use it." Well, you're not alone. Computers were supposed to make our lives simpler, but they've gotten so complicated that they are not worth the trouble. With all of the "pointing and clicking" and "dragging and dropping" you're lucky if you can figure out where you are. Plus, you are constantly worrying about viruses and freeze-ups. If this sounds familiar, we have great news for you. There is finally a computer that's designed for simplicity and ease of use. It's the WOW Computer, and it was designed with you in mind. This computer is easy-to-use, worry-free and literally puts the world at your fingertips. From the moment you open the box, you'll realize how different the WOW Computer is. The components are all connected; all you do is plug it into an outlet and your high-speed Internet connection. Then you'll see the screen – it's now 22 inches. This is a completely new touch screen system, without the cluttered look of the normal computer screen. The "buttons" on the screen are easy to see and easy to understand. All you do is touch one of them, from the Web, Email, Calendar to Games– you name it… and a new screen opens up. It's so easy to use you won't have to ask your children or grandchildren for help. Until now, the very people who could benefit most from E-mail and the Internet are the ones that have had the hardest time accessing it. Now, thanks to the WOW Computer, countless older Americans are discovering the wonderful world of the Internet every day. Isn't it time you took part? Call now, and a patient, knowledgeable product expert will tell you how you can try it in your home for 30 days. If you are not totally satisfied, simply return it within 30 days for a refund of the product purchase price. Call today.

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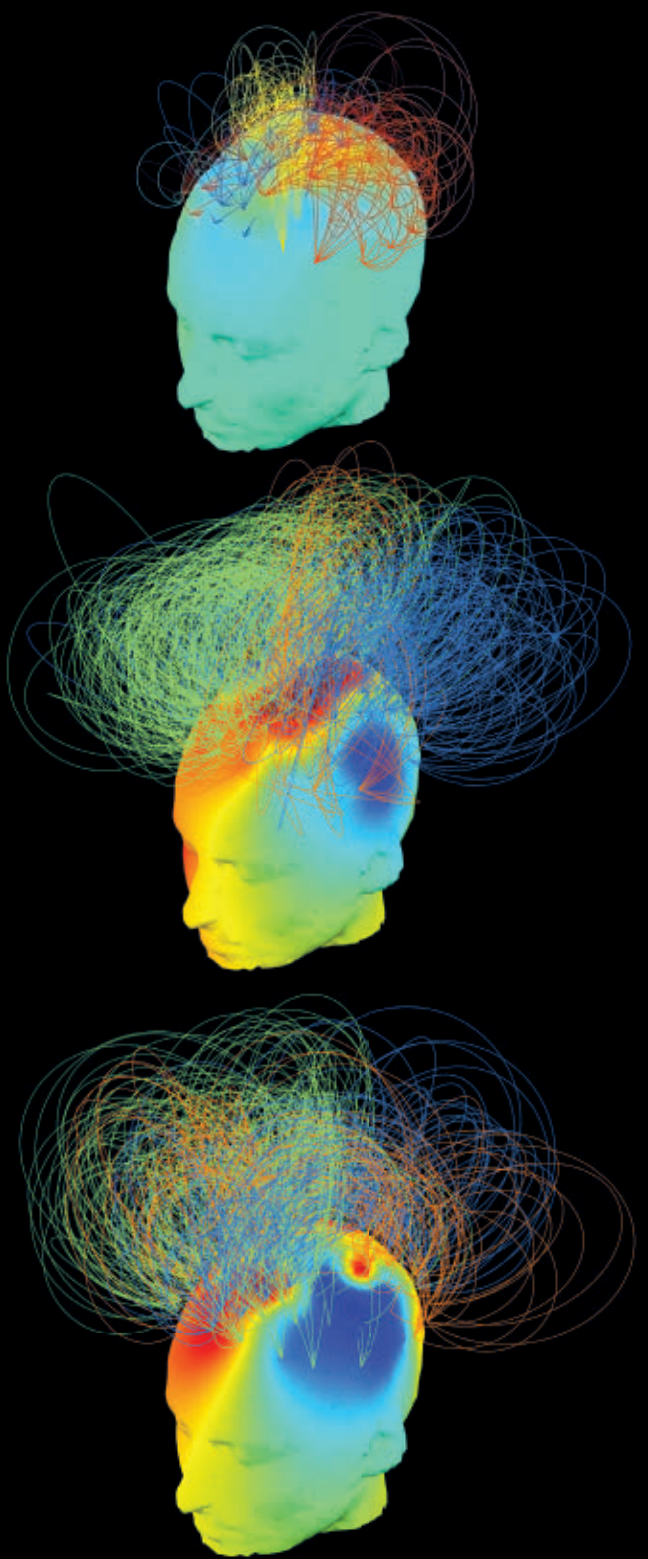
Locked Inside

As more people survive brain injuries, scientists work to reach patients with hidden consciousness

By Laura Beil



The average brain weighs about 1.3 kilograms and consumes 20 percent of the body's energy budget. Much of that energy powers the brain's 86 billion nerve cells, or neurons, which conduct tiny electrical currents that can travel close to 120 meters per second. A typical neuron transmits its signals to about 7,000 neighboring cells and to cells beyond. These neurons assemble into structures responsible for specific tasks. But like individual chords in a symphony, their work blends in seamless harmony. Your visual cortex allows you to see these letters. Your motor cortex controls the movement of your hand to reach for the next page or scroll down the screen. Your prefrontal cortex helps assemble letters into words, words into sentences and sentences into meaning. All you know is that you're reading.

None of these facts explain one of the greatest mysteries in biology: your conscious existence. The electrical and chemical chitchat among neurons somehow gives rise to awareness, thought, imagination and feeling. Your brain is creating a presence in this moment in a mind that belongs to you alone.

Yet even without consciousness, your body can carry on. Each year, more than 2 million Americans suffer a blow to the head that seriously damages the brain. Another million or so experience cardiac arrest or strokes that deprive the brain of blood, starving nerve cells of oxygen until they no longer function. Some people who survive will be left in a coma, unconscious and unaware of the world around them. Others will live in what's considered a vegetative state, able to open their eyes and make sounds, but uncoupled from true consciousness. Or so it seems.

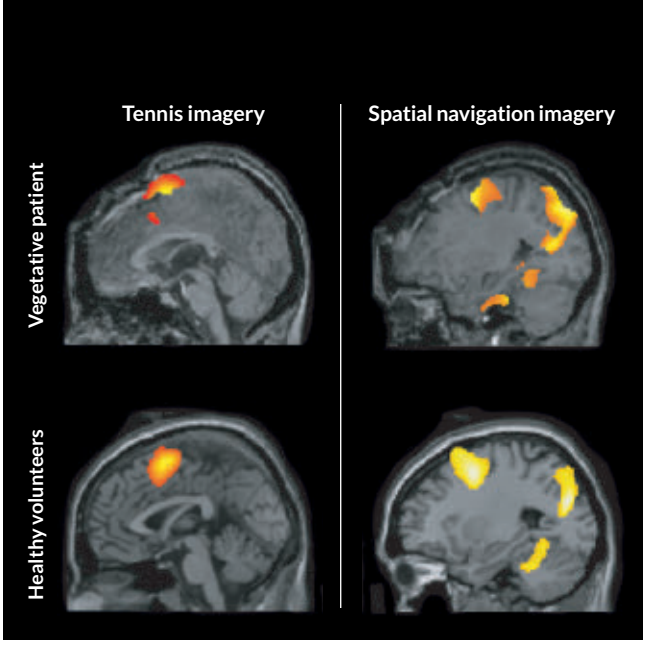
"How do I know you're conscious? If you can say you are, I believe you," says Srivas Chennu, a neuroscientist at the University of Cambridge. In millions of hospitals, he says, that's the simple test of consciousness.

Patients in the top two images are outwardly in a vegetative state. But the neural connections, measured by electrical activity, are much more active in the middle patient, whose brain network more closely resembles a healthy volunteer's (bottom image). All three were asked to imagine themselves playing tennis.

S. CHENNU/UNIV. OF CAMBRIDGE

It is probably too simple. Recent experiments have revealed a perplexing and profound no-man's-land of awareness. Outwardly, some patients are in a vegetative state, but brain scans reveal clusters of neurons that appear to form deliberate thought, raising the unsettling possibility of a trapped but cognizant mind.

First verified in 2006 by a brain scan of a woman in a vegetative state, covert consciousness has been sought by researchers among other patients ever since. Scientists are working to develop tests that could reveal silent consciousness and eventually allow those trapped in inert bodies to communicate with the world around them.



Imagine In a 2006 landmark experiment, researchers asked a woman who suffered a brain injury and was in a seemingly vegetative state to imagine herself playing tennis or moving around the rooms of her house. Scans of her brain with fMRI, which measures blood flow, were nearly indistinguishable from those of healthy adults asked to imagine doing the same tasks.

Progress has been slow. It's not possible or practical to obtain scans of the brain as it functions (or doesn't) for everyone in a vegetative state. But there is hope. Recent studies raise the possibility that the brain's electrical signals may provide the window doctors need. Brain waves are easy to measure, inexpensive to gather and vary with different states of consciousness. It's just a matter of figuring out how to read them.

While still experimental, results are compelling enough to raise emotional uncertainties for families of seemingly unconscious patients: the distressing possibility that their loved one may be physically dormant but mentally present.

"We're coming up on 10 years since the first paper," says Damian Cruse, a cognitive neuroscientist at the University of Western Ontario in Canada. "It's broadly accepted that there are patients who are misdiagnosed." They are in an unrecognized state of consciousness.

> "It's broadly accepted that there are patients who are misdiagnosed."
>
> DAMIAN CRUSE

The effort to reach them is expected to become even more critical as advances in medicine allow people to live with wounds that a generation ago would have been fatal, says Robert Stevens of Johns Hopkins University School of Medicine, who studies brain injury recovery. Over the last decade, as the survival of patients with severe brain injuries has increased, so has the number of patients with disorders of consciousness, he says. How many people are silently trapped?

Ghost in the machine

At its extremes, consciousness is easy to discern. A conscious brain is awake and interacting with the environment. An unconscious brain is not awake and not responsive to the outside world (*SN: 2/11/12, p. 22*). In 1972, neurologists Bryan Jennett and Fred Plum described a condition they named "persistent vegetative state." In their assessment, a vegetative person wakes for periods of time, but never reaches the capacity for awareness or produces "any adaptive response to the external environment."

A series of findings over the last decade, though, has people rethinking this definition, to the point that the term itself is falling out of favor. Even as early as the mid-1990s, doctors were finding hints of hidden consciousness in some vegetative patients. In 1996, in *BMJ,* researchers from the Royal Hospital for Neuro-disability in London suggested that about 40 percent of patients considered vegetative showed some ability to communicate, such as following a simple command to look at an object when their eyes were open.

Still, some saw these flickers of engagement as no more than the brain's passive, involuntary response to outside stimulation. So a 2006 report in *Science* was met with great surprise and more than a little skepticism. A team of scientists in England and Belgium used functional MRI to measure blood flow in different parts of the brain, an indicator of neural activity. The experiment involved a 23-year-old woman who had been diagnosed as in a vegetative state following a traffic accident.

Researchers asked her to perform two tasks while being scanned with fMRI. In one, she was asked to imagine playing tennis. In the second, she was told to mentally walk through all the rooms of her house, starting at the front door.

Asking normal volunteers to play phantom tennis activates the supplementary motor area of the brain, which they would be using if they were on the court. Asking people to imagine going through their houses activates the parahippocampal gyrus (important in memory), the posterior parietal cortex (involved in planning movements) and the lateral premotor cortex (which has a role in directing behavior). The brain scans of the supposedly unconscious patient lit up in those same areas. Her scans were nearly indistinguishable from the scans of healthy volunteers.

"This patient retained the ability to understand spoken commands and to respond to them through her brain activity, rather than through speech or movement," the scientists wrote.

A similar but larger study, published in the *New England*

A. OWEN *ET AL/SCIENCE* 2006

Journal of Medicine in 2010, involved 54 patients from England and Belgium with disorders of consciousness. As in the 2006 study, patients were placed in an fMRI scanner and asked to imagine walking around their houses or a familiar city. Five (including the patient from the original tennis study) had brain activity indicating they were experiencing the commands.

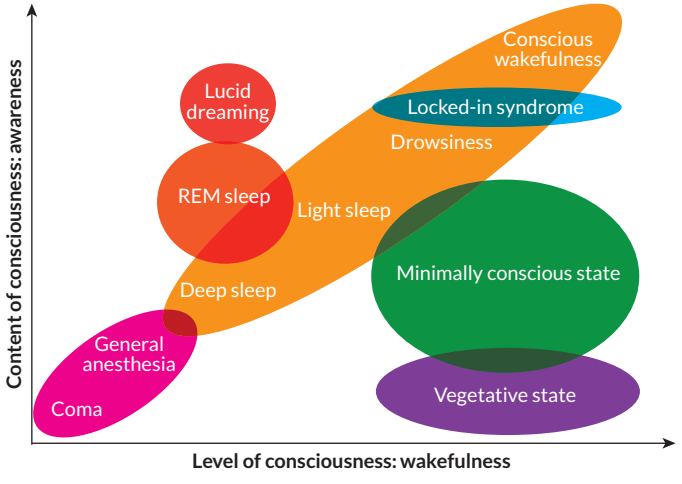
The greatest revelation came from patient number 23. The scientists asked patients a series of "yes" or "no" questions (such as, "Is your father's name Alexander?"). If the answer was yes, the patient was to picture himself playing tennis; if the answer was no, he was to imagine moving around his house. Patients were given the cue "answer" to address a shortcoming of the earlier study — there was a possibility that the word "tennis" or "house" could provoke an involuntary reaction that did not involve deliberate concentration. Patient 23 correctly answered five of six questions.

Evidence of covert consciousness kept building. In 2013, Israeli researchers published a study suggesting that in some vegetative patients asked to imagine their parents' faces, fMRI showed activity in the brain areas associated with emotion.

Finally, that same year, there was the case of Scott Routley, described in *JAMA Neurology*. The 39-year-old from Ontario, Canada, had been in a vegetative state for 12 years after a car accident. While in a scanner, Routley was asked yes-or-no questions and told to pay attention to certain words at different times. He was asked yes or no for the question often agonized over: Are you in pain? To the relief of his family, Routley answered "no." He died a year after the experiment.

The collective conclusion from all of these studies is that some patients are marooned in their own bodies. They can see, hear and contemplate to some degree, but not move or communicate.

Two dimensions of consciousness



A spectrum of alertness Consciousness is determined by a combination of wakefulness and awareness. In a coma, the brain is neither awake nor aware. A fully conscious person is both awake and aware. Different states of consciousness are determined by how aware a person is. In a vegetative state, a person can be awake, but not aware; a sleeping brain is characterized by awareness, but not wakefulness.

SOURCE: S. LAUREYS *ET AL/ENCYCLOPEDIA OF NEUROSCIENCE* 2009

Consider the story of Martin Pistorius of Johannesburg, South Africa, author of the 2011 book *Ghost Boy*. At age 12, he fell into in a coma after an infection. Doctors told his family his brain was permanently compromised and he would never recover. When he was a teen, his brain woke up, but his body did not. No one around him knew he was mentally aware as they fed, bathed and cared for him, and once, in a trying moment, told him they hoped he would die. He lived locked in this way for 12 years before he was finally able to move.

"I couldn't make a sign or a sound to let anyone know I'd become aware again," Pistorius wrote in a 2015 *Daily Mail* article. "I was invisible." He eventually began to communicate with his eyes, then learned how to use a computerized voice. Today, he is married and working as a freelance web designer.

Making waves

Scientists assume that stories like these, astonishing as they are, represent only a small fraction of patients who are diagnosed as lacking consciousness. Problem is, there's no reliable way to separate truly conscious minds from those that are fallow or adrift in some state in between. All patients can't be put into fMRI scanners, which are expensive and difficult to use. The machine requires a person to lie flat, and many patients have bodies that are frozen in rigid contortion. If the brain was injured in an accident, a person may have metal pins and plates for support and so can't be exposed to the powerful magnets of the scanner. Neither can a patient who has a metal pacemaker.

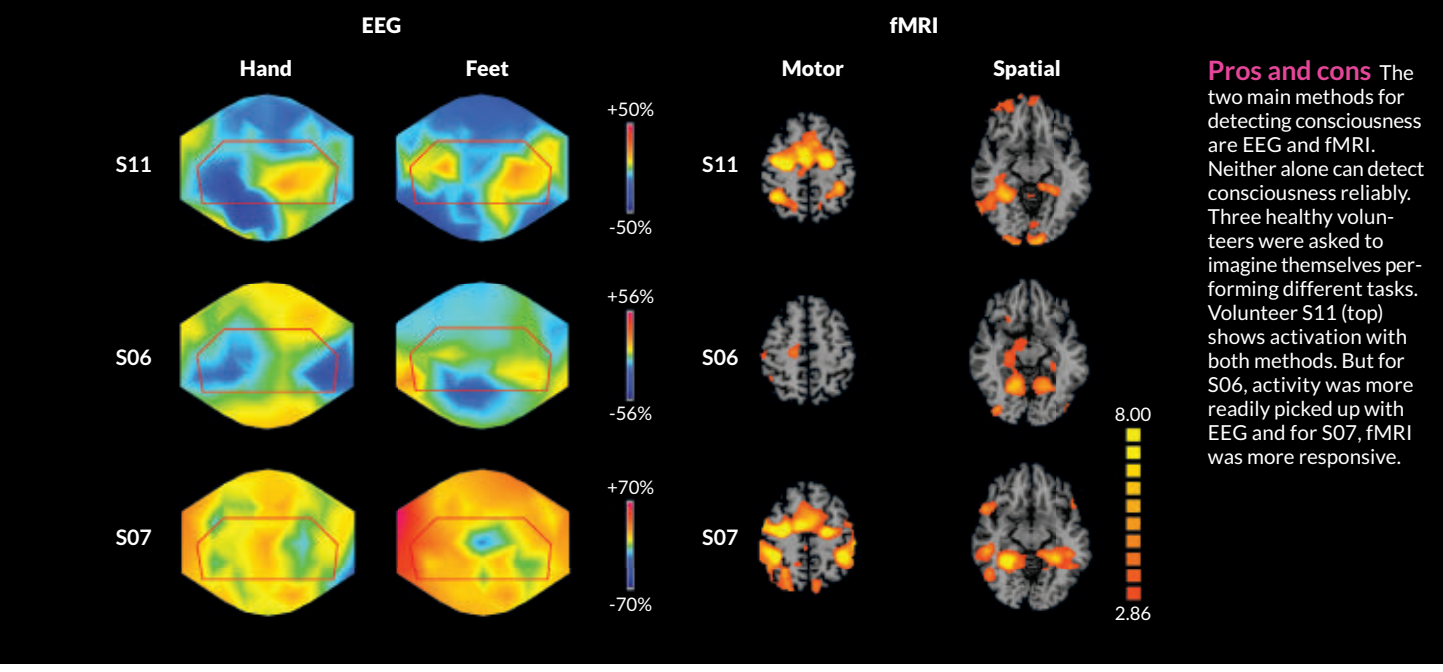
Even if a person can physically accommodate the scanner, some say a negative result may very well be meaningless. Suppose a patient is conscious, but unable to hear the command? Or "maybe they were just sleeping during the experiment; you don't know," says Damien Gabriel, a neuroscientist at the University Hospital of Besançon in France. A negative finding, he says, "just means we weren't able to measure awareness at that moment."

As an alternative, or more likely a complement, to fMRI, some researchers are turning to experiments with EEG, or electroencephalography, which measures electrical signals from the brain. Compared with fMRI, EEGs are relatively inexpensive and portable — easy to perform even at a patient's bedside. Tests can be repeated at different times to help account for undetected sleep. The challenge is figuring out what a "conscious" EEG looks like.

EEG readings come from a series of electrodes placed across the scalp. Each electrode detects the frequency and amplitude of tiny electrical currents generated by the brain. The result is a pattern of wavy lines that reveals something about the state of consciousness. A sleeping brain looks different from an awake brain, and an unconscious brain looks like something else altogether. Computer models can render sophisticated full-color maps of brain waves.

But the electrical approach isn't without problems. "EEG signals are complicated, and it's difficult to translate them

M. TELFER



Pros and cons The two main methods for detecting consciousness are EEG and fMRI. Neither alone can detect consciousness reliably. Three healthy volunteers were asked to imagine themselves performing different tasks. Volunteer S11 (top) shows activation with both methods. But for S06, activity was more readily picked up with EEG and for S07, fMRI was more responsive.

into a yes or a no," says Cruse of the University of Western Ontario. In 2011, he and colleagues from Europe reported in the *Lancet* on an experiment with 16 patients diagnosed as vegetative. The patients were told to imagine themselves doing several things, such as moving their right hand and right toes when they heard a beep. A portable EEG recorded their brains' electrical activity. The test was repeated on 12 healthy volunteers. In three of the 16 vegetative patients, the brain wave patterns responding to the commands matched the patterns of nine healthy participants, raising the possibility that those three vegetative patients were conscious.

Similar findings with EEG were reported in 2014 in *PLOS Computational Biology* by Chennu, of Cambridge. Using computer-enhanced images of EEG waves in patients, he and his colleagues found that 32 patients diagnosed as vegetative or minimally conscious showed surprisingly varied levels of active neural connections in the brain; some almost appeared as robust as healthy individuals.

In a testament to the vagaries of EEG interpretation, in 2013 neurologist Nicholas Schiff of Weill Cornell Medical College in New York City and colleagues published a reexamination of the 2011 *Lancet* data. Their intent was to validate the original findings, not disprove them, Schiff says. But when they took into account factors that could contaminate the original readings, such as involuntary muscle movement, their findings did not support the earlier conclusions.

Last year, however, Schiff and collaborators found that four patients who appeared able to follow commands during an fMRI scan also had EEG patterns that looked normal when they were awake. All four also had one other characteristic on their EEGs: spindles, which are electrical rhythms commonly produced during normal sleep. These healthy sleep patterns could be a signal that brains have some normal function, Schiff and colleagues reported in the *Annals of Neurology*.

All agree that it's important for the scientific process to work out the most accurate way to use EEGs for communication with patients, and to explore even tougher questions: What biological mechanisms drive the recovery of consciousness? What are the hallmarks of recovery? Is it possible to revive injured brains? In that regard, Schiff published a study in 2007 in *Nature*: the case of a 38-year-old man who was minimally conscious following an assault. The man received electrical stimulation to the thalamus, which sits in the center of the brain and connects to many other structures. Most important in this context, the thalamus appears capable of rebooting dormant functions, Schiff says. Following the experiment, the man was able to consistently converse using short phrases until his death six years later. But Schiff has seen little funding for pursuing the work since 2007. "There's a lot of ambivalence among people who aren't touched by this problem," he says.

Those most interested are families, who often carry on with extreme fortitude when their parents, sons and daughters fall into a heartbreaking limbo, Chennu says. "It makes you realize what families have to deal with. You go from having someone with you, to them disappearing, but they are still there," he says. "We're hoping these tools will take away some of that uncertainty." Eventually, he hopes, families will know if their loved ones are truly as vacant as they appear.

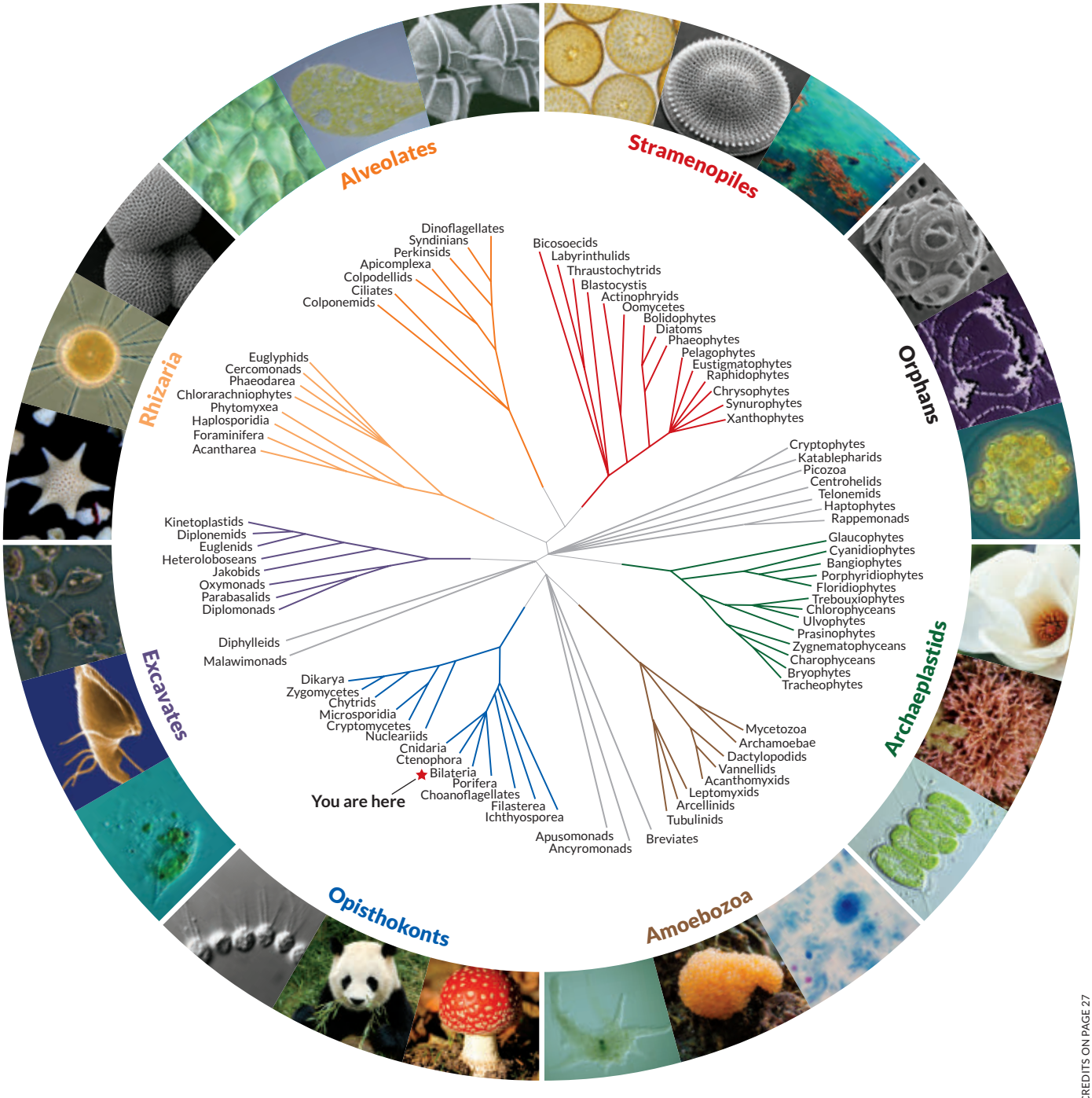
The findings also have immediate implications for medical staff and caregivers. "We need to be very, very prudent and cautious about how we behave and what we say in the presence of people we think are unconscious," says Stevens, of Johns Hopkins. "You can't walk into a room with a patient and make statements about how they are doing and their prognosis without knowing they aren't listening in." ■

Explore more

- Andrew Peterson *et al.* "Risk, diagnostic error, and the clinical science of consciousness." *Neuroimage: Clinical*. February 20, 2015.

D. GABRIEL ET AL/NEUROSCIENCE 2015

STRANGE Relations



Eukaryote treetop of life A new view of evolutionary branchings among organisms with cell nuclei is emerging. It spreads far beyond the old treetop kingdoms. Multicelled organisms mingle with singles. Some organisms (orphans, above) have not yet been placed in one of the seven or so supergroups. Clockwise from mushroom at bottom: *Amanita muscaria*, giant panda, *Desmarella*, *Euglena*, *Giardia*, *Trichomonas*, star sand foram, *Allogromia* foram, *Globigerina* foram, *Colpidium* ciliates, *Stentor*, dinoflagellate, *Coscinodiscus*, *Stephanodiscus*, giant kelp, *Gephyrocapsa*, *Ceratolithus*, *Phaeocystis*, *Magnolia*, *Galaxaura* red seaweed, *Scenedesmus* green algae, *Entamoeba*, *Tubulifera* slime mold, *Chaos* amoeba. SOURCE: A. WORDEN *ET AL*/*SCIENCE* 2015

J. HIRSHFELD; IMAGE CREDITS ON PAGE 27

Schoolroom kingdoms are taking a backseat to life's supergroups

By Susan Milius

The tree of life might seem like a stable design, appropriate for indelible ink. Plenty of people think so. An Internet search for "phylogenetic tattoos" turns up some showy skin art.

But the branches are shifting. Since a radial diagram based on 1990s genetics inspired a rush for tree-of-life tattoos, technical diagrams of life's ancestral connections have been redrawn. And the simplified version of the tree of life memorized by schoolchildren for decades lags far behind what researchers depict today.

When Patrick Keeling at the University of British Columbia in Vancouver unveils a working scientist's current diagram for his students, most have never heard the names of the major branches. "Kind of fun," Keeling says.

In the new vision — based on increasingly sophisticated genetic analyses — people and other animals are closer cousins to single-celled choanoflagellates than to other multicellular organisms. Giant kelp that grow as wavering undersea forests off the California coast are closer relatives to single-celled plankton called diatoms than to multicelled red seaweeds or plants.

The old tree isn't exactly wrong. The kingdoms that used to crown its top — plants, fungi and animals — still exist. But they've moved. In the new diagram, the tree's former crowning glories shrink to mere side branches, three among hundreds, crowded by the vast diversity of complex single cells.

Biologists analyzing this treetop rarely use the word kingdom anymore. They talk of five or maybe seven bigger branches called supergroups. And the story of demoting kingdoms and introducing supergroups is far from over. A 2014 review noted five proposals for designating the most ancient stretch of supergroup branches, the bit that goes lowest on the new tree. A paper appearing in the *Proceedings of the National Academy of Sciences* in February described a new method for resolving this debate, and discussions continue.

Even as a work in progress, the new groupings offer benefits, such as help in searching for new medicines and insight into evolutionary puzzles such as the supposed wastefulness of sex. As the tree continues to morph, it will no doubt inspire new tattoos.

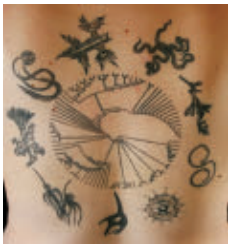
Old school

Over time, drawings of the tree of life have changed to keep up with evolving ideas about how to categorize life.

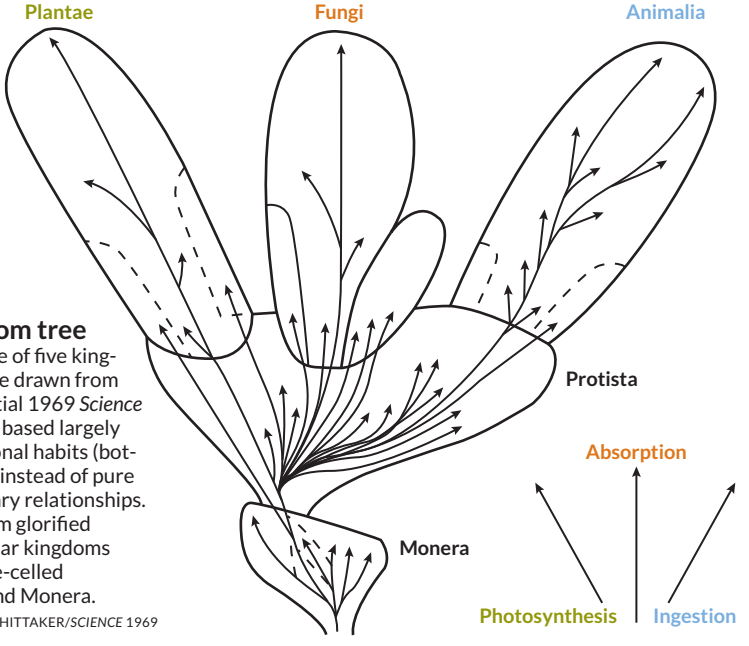
In 1735, Swedish physician and botanist Carl Linnaeus published the first edition of his classification system for nature, incorporating three kingdoms: plants, animals and stones. (Stones never caught on.) In that early scaffolding, evolutionary relationships between organisms didn't matter. Linnaeus was just striving "to reveal God's creation to mankind in an orderly manner," says archivist Gina Douglas of the Linnean Society of London. Charles Darwin wouldn't nervously publish *On the Origin of Species* for another 124 years.

By 1969, ecologist Robert Whittaker openly waved aside some evolutionary distinctions when describing his ideas for kingdoms, in *Science* (see illustration below). His approach to the top of the tree (home to eukaryotes, which wrap their DNA in membrane-bound cell nuclei) would rule biology classrooms for decades. Yet his system is based only partly on evolutionary relationships.

Whittaker crowned his tree of life with three kingdoms of primarily multicellular eukaryotes sorted in large part by nutritional style: plants (capturing light energy), fungi (absorbing nutrients by contact) and animals (ingesting their food). He recognized a fourth kingdom of eukaryotes: the Protista. It was a hodgepodge of single-celled

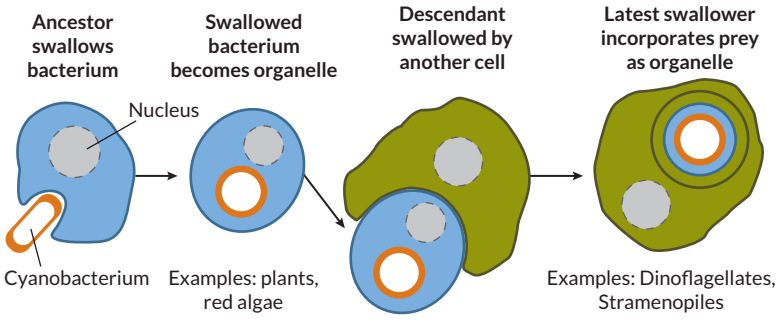


Genetics-based versions of the treetop of life have inspired a new genre of tattoo, often with symbolic organisms rather than multisyllabic labels.



Classroom tree
The outline of five kingdoms of life drawn from an influential 1969 *Science* paper was based largely on nutritional habits (bottom right) instead of pure evolutionary relationships. This system glorified multicellular kingdoms over single-celled Protista and Monera.
SOURCE: R. WHITTAKER/*SCIENCE* 1969

FROM TOP: *SCIENCE INK: TATTOOS OF THE SCIENCE OBSESSED*, CARL ZIMMER (STERLING); © 2011 CARL ZIMMER; J. HIRSHFELD



Like matryoshka dolls Engulfing another organism and turning it into an organelle has been important in the history of complex life. Even engulfers get engulfed themselves sometimes. SOURCE: A. WORDEN *ET AL*/*SCIENCE* 2015

organisms, differing in forms and lifestyles but lumped together largely for convenience. He said as much, acknowledging that none of the classification systems he discussed "can be wholly satisfactory."

Today many scientists hope for biological categories that consist of a single ancestral lineage and all its evolutionary descendants. A tree of life built this way "actually changes how you interpret a lot of stuff," Keeling says. Much of biology rests on information gleaned from one organism and hypothesized to be true for its close kin. Identifying relatives is important. "If you've got the tree wrong, then you could be wrong about a lot of things," he says.

The challenge of getting that tree right looms sequoia-high, since so much of the diversity of life lies in complex microbes still unknown to science. Out of about 150,000 kinds of marine plankton detected during the *Tara* oceans expeditions, as reported May 22 in *Science,* researchers could genetically identify about a third only as some eukaryote. They couldn't place them in any known group.

Great idea, but

The early attempts to see what genetics could say about the tree of life seemed to work beautifully. But "science doesn't go in a linear path," says Andrew Roger of Dalhousie University in Halifax, Canada, who entered the field during the tumultuous 1990s.

Those first genetics-based trees of life for eukaryotes were built by comparing variations in the gene for small subunit ribosomal RNA across species. The result looked believable, with plants, animals and fungi on big branches at the top. Lower down, in the zone for more ancient branches, sprouted some oddball parasites such as *Giardia* (the bane of hikers who drink untreated water), sexually transmitted *Trichomonas* and tiny microsporidia, which attack many animals.

Researchers had begun to wonder if these bizarre parasites and their relatives could be living relicts of an early, pivotal time in eukaryote history. The organisms had no obvious mitochondria, the organelles that serve as the cell's power stations. Perhaps the parasites had never had any mitochondria, Thomas Cavalier-Smith of the University of Oxford had suggested in 1983. This notion played off the idea championed by maverick biologist Lynn Margulis at Boston University in 1970 in *The Origin of Eukaryotic Cells*. She suggested that mitochondria came from a free-living microbe that some ancestor of eukaryotes had swallowed and put to work. Perhaps the parasites were relicts from before the Big Swallow.

To use these select parasites as glimpses of life before mitochondria "would be really, really interesting," says Dalhousie biologist Alastair Simpson. "It was a lovely hypothesis. But then it all went to hell."

One problem came when researchers expanded their analyses to look at more than one gene. Unexpectedly, says Roger, "we had different genes saying different things."

The potential unraveling of the parasites-as-relicts hypothesis had a special zing for Roger. He was in the middle of a Ph.D. project based on the assumption that the parasites came from premitochondrial times. "It was one of those cases when you're trying to work on the carpet that's being pulled out from under you," he says. "I thought it was pretty exciting."

Yes, he said "exciting." That view of eukaryote evolution based on analysis of a single gene "was in textbooks, and it was what many people had made their careers on," he says. "It seemed like if it was going to fail, it was going to be something big." He and his lab mates were going to be in on it.

Roger and his colleagues struck a blow to the old hypothesis by looking for genetic traces of bygone mitochondria lingering in the cell nucleus of select parasites. Even though mitochondria need some 700 to 1,000 genes to operate, only about 10 to 100 of them are inside the organelle itself. The rest reside in the cell nucleus and ship proteins to the mitochondria. The researchers detected some left-behind nuclear genes in supposed ancients, such as *Giardia*, *Trichomonas* and some microsporidia.

Various research groups eventually found the tiny, overlooked remnants of mitochondria

J. HIRSHFELD

themselves inside the fake relicts. The parasites looked very ancient only because their mitochondria had shriveled into hard-to-recognize bits.

Microsporidia, it turned out, were nowhere near being relicts. Examining a handful of genes, Keeling and other researchers demonstrated that the single-gene tree had put microsporidia in the wrong kingdom.

Microsporidia are "really nasty parasites, but fascinating," Keeling says. Their tough spores enclose a coiled tube. To infect a victim, they pump inward such a rush of water that the pressure blows the top off the parasite and the tube shoots out like a harpoon. As much as 100 times longer than the spore, the tube-harpoon punches into its prey. The parasite cell nucleus and other internal parts are injected through the tube into the victim. Although they have this elaborate equipment for infection, microsporidia are simple cells with genomes that are "tiny, tiny, tiny," Keeling says. Another misleading hint that they were ancient, simple creatures.

Keeling and his colleagues in the 1990s found evidence that the microharpooners didn't belong at the bottom of the tree. They were fungi, a more recent and much more metabolically versatile branch of organisms. Before this revelation of misclassification, researchers accepted the simplicity of microsporidial cells by assuming that complicated traits hadn't evolved in supposedly ancient, simple cells. After recognizing microsporidia as members of the fungal kingdom with all its elaborate metabolic tricks and lifestyles, biologists could see that microsporidia had been more complex at one time, but eventually lost fancy traits. "You have the exact opposite view of how they got to be the way they are, based on where they go on the tree," Keeling says. "The tree matters."

As evidence built that the supposed ancient parasites and their relatives weren't so ancient, "smart people worked out that the molecular trees were just wrong," Simpson says. The problem, now widely recognized, was the peril of "long-branch attraction."

Lineages that change a lot end up as long-branch lines in an evolutionary tree. Younger branches that change fast can by chance develop similarities to genuinely old branches. In simple analyses, they end up closer than they should be at the base of the tree, as if they've "attracted" each other.

Supergroups

All the challenges to the first genetic tree of life "left us with a mess," Keeling says. It became clear that the history of all eukaryotes cannot be reconstructed in any sensible tree based on one gene. "We ripped it all apart and put it back together. And it came together very differently."

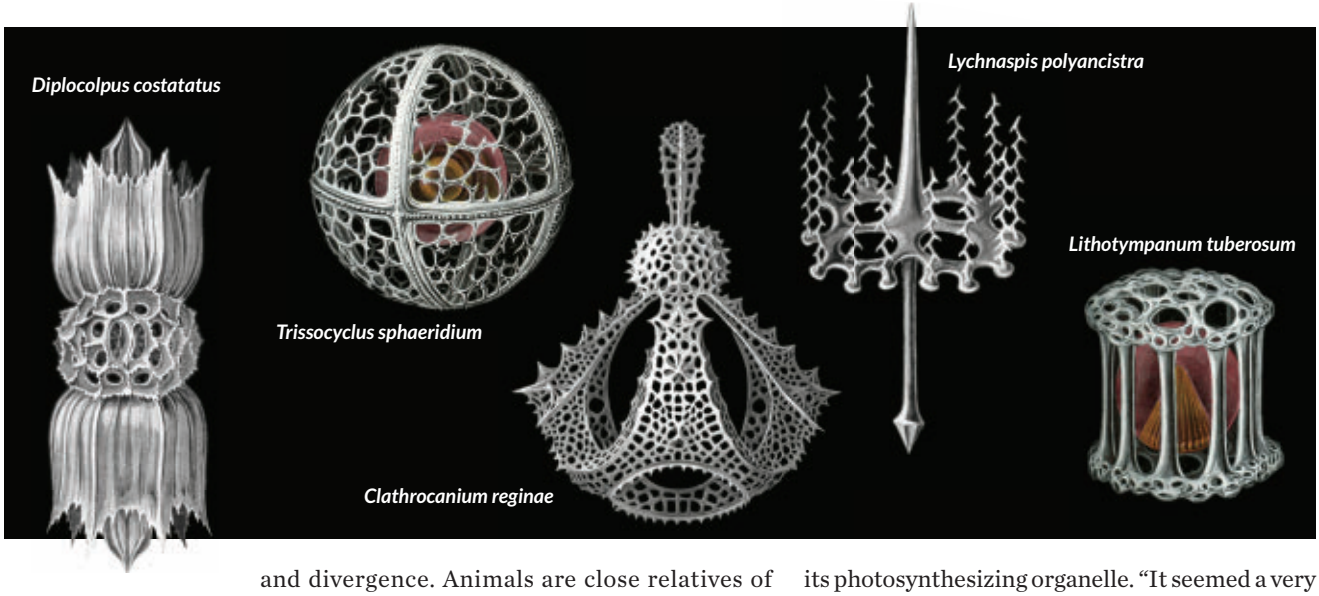
Instead of a crown of multicellular groups rising over relicts on long branches, the organisms "coalesced in a small number of very large groups," he says.

The new arrangement, summarized in 2012 by Sina Adl of the University of Saskatchewan and colleagues in the *Journal of Eukaryotic Microbiology*, makes a fabulous mix of convergence

An opisthokont's guide to supergroups

Kingdoms are so 20th century when it comes to the main evolutionary branches of the tree of life. Decades of increasingly clever genetic analyses reveal that the first organisms to wrap their DNA inside a cell nucleus have diverged into seven or so major branches of eukaryotes that researchers somewhat whimsically call supergroups. SOURCE: F. BURKI/*COLD SPRING HARBOR PERSPECTIVES IN BIOLOGY*, MAY 2014.

Opisthokonts	You are here. Two whole kingdoms from the old tree, animals and fungi, share the same big lineage. Some single-celled organisms, such as the *Ichthyosporea* parasite, belong here too. They're more closely related to the multicellular world of people, pandas and portobello mushrooms than to most other one-celled creatures.
Excavates	Several infamous pathogens live here, such as *Giardia*, a bane to hikers and travelers who drink untreated water. This supergroup was proposed as the dust cleared from the collapse of the late 20th century version of the treetop. The case for uniting the excavates rests on new genetic evidence plus details of cell structure — for example, the parts that form what's called a feeding groove.
Amoebozoa	One of the most familiar genera of microbes, *Amoeba*, belong here. It evolved in a lineage with other soft shapeshifters, including the social amoebas, or slime molds. The form also arose independently elsewhere in the treetop.
SAR (Stramenopiles, Alveolates and Rhizaria)	This supergroup of supergroups is often nicknamed SAR for its components. Its members are so diverse that biologists built the case for uniting them mostly on genetics.
Archaeplastids	The whole plant kingdom fits here, along with red and green algae, but not kelps. The power to photosynthesize exists in a wide variety of branches in the treetop of life.



Structural beauty
Ernst Haeckel's remarkable drawings of microscopic organisms (radiolarians shown) introduced generations to the beauty of complex, single-celled life. Even in the 19th century, he protested biologists' neglect of microbial marvels.

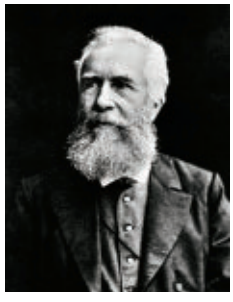
and divergence. Animals are close relatives of fungi. Both are opisthokonts, along with some one-celled cousins. A *Phytophthora* potato pathogen, once famous as the "fungus" that caused famine in Ireland in the 1840s, is not a fungus at all. It belongs in the same supergroup as the giant kelp. Red and green seaweeds join plants in a distinct group called the archaeplastids.

These are big, deep-history groups, but don't call them kingdoms. "Alastair is allergic to kingdoms," Roger says of Simpson. The two collaborated on a 2002 paper enumerating supergroups instead.

Simpson wanted a term no one would treat as a formal rank. "'Kingdom' has such gravitas," he says, not admiringly. Biologists assign kingdom rank based largely on subjective impressions, so he sees little information conveyed just by knowing something is a kingdom instead of some other rank in a hierarchy. To avoid the whole nonsense, he uses *supergroup* in a lighthearted nod to bands such as the Traveling Wilburys, which united (briefly) Bob Dylan, George Harrison and three other independently famous musicians.

Like Dylan and the others, each biological supergroup has its own illustrious story. The proposed one that Simpson found most surprising united all modern eukaryote groups that have algae with chlorophyll c. That's a huge crowd with no other obvious trait in common. Although chlorophyll c organisms seem so different at first sight, Cavalier-Smith suggested that they all descended from one eukaryote that swallowed another, which became its photosynthesizing organelle. "It seemed a very bold hypothesis," Simpson says.

Sequential swallowings are a big part of eukaryote history. Engulfers were themselves engulfed and in turn engulfed yet again. "Like matryoshka dolls," Keeling says.



"Man is not above nature, but in nature."
ERNST HAECKEL

Some genetic evidence now links three big groups to a single ancestral engulfment of chlorophyll c, Simpson says. Stramenopiles, with giant kelp and potato pathogens, now join alveolates and rhizaria (even though they have no chlorophyll c) as what's often abbreviated as SAR. Other chlorophyll c carriers are still under study, so the bold hypothesis might someday turn out to be right. "The really cool thing is, we still don't know the answer," Simpson says.

This and other eukaryotic mysteries may resolve more easily as geneticists refine a technique for deciphering DNA from one individual cell. *Nature Methods* called it "method of the year" for 2013.

The technique's possibilities intrigue researchers because single-celled species can be difficult or impossible to grow in the lab. Roger lovingly describes radiolarians, some of which build skeletons of strontium sulfate while others manage to eat multicelled animals. "Just beautiful organisms," he says, but "they're a real pain actually to work on." Single-cell DNA sequencing has helped in the study of bacteria, and papers here and there report results for eukaryotes. The technique revealed an interplay of chemistry between a termite-gut dweller and its own live-in spirochete bacteria

FROM TOP: ERNST HAECKEL/*KUNSTFORMEN DER NATUR* 1904; ARCHIVIO MONDADORI

in work published May 15 in the *Proceedings of the National Academy of Sciences*.

Practicalities and beyond

Reconstructing all this evolutionary history can have practical implications. Early in Keeling's career, he investigated the peculiar discovery that malaria parasites have remnants of organelles that once carried chlorophyll. "Why would malaria have a chloroplast? They live in the dark," Keeling says. The researcher, Iain Wilson, who originally proposed the notion was dismissed for a long time as ridiculously wrong. But evidence grew, and today scientists agree that a certain small bit in the parasite left over from a photosynthetic past still has some function in the dark. That finding helps explain the effectiveness of some formerly mysterious treatments for malaria: The drugs attack chloroplasts.

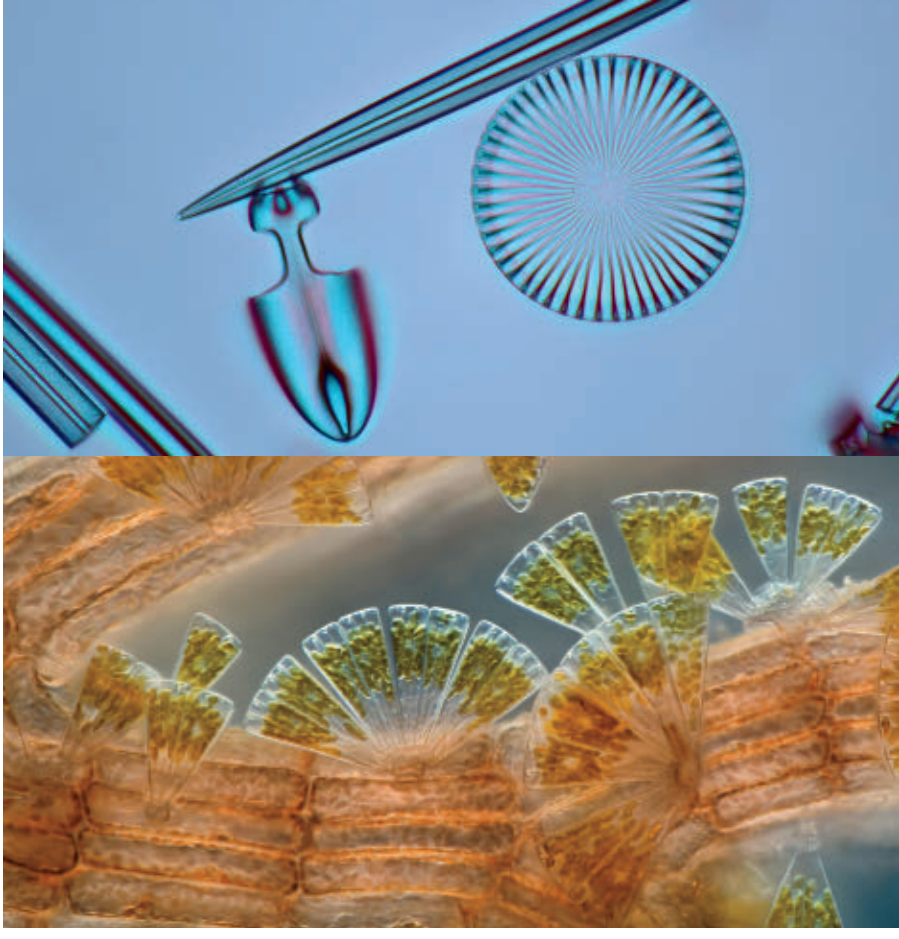
A realistic tree of life can also change the way researchers look at more theoretical questions, such as how in the world such a supposedly wasteful and irrational process as sex evolved. Only one of two partners can bear young, halving productivity from the start. Or so goes a long-running thread of research and debate (*SN: 2/14/09, p. 16*).

Yet that furor is so multicellular. Simpson and Roger along with philosopher Maureen O'Malley of the University of Sydney in *Biology & Philosophy* in 2013 pointed out that the basics of sex must have evolved long before birds, bees or anything else multicellular.

In single-celled organisms, reproduction does not require sex, nor does sex always produce offspring. Two ciliate cells can meet, mingle genes and remain only two cells. The eukaryote tree abounds with single-celled organisms practicing the basics that combine to make multicellular reproduction possible. The alleged wastefulness of sex is really a question of why the peculiar form of sex tied to multicellular reproduction persists in a few outliers.

Useful as a good tree of life can be, Keeling objects to the idea that eukaryotes should be appreciated just for their utility. People enjoy animals and plants for their own sake. "A giraffe won't save your life, but people like giraffes," he says. To him, one-celled eukaryotes are Serengeti charismatic, just smaller. Some species have a structure — similar to camera-like animal eyes — with a cornea-like outer covering derived from mitochondria and a light-sensitive inner cup from an engulfed red-algal organelle, Keeling and colleagues reported July 9 in *Nature*. Several large dinoflagellate species hunt despite living inside a rigid shell. They push a stomachlike structure out a hole in the shell and digest prey larger than they are. Other single cells grow delicate, multipointed outer casings that eventually wash ashore, covering beaches with millions of miniature stars.

Knowing that the living world has so much invisible variety can change a person's perspective, says Fabien Burki, who works with Keeling at the University of British Columbia. The supergroup tree offers the little back-of-the-neck shiver-thrill of realizing that every tomato patch, termite gut or beach bucket of seawater holds life much vaster and stranger than imagined. Says Burki: "It's like the astronomers discovering there are planets around other stars." ■

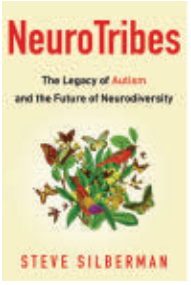


Diatoms (top) with glasslike casings belong in the stramenopile supergroup. They come in diverse shapes, including the fanlike diatom (bottom) that lives on red algae, which are archaeplastids.

FROM TOP: FRANK FOX/WIKIMEDIA COMMONS (CC BY-SA 3.0 DE); © WENN LTD/ALAMY

Explore more

- Fabien Burki. "The eukaryotic tree of life from a global phylogenomic perspective." *Cold Spring Harbor Perspectives in Biology*. May 2014.



NeuroTribes
Steve Silberman
AVERY, $29.95

BOOKSHELF

Autism's journey from shadows to light

To understand the future of autism, take a trip to its past. In *NeuroTribes*, science writer Steve Silberman serves as a knowledgeable and evenhanded guide to the often dark history of autism.

It's a sad, difficult story that Silberman confronts head-on. In a wide-ranging narrative, he describes desperate parents, children abandoned to grim institutions and experimental treatments that relied on starvation and abuse. He also describes the work of early clinicians who studied autistic children in the 1940s. Their piecemeal observations led to ongoing diagnostic wrangling that may be behind the recent seeming spike in autism cases, Silberman writes.

Throughout the book, Silberman situates events in their larger cultural context, an illuminating contrast that works well to explain how the "refrigerator mother" idea took hold, for instance. In a seminal 1943 paper describing 11 children with autism, Johns Hopkins physician Leo Kanner implied that aloof parenting could contribute to the disorder. That idea, based on little more than anecdotal observations, pervaded the '50s and '60s.

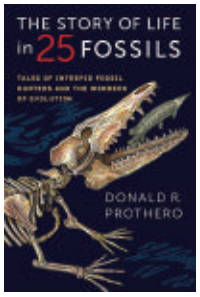
The power of culture to sculpt perceptions of autism is also at work in Silberman's explanation of how the 1988 hit movie *Rain Man* was received.

The movie had a profound effect: It made autism visible, Silberman writes. A mother of an autistic child wrote that after *Rain Man* came out, other people were much more tolerant of her son's meltdowns at the market. Another family reported that on the way home from the movie, a rarely verbal autistic son declared, "I'm autistic!"

These hopeful moments are part of a larger trend. As a reader travels through the book's 477 pages, tales of woe give way to creeping optimism. Silberman describes chat rooms and Internet groups run by people with autism, providing camaraderie to people who may, as Temple Grandin once said, want to be hugged but can't stand the feeling of the embrace.

Thoughtfully designed retreats for people with autism also offer safe havens. The first "autreat" celebrated autistic culture in 1996 in Canandaigua, N.Y. There, tranquil spaces offered both solitude and opportunities to be social. People wore badges with colors signaling their levels of desire to talk. To reduce the chance of overstimulation, cigarette smoke and perfume were banned, as was indoor flash photography. The accommodations put autistic people at ease and allowed them to feel less disabled, Silberman writes.

Silberman argues that more room is necessary for all of the various neurotribes — people with distinct forms of neural wiring. Differences should not just be accommodated but celebrated, he argues. The world should welcome brains of all sorts. — *Laura Sanders*



The Story of Life in 25 Fossils
Donald R. Prothero
COLUMBIA UNIV., $35

BOOKSHELF

Fossils illustrate 3.5 billion years of life

When it comes to life on Earth, perhaps we should consider ourselves lucky — the largest land and sea creatures of today don't tend to devour people. But had we shared the planet with such terrors as *Giganotosaurus* and the enormous shark *Carcharocles megalodon*, we probably wouldn't have fared so well. Paleontologist Donald Prothero introduces readers to these beasts and others in *The Story of Life in 25 Fossils*.

The gee-whiz aspects of big dinosaurs and other bizarre critters aren't the meat of the book; it's Prothero's careful description of 25 fossils that offer an overview of the progression of plants and animals in the last 3.5 billion years.

Prothero starts at life's beginning, with mats of microbes that ruled the world until roughly 600 million years ago. Eventually those microbes morphed into multicelled sea creatures that looked liked worms, jellies and underwater ferns. From there, an explosion of creatures occurred, producing everything from early mollusks and sponges to nightmarish sea creatures that now carry names like *Hallucigenia* (see Page 5). Later came land plants, fish that grew the size of *Carcharocles* and fish that crawled out of water. Those critters branched into frogs, turtles and snakes. Ultimately, the animals transitioned into dinosaurs, birds and mammals.

Chapters chronicle critical stages of evolution in which spineless animals developed backbones and animal groups diverged into arthropods, amphibians, reptiles, whales, humanlike ancestors and much more. The chapters are short and packed with details, which sometimes tangle into tangents.

Still, the tangents act as good teasers, briskly walking readers through the whirlwind of life on Earth and celebrating the diversity of creatures that once existed. That celebration ends abruptly, however, as Prothero reminds readers that *Homo sapiens* is now the terror of the planet, threatening to drive nearly all species, including itself, extinct. — *Ashley Yeager*

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SCREENTIME

Help ornithologists develop bird photo ID tool

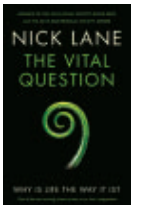
If you have a terrific picture of a Tennessee warbler, you can help the Cornell Lab of Ornithology improve its Merlin Bird Photo ID program. Upload your picture and put dots on the beak, eye and tail tip. Then, using patterns in the data, Merlin attempts to identify the bird. The aim is to help Cornell create a mobile device tool for beginning or intermediate birders to identify what they've snapped a picture of. (The lab's Merlin app already does well helping birders ID what they've seen based on a bird's size, colors, behavior and location, but not with a photo.)

Without a tail showing, this hairy woodpecker shot confused the Merlin photo ID program.

The tool is a fantastic idea but needs work. Developers are gradually adding species to the 400 common North American birds currently in the database. Each bird can be seen in many postures and plumages, so Merlin sometimes struggles to identify easy backyard birds. It gives users choices of possible species but little help in determining which is correct. An easy fix would be to link possible identifications to Cornell's own online All About Birds guide, which provides excellent information about each bird. *—Lila Guterman*

BOOKSHELF

The Boy Who Played With Fusion
Tom Clynes
A journalist profiles Taylor Wilson, a child prodigy in science (and a 2011 Intel ISEF award winner), extracting lessons for parents and schools.
Houghton Mifflin Harcourt, $28



The Vital Question
Nick Lane
Biological energy production and constraints on its flow underlie the rise of complex life, a biochemist argues.
W. W. Norton & Co., $27.95

SOCIETY UPDATE

Support for an alumna's nonprofit

The Society for Science & the Public recently provided $2,500 to ProjectCSGIRLS, an organization dedicated to cultivating a love for technology and computer science in girls and encouraging them to pursue their interest in these fields. This funding will support the nonprofit's 2015–2016 program year.

ProjectCSGIRLS was founded by Pooja Chandrashekar (above), an Intel Science Talent Search 2015 semifinalist. The organization's focus is an online competition run by high school and college students from around the country. The competition challenges girls in middle school to use computer science and technology to solve an imminent social problem.

Maya Ajmera, president and CEO of the Society for Science & the Public, was the keynote speaker at the 2015 ProjectCSGIRLS National Gala held in June.

Broadcom MASTERS applications soar

This year, the Society for Science & the Public received 2,230 applications for the Broadcom MASTERS, the premier middle school science and engineering fair competition. That number tops last year's submissions by more than 170 students and marks the most applications ever received. Applications arrived from nominees in 47 states and two U.S. territories.

Out of this group of entrants, 300 semifinalists will be announced on August 19 and then 30 finalists will be selected on September 2. Finalists will travel to San Jose, Calif., to compete for a top award of $25,000 in early October.

FROM TOP: TOM SIEGFRIED; COURTESY OF P. CHANDRASHEKAR

MAY 30, 2015

JUNE 27, 2015

SOCIAL MEDIA

Murder in the Stone Age

An ancient skull from Spain shows signs of foul play, **Julia Rosen** reported in "Stone Age killing is oldest whodunit" (*SN: 6/27/15, p. 14*). Readers on Facebook and Twitter had their own theories about the case.

"I think it was Grog! Clearly, he tried to frame Oog for the murder!"
Kurt Hildebrandt on Twitter

"Probably a drive-by with a Clovis point from a tamed bison."
Michael O'Donnell on Twitter

"I saw who did it. It was the one-armed man."
Mark Johnson on Facebook

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Space travel vs. the brain

*Getting to Mars may leave a mark on astronauts' minds. In "Trip to Mars could damage brain cells" (*SN: 5/30/15, p. 11*), **Laura Sanders** explained that high-energy particles smash into nerve cells and leave laboratory mice with memory deficits.*

"Most recent science fiction gives the impression that spaceflight is easy and the universe is filled with life-friendly environments. In reality, human spaceflight is almost impossibly dangerous, and beyond our blue sphere the universe is downright hostile to life," remarked **Mark S**. He wondered if leadlined helmets could shield space travelers from brain-damaging radiation.

Depending on the thickness, such helmets might provide some protection against lighter particles such as protons and helium, says study coauthor **Charles Limoli** of the University of California, Irvine. But thick helmets might be too cumbersome for astronauts, who need to be nimble, and too heavy to wear constantly. So far, says **Sanders**, there's no perfect solution to avoid brain damage, but scientists are exploring ways to protect delicate tissues, including new ways of shielding a Mars-bound spacecraft and even drugs that could combat radiation's damage.

No pause for warming

*A curious 15-year slowdown in rising global temperatures may not have happened after all. Incomplete and biased data might be behind the apparent trend, **Thomas Sumner** reported in "Global warming 'hiatus' an artifact" (*6/27/15, p. 6*).*

William Hopkins questioned the idea that 2014 was the hottest year on record. "If I asserted that in my graduate statistics course, I'd get a failing grade," he wrote. "The mean temperature value for 2015 may be greater than the mean value for all previous years, but the associated variability does not allow for 2014 to be differentiated from multiple prior years."

Managing editor **Tom Siegfried** explains that calling 2014 the hottest year on record was a concise way of conveying that its average temperature was the highest measured. Statistical uncertainties make it possible that the actual mean temperature, as opposed to the mean as measured, might not necessarily have been higher than for any other year. In this case, though, it's by far the strongest candidate for the top spot. Accounting for the uncertainties, the National Oceanic and Atmospheric Administration calculates a 48 percent probability that 2014 was in fact the hottest; probabilities for the next four hottest years combined are less than the probability for 2014.

One-way proteins

*In "Twisty chains of proteins keep cells oriented" (*SN: 6/27/15, p. 32*), **Tina Hesman Saey** explained how the fibers that make up the scaffolding of a cell develop a distinctive counterclockwise twirl.*

The article reminded **Lillian Greeley** of an experience with evolutionary biologist Stephen Jay Gould. "During the '80s, he would have open office hours on Friday afternoon from 12 to 3 p.m. and anyone could drop in and discuss anything, which was great fun. One afternoon, he passed around a shell whose pattern wound around in the opposite direction [from most] and told us that there were very few in the world, and this was one of them. It was thrilling for each of us to hold that shell," she wrote. "The basic question of your article and professor Gould's fascination is, why do some things go this way and not that way? Hopefully, this century's neuro-physicist-philosophers may be able to answer this question for us."

Correction

A caption on Page 26 of "Life's Cycles" (*SN: 7/25/15, p. 24*) stated that the last universal common ancestor of all living things may have had a primitive circadian clock. Instead, researchers have evidence that the first circadian clocks evolved more than a billion years later in a common ancestor of eukaryotes, organisms that have a nucleus where DNA is stored and organelles that carry out cellular processes.

JAVIER TRUEBA/MADRID SCIENTIFIC FILMS

Encased algae create kaleidoscope of color

Under a microscope, carefully arranged diatoms form a dazzling display.

Diatoms are single-celled algae (in the stramenopile supergroup; see Page 22) that live in sunny, wet habitats. The organisms come in many shapes and sport natural pigments of green, gold and brown. To complete their look, diatoms extract silica, a mineral used in glass, from the water and erect intricate outer skeletons. The hard shells are riddled with holes that allow nutrients in and waste out.

Artist Klaus Kemp from East Brent, England, arranges the tiny organisms into ornate microscopic patterns. The design above, which is about half a millimeter across, incorporates freshwater, marine and fossilized diatoms.

Like plants, diatoms exhale oxygen. The algae exist in such great numbers in the world's oceans that they produce at least 20 percent of the oxygen on Earth.

But some diatoms are a health hazard to humans and marine animals, including birds and sea lions. *Pseudo-nitzschia* diatoms produce domoic acid, a toxic substance that accumulates in fish and shellfish. People who eat contaminated seafood can suffer vomiting, seizures and short-term memory loss. In recent months toxic diatoms have churned out high concentrations of domoic acid in coastal waters from central California to Alaska. — *Sarah Schwartz*

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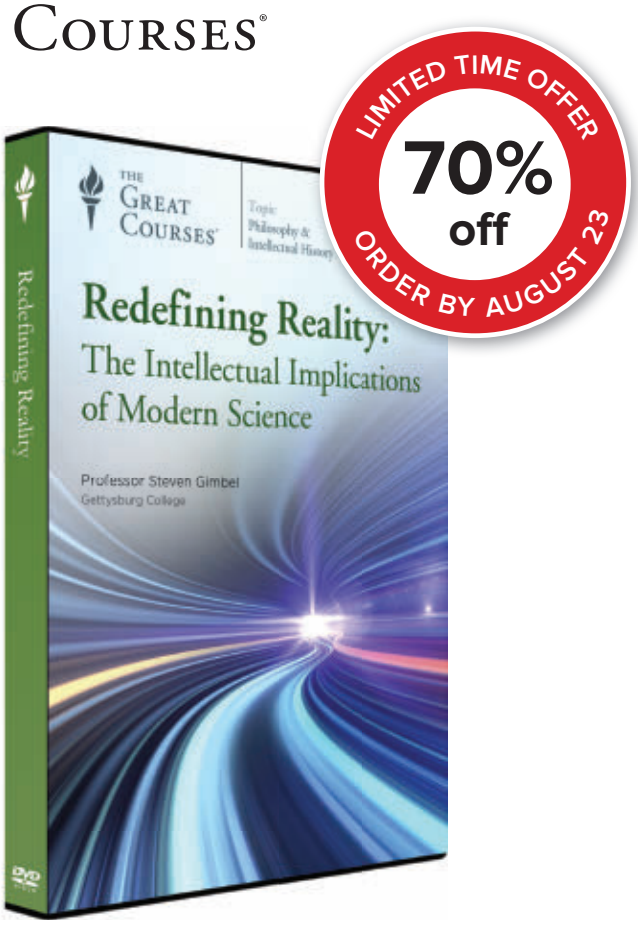

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