SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
MAY 31, 2014

Born Too Big

MERS Breaks Out of Middle East

Youth Transfused

A More Perfect Qubit

INTO THE UNKNOWN

The voyage across a black hole's event horizon

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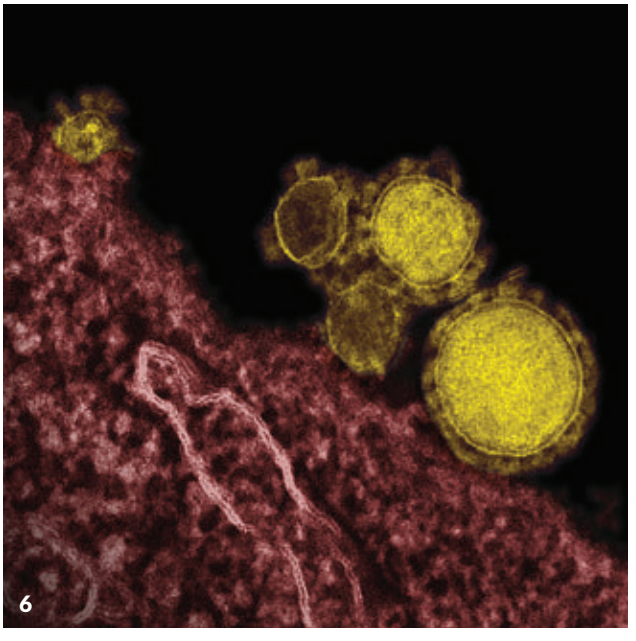
Features

News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Departments

COVER X-rays emanate from gas falling into a black hole in a computer simulation. *NASA GSFC, J. Schnittman and J. Krolik/JHU, S. Noble/RIT*

CLOCKWISE FROM TOP: ANDI ANSHARI/AP PHOTO; WORLDSWILDLIFEWONDERS/SHUTTERSTOCK; RML/NIAID

One of the best ways for kids to learn science: by doing it

A biodegradable Band-Aid. A low-cost, ultrasonic guide to parallel parking. A reinvention of the toilet. These were among the nearly 1,400 science fair projects on display at the 2014 Intel International Science and Engineering Fair. *Science News*' parent organization, the Society for Science & the Public, has run the annual event since 1950. This year's fair brought a record-breaking number of student finalists to compete in Los Angeles. And that's where I found myself in mid-May as this issue of the magazine was going to press.

My first day there, I had to dodge teen scientists using yards of double-sided tape to affix posters to three-panel boards; a congregation from Team Brazil (clad in green-and-yellow jackets) practicing science spiels with the same intensity as any sports warm-up; and, as one might expect with an event for high-schoolers, lots of socializing.

On our *Science News for Students* website (www.sciencenewsforstudents.org), you can read about a few of the many fascinating projects. A trio from Dix Hills, N.Y., focused on trapping bedbugs. Polystyrene recycled from a Styrofoam coffee cup proved the best material to immobilize a hairy bedbug leg. An Iraqi girl studied whether infrared light could be used to counter movie piracy. A team from Hanoi showed that plant compounds called saponins, extracted from a by-product of fiber production, could help keep fresh fruits from spoiling.

Some of the projects, though done by young folk, would not be terribly out of place in the pages of *Science News*. Many are sophisticated, if somewhat incremental, and engage in an ongoing scientific conversation. Others are more idiosyncratic — questions you can imagine a 16-year-old asking and trying to answer. All show the benefits of getting kids involved in original research. I couldn't walk down an aisle of the exhibition hall in the L.A. Convention Center without learning at least one new thing. There's no way that the students producing these projects didn't learn a huge amount, both about doing science and about how to communicate the results in a clear and compelling way. Budding scientists need both.

Tune in next issue to find out about this year's winners. I'm sure that you, like me, will find their enthusiasm and ingenuity inspiring. — *Eva Emerson, Editor in Chief*

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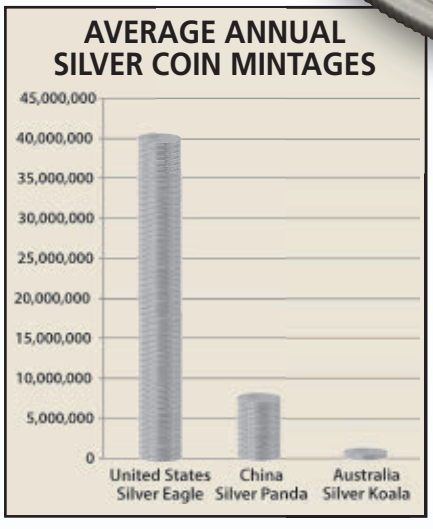

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Excerpt from the May 30, 1964, issue of *Science News Letter*

50 YEARS AGO

Size of Universe Studied

The universe is much bigger than scientists thought as little as 15 years ago, Dr. Ira S. Bowen, director of Mt. Wilson and Palomar Observatories, said. It is billions of light years in size as seen from the earth, exactly how big even astronomers can not yet say. The amount of space and matter the world's largest telescope, the giant 200-inch atop Mt. Palomar, can see is so great that how the universe is put together should soon be known.... Before the 200-inch went into operation, the most distant objects in the heavens were thought to be only hundreds of millions of light years away.

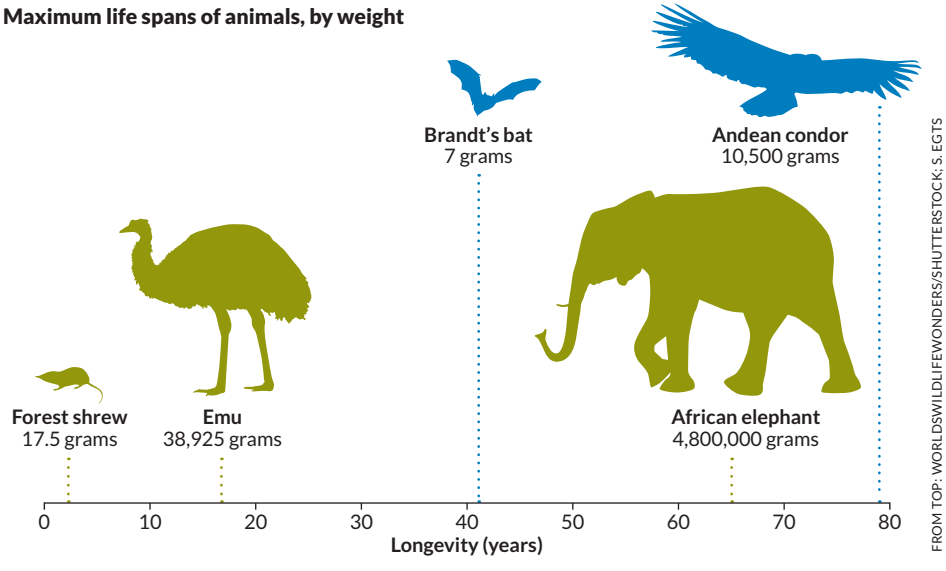
UPDATE: Data from the Hubble space telescope in the 1990s revealed more about the size of the observable universe, and since then NASA's WMAP satellite has detected light from 13.8 billion light-years away. No one knows, though, whether the universe is infinitely large, or even if what has been observed is the only universe that exists.

SCIENCE STATS

Fly more, live longer

Larger animals tend to live longer than smaller ones, but a new study finds some interesting exceptions to the rule. Some species live far longer than expected based on their size, and an examination of their lifestyles reveals that the most important factor linked to longer life is the ability to fly. Many birds and bats have long lives for their size, but the effect depends on what time of day the animals are active. Being nocturnal or diurnal gives the biggest life span boost compared with being active at dawn and dusk, when more predators may be out. SOURCE: K. HEALY *ET AL*/*PROC. ROYAL SOC. B* 2014

Maximum life spans of animals, by weight



FROM TOP: WORLDSWILDLIFEWONDERS/SHUTTERSTOCK; S. EGTS

IT'S ALIVE

Upside down and can't throw up

A sloth can't vomit. It has a one-way throat, handy for eating while dangling upside down by the toes. But the animal has to be careful not to poison itself by nibbling too many toxic leaves that it can't easily purge.

There are upsides and downsides to evolving a body that can hang toes-up for some four to six hours a day, as the three-fingered sloth does, says sloth biologist Rebecca Cliffe of the Sloth Sanctuary of Costa Rica near Limón.

She calls her sloths "three-fingered" instead of the more common "three-toed" because all sloths, even so-called two-toed species, actually have three toes on their hind legs. It's the digits of the front limbs, the fingers, that number either two or three.

A baby three-fingered sloth has to cling tight to mom. Baby sloths are born among the branches and can grip and clamber right away.

One reason both two- and three-fingered sloths have ended up up-ended is that it helps them carry out their fastidious grooming for several hours a day. "They like to scratch with both hands," Cliffe says.

Three-fingered sloths practice an extreme slothful vegetarianism that can call for topsy-turvy dining. Their digestive systems can't cope with much fruit or root material, so they snag tender new leaves, sometimes easier to reach from an upside-down perch. Those new leaves may be less likely to deploy a full arsenal of plant-defense toxins that the vomitless sloths can't get rid of, Cliffe says.

Eating upside down is one thing, but breathing is another. Gravity can pull heavy organs down onto the diaphragm. A brown-throated sloth's gut (*Bradypus variegatus*), for instance, can store up to a third of the animal's body weight in wastes before the weekly (or so) bathroom trip to the forest floor. The gut and other heavy organs are held in place by a web of membranes and internal adhesions, Cliffe and her colleagues report in the April *Biology Letters*. Breathing easier saves up to 8.6 percent of a sloth's notoriously tight daily energy budget.

Exploring sloth organs during necropsies, Cliffe and the sanctuary staff at first thought the bits of webbing and adhesions were caused by old injuries. But the "scar tissues" kept turning up in the same places, such as connecting the liver and stomach to the rib cage.

Now Cliffe and her colleagues are looking at the sloths' upside-down circulatory systems. They don't know yet, she says, why blood doesn't rush to a sloth's upside-down head.
— Susan Milius

THE –EST

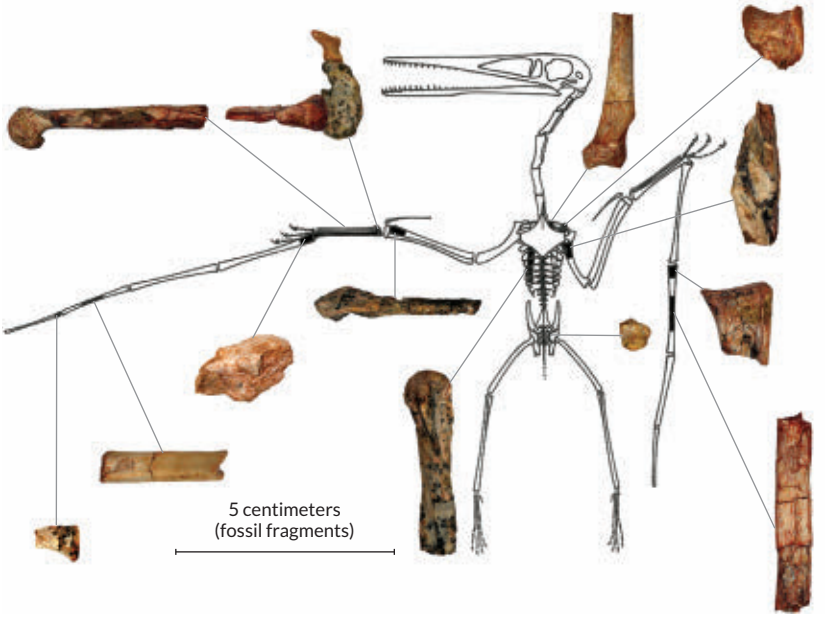
Oldest flying reptile

Deep beneath an ash bed in an area of northwest China famed for mud-filled "dinosaur death pits," researchers have unearthed the oldest pterodactyl fossil ever discovered.

The ancient flying reptile has been named *Kryptodrakon progenitor*, or "hidden serpent first-born," for its discovery near the filming site for the movie *Crouching Tiger, Hidden Dragon*. It lived about 163 million years ago, pushing back the fossil record for this type of pterosaur by more than 5 million years to the boundary between the middle and late Jurassic period.

Researchers pieced together fragile fossil fragments of *Kryptodrakon*'s spindly skeleton, which once belonged to an adult with a wingspan of 1.47 meters, about as long as a bicycle, Brian Andres of the University of South Florida in Tampa and colleagues report April 24 in *Current Biology*.

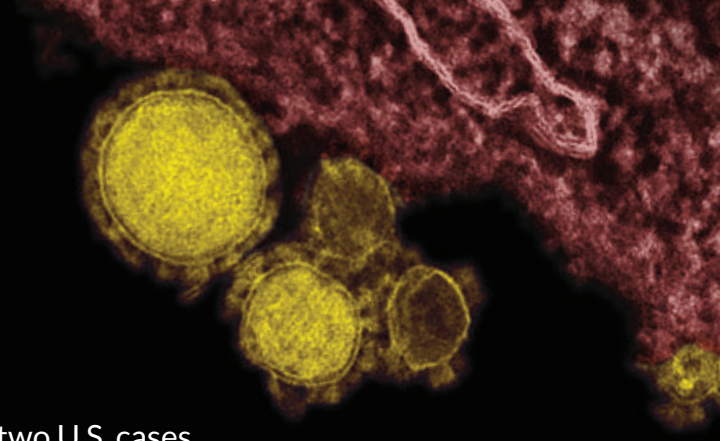
Though petite, this winged reptile is the ancestor of what would eventually become the largest flying animals ever to soar over the Earth, some reaching more than 10 meters in wingspan. *— Meghan Rosen*



Fossil fragments (above) of the flying reptile *Kryptodrakon progenitor* were uncovered in China's Xinjiang region (left), known for Jurassic mud pits that snared all sorts of prehistoric creatures.

B. ANDRES *ET AL/CURRENT BIOLOGY* 2014

See video of Rebecca Cliffe answering sloth questions at **bit.ly/SNsloth**



GENES & CELLS

MERS outbreak picks up pace

In recent weeks, virus infected hundreds, including two U.S. cases

BY TINA HESMAN SAEY

More than two years after it first appeared, the Middle East Respiratory Syndrome virus has suddenly exploded, with more than 200 new cases in April. As doctors struggle to treat patients, scientists are rushing to answer some basic questions about the virus's biology, whose answers could stop the outbreak from becoming a pandemic.

As far as anyone knows, the first human victims of MERS were a university student and a nurse who got sick and died in Jordan in the spring of 2012. In the two years between then and March 2014, public health officials recorded a total of 207 cases. Of those cases, 93 people died, making the mortality rate about 45 percent.

"If you do the math on the mortality rate of the virus and the number of people on the planet, it's scary," says Ralph Baric, a virologist at the University of North Carolina at Chapel Hill, who has long studied coronaviruses, including MERS and its cousin SARS.

The situation has rapidly worsened. In April 2014, the MERS virus infected at least 261 people — more than in the previous two years combined — and killed 38, mostly in Saudi Arabia and the United Arab Emirates. Those countries have been focal points of the disease since early in the outbreak. The first two documented cases in the United States were announced on May 2 and May 12; the patients are both health care workers who recently traveled from Saudi Arabia (*SN Online: 5/2/14, 5/5/14, 5/12/14*). By mid-May, the world's case total was 538, according to the U.S. Centers for Disease Control and Prevention.

The World Health Organization has a team in Saudi Arabia attempting to determine why MERS has begun to spread so rapidly, says WHO spokesperson Tarik Jasarevic. Scientists have already ruled out one possibility: "There is absolutely no evidence that the virus has changed," he says.

Part of the mystery is that no one is certain how people become infected, Jasarevic says. Camels and bats have been found to carry related viruses, with camels regarded as the most likely source for human infections.

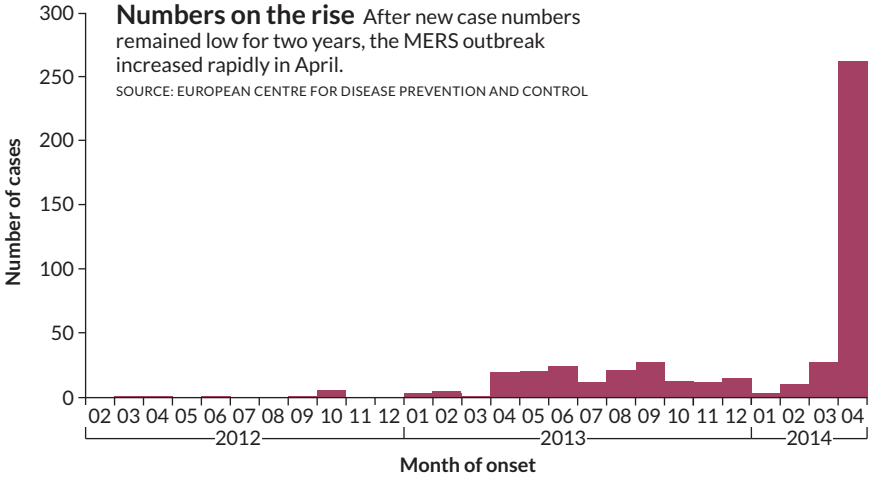
Now, researchers have discovered that dromedary camels carry live MERS viruses in their noses that can infect primate cells. Thomas Briese, a virologist at Columbia University, and his colleagues report the finding April 29 in *mBio*. Previous studies had hinted that the dromedaries could carry MERS (*SN: 4/5/14, p. 8*), but fell short of demonstrating that the animals have live viruses that can transmit to humans.

Camels can't be blamed for all MERS cases. Many people who have fallen ill were city dwellers who had no contact with camels, Briese says. And if the animals were the primary source, he says, one might expect camel handlers or people who work at slaughterhouses or otherwise have intense contact with camels and their bodily fluids to be the people who get MERS most often. But that's not the case, Briese says.

The MERS virus (yellow) was unknown two years ago. Now it has infected at least 538 people in 16 countries.

Instead, the virus most often attacks the old and already sick. Scientists are trying to determine what makes some people susceptible. Also unclear is exactly how the virus makes the leap from camel to human. Briese and his colleagues are testing camel meat, milk and urine as possible sources of the virus.

The method of transmission is just one of the fundamental questions that scientists have yet to answer about MERS. Researchers have learned that the virus uses a protein on its surface, known as the spike protein, to pick a particular molecular lock and gain access to human cells. The lock is a protein



known as dipeptidyl peptidase 4, or DPP4, that sits on the surfaces of cells (*SN Online: 3/13/13*). Many species make a version of DPP4; the MERS virus can crack a limited number of those, including the versions made by humans, camels and bats. It can't get past the DPP4 locks on the surfaces of cells from mice, rats or ferrets, says Vincent Munster, a virologist at the National Institutes of Health's Rocky Mountain Laboratories in Hamilton, Mont.

That's a problem, because it means those laboratory favorites can't be experimentally infected with MERS. Munster and his colleagues discovered that the coronavirus can infect rhesus monkeys. But the monkeys don't completely mimic the human infection, Munster says, and "not that many labs can handle nonhuman primates."

The problem of finding a useful animal MERS model may be partially solved thanks to a team led by Stanley Perlman, a virologist at the University of Iowa in Iowa City. Perlman and his colleagues devised a way to get mice to temporarily produce the human version of DPP4 in their respiratory tracts, the researchers reported in the April 1 *Proceedings of the National Academy of Sciences*.

Mice with human DPP4 can be infected with MERS, enabling the researchers to learn how the immune system handles the virus. Perlman's group is now genetically engineering mice to permanently replace their DPP4 protein with the human version.

Other potentially good news surfaced when two groups of researchers reported April 28 in the *Proceedings of the National Academy of Sciences* and in the April 30 *Science Translational Medicine* that they had isolated human antibodies that could prevent the MERS virus from latching on to its target.

The discovery raises the possibility that the antibodies could treat MERS infections or protect health care workers or close contacts of MERS patients from infection, says Wayne Marasco, an immunologist at Harvard Medical School and a coauthor of one of the reports.

The study also suggests that healthy human immune systems can keep the MERS virus in check, Marasco says. During the course of the experiments, the virus sometimes developed mutations in its spike protein, allowing MERS to evade the antibodies. "In cases where viruses could escape, they did so at the expense of their own fitness," says Marasco. The mutated viruses either had a harder time grasping cells, which would make infection harder, or they grew less well in primate cells. Weakened viruses may be easy pickings for a strong immune system.

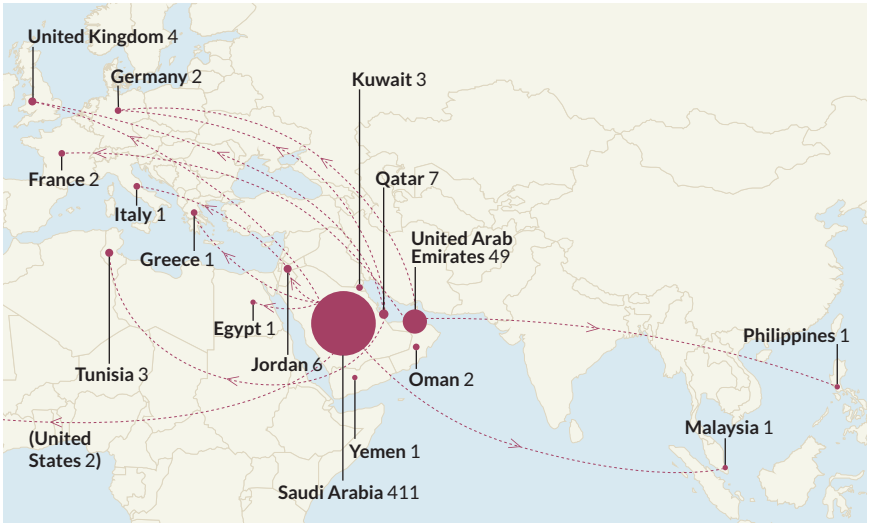
Unfortunately, many people who have contracted MERS already had other illnesses that may have damaged their ability to fight the virus. Each infected person is like a test tube where the virus can mutate; having more test tubes means an ever-increasing chance that the virus could become better at growing in humans. "A weakened immune system is clearly consistent with an environment where adaptation can occur," says Marasco.

Many of the new cases in Saudi Arabia and the United Arab Emirates have been spread from a sick person to a health care worker, family member, hospital patient or another contact. People who caught the virus from someone else tend to have mild illnesses or no symptoms at all, Jasarevic says, and the virus rarely transmits beyond the second person infected.

That's an assertion that Trish Perl, an epidemiologist at Johns Hopkins University, challenges. Perl traveled to Saudi Arabia last year to investigate a large MERS outbreak at hospitals. Her team found evidence for long chains of person-to-person transmission of the virus, especially among dialysis patients (*SN Online: 6/19/13*). "It's clear that there is a lot going on in the health care environment," Perl says.

In recent weeks, health officials have reported a growing number of milder cases and cases with no symptoms. Some may have been detected thanks to better surveillance; mild cases may have been missed earlier. The growing number of milder cases has also lowered the virus's overall mortality rate to somewhere around 30 percent. That's still a frightening number, Perlman says, but "it's not as scary as it could be."

He sees MERS as primarily a camel cold virus that sometimes leaps into susceptible people; proper precautions, he says, may make it disappear. "If you have good infection control measures and people stop getting so close to sick camels, there's a good chance it will die out." ■



A moving target The MERS outbreak has centered on the Middle East, but travelers have carried the respiratory virus to many other countries. The numbers represent cases documented through May 6 in each country, with the exception of the United States, which saw its second case later in May. SOURCE: EUROPEAN CENTRE FOR DISEASE PREVENTION AND CONTROL

REDMAL/ISTOCKPHOTO. ADAPTED BY E. OTWELL

BODY & BRAIN

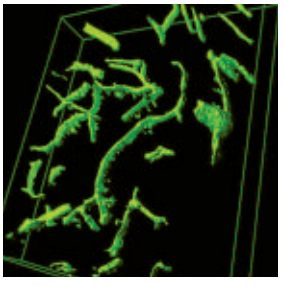
Young blood proven good for old brain

Plasma component restores some of youth's vibrancy

BY LAURA SANDERS

Vampires knew it all along, but now scientists have discovered that young blood can keep an old brain sharp. Plasma or blood from a young mouse — or even a single protein from plasma — rejuvenates sluggish bodies and minds in a host of ways, three new studies find.

Throughout the ages, people have searched far and wide for an elixir that replenishes the body. "Maybe they were just looking too far," says Tony Wyss-Coray of Stanford University School of Medicine, coauthor of a May 4 study in *Nature Medicine*.



Young blood spurs the growth of blood vessels (green) in the brains of old mice, as shown in a 3-D reconstruction of microscope images.

Young blood recharges old neurons, improving mice's ability to learn and remember things, Wyss-Coray and colleagues found. Two other papers, appearing May 4 in *Science*, identified a particular ingredient in young blood that improves both brain and muscles.

Scientists had already found benefits of young plasma for other tissues, such as the heart, liver and pancreas. Finding that the brain can be refreshed too may point out ways to counter age-related declines, either with plasma from young people or drugs made to mimic important parts of it, scientists say.

That the elderly brain can be rescued suggests that cognitive decline with aging may be avoidable, says Lee Rubin of Harvard University, coauthor of one of the *Science* papers. "It's not a unilateral descent into complete degeneration in an inexorable kind of way."

The premise of the experiments was deceptively simple: Scientists surgically linked the circulatory system of an old mouse to that of a young one, allowing their blood to mingle. In earlier experiments, Wyss-Coray and colleagues had found that this surgery to make mouse Siamese twins is bad for the young mouse. Ingredients in old blood harm the young mouse's brain, the researchers reported in 2011.

This time around, he and his colleagues looked for benefits that young blood might confer on older mice.

In the experiment, 18-month-old mice — the rodent equivalent of about a 55- to 70-year-old person — were tethered to 3-month-old mice, the equivalent of about a 20- to 30-year-old. The infusion of young blood kicked off a cascade of changes in the behavior of genes important for neuron behavior, the team found. And the neurons themselves appeared to sprout more docking places for other neurons to connect, a property of healthy neurons in young brains. These changes weren't present in old mice that had been surgically connected to other old mice.

Directly injecting old mice with plasma from young mice created benefits too — no surgery required. After receiving intravenous injections of young plasma eight times over 24 days, old mice were better at remembering the location of a hidden platform and responded more strongly to a scary environment, compared with old mice that had received injections of plasma from other old mice. No improvements occurred when the plasma was heated before it was injected, a process that can destroy sensitive proteins.

In a different experiment that connected mouse circulatory systems, Rubin and colleagues found that young blood increases the rate of cell birth in a brain region of the mouse called the subventricular zone. This region gives birth to cells that help a mouse smell. Old mice surgically linked to a young mouse were better able to discriminate odors.

The benefits weren't restricted to the smell system. Rubin and colleagues found blood vessels remodeled in a way that boosts flow. "The increase in blood vessels and blood flow is all over the brain, so we think that there will be other benefits to the older brain," he says.

Rubin thinks that the positive effects of young blood probably last several weeks. "Maybe you wouldn't have to be a Dracula feeding on fresh blood every day." (Here's another way vampires might have gone wrong: The beneficial molecules probably wouldn't survive a trip through the digestive system, Wyss-Coray says.)

Of course, there would be no need to drain blood from young donors (or victims) if the key ingredients could be isolated. The *Science* studies identify one such contender: a protein called GDF11, which normally declines with age. Delivering this molecule partially mimicked some of the gains in the brain, Rubin and colleagues found, and in skeletal muscle, as described in a paper by Amy Wagers of Harvard Medical School and colleagues.

In the brain, GDF11 alone remodeled brain blood vessels and enhanced the birthrate of new cells in the subventricular zone, Rubin's team found. But it's unlikely that GDF11 acts alone. A reduction of harmful ingredients in old blood may also be important, Rubin says.

"All of these studies concentrate on what's being enhanced," says immunotherapy expert Dobri Kiprov of California Pacific Medical Center in San Francisco. "What they address to a much lesser extent is what's being removed." Inflammatory molecules that rise with age may be important to consider, he says.

One day, designed molecules may stave off decline in the entire body. But much more work needs to be done to reach that point. Moving the research into human experiments will be difficult, but Wyss-Coray has started a biotechnology company, Alkahest, and plans to test the effects of plasma from young donors on people with Alzheimer's disease. He hopes to start in a few months. ■

LIDA KATSIMPARDI

EARTH & ENVIRONMENT

Ocean bacteria may have shut off ancient global warming

Mineral spikes in seafloor sediments coincide with halt in temperature rise

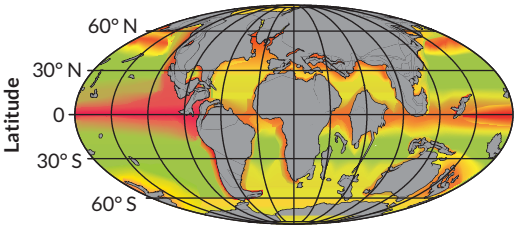
BY GABRIEL POPKIN

Ocean bacteria may have vacuumed up carbon and halted a period of extreme warmth some 56 million years ago, according to a study published April 13 in *Nature Geoscience*.

The finding suggests how Earth might once have rapidly reversed a runaway greenhouse effect. However, rapidity is relative: The bacteria would be far too slow to head off today's human-caused climate impacts.

The Paleocene-Eocene Thermal Maximum was a hot episode that occurred around 55.9 million years ago. During the roughly 170,000-year span, atmospheric carbon dioxide levels soared, temperatures rose by 5 degrees Celsius or more and ocean acidity spiked. The event ended in a relative hurry, over the course of 30,000 to 40,000 years. Scientists are unsure what stopped the warming; possibilities include uptake of carbon by organisms or by rock.

To investigate organisms' role, University of California, Santa Cruz marine scientist Adina Paytan and colleagues measured how much of the mineral barite, or barium sulfate, was present in 12 seafloor sediment cores from around the globe. Oceanic bacteria produce barite when they break down dead phytoplankton that has fallen from surface waters; the barite then accumulates in sediment.

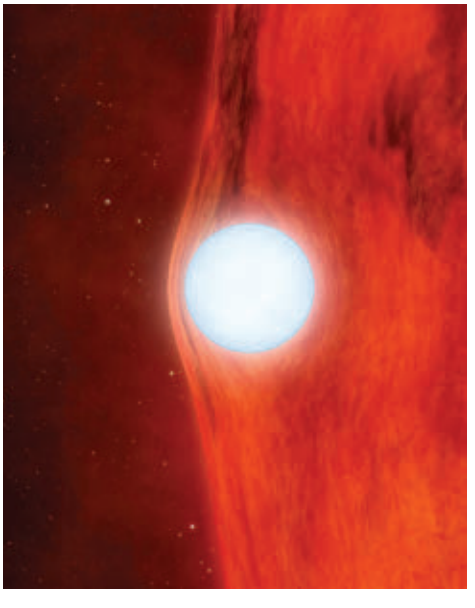


The amount of carbon-containing matter falling to the deep ocean increased during an extraordinarily warm period around 56 million years ago, researchers argue. In this computer simulation of the oceans at the time, red indicates high levels of falling carbon-rich material and green indicates low amounts.

Paytan's team found that barite spiked globally during the Paleocene-Eocene Thermal Maximum. The researchers think the elevated barite resulted from more phytoplankton falling from the ocean surface and being consumed by bacteria during the warm period. The phytoplankton that the microbes munched probably absorbed more carbon from the atmosphere as temperatures and carbon dioxide levels increased. The bacteria could have removed enough carbon from the atmosphere for long enough to reverse global warming, the authors conclude.

Using barite records is "a really creative, cool way to visualize these biogeochemical processes," says Aradhna Tripati, a geologist at UCLA. But she questions the researchers' assumption that bacteria in the much warmer ocean of 56 million years ago captured carbon at rates similar to today's.

While the finding suggests oceanic bacteria could play a role in stopping human-caused climate warming, the microbes would take thousands of years, says team member and Wesleyan University environmental scientist Ellen Thomas. "Humans can't wait for this." ■



FROM TOP: Z. MA ET AL/*NATURE GEOSCIENCE* 2014; JPL-CALTECH/NASA

ATOM & COSMOS

White dwarf boosts light of companion

Astronomers have discovered a unique pair of stars consisting of a white dwarf, the compact core of a dead star, and the sunlike star it orbits. When it passes between its companion and Earth, the white dwarf's gravity magnifies the other star's light (shown in an artist's illustration). The pair represents the first clear sign of a gravitational lens in a binary star. The white dwarf — with a mass about 60 percent of the sun's and a volume not much bigger than Earth's — orbits its companion every 88 days, astronomers report in the April 18 *Science*. Ethan Kruse and Eric Agol of the University of Washington in Seattle discovered the binary, lurking 2,600 light-years away in the constellation Lyra, while mining data collected by the planet-hunting Kepler space telescope. Self-lensing binaries provide a rare opportunity to directly measure masses of stars that otherwise could not be measured. Doing so might help scientists unravel the exotic physics of white dwarfs and the evolution of binaries, which make up nearly 40 percent of the sunlike stars in the galaxy.

— Christopher Crockett

Watch a video of a white dwarf contorting light at **bit.ly/SN_lens**

MATTER & ENERGY

In search of the unflappable qubit

Stable quantum information could speed calculations

BY GABRIEL POPKIN

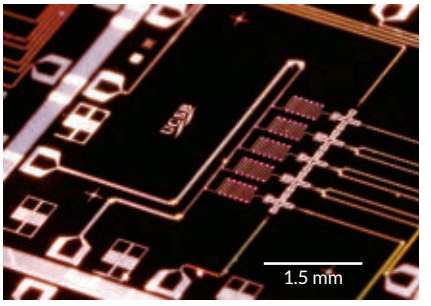
Quantum computing has overcome an important barrier: Scientists have achieved nearly perfect control over a bit of quantum information in a way that could bring them a step closer to error-free calculations.

All digital information comes in tiny packets called bits. In consumer devices, bits flip between two distinct states. But thanks to quantum weirdness, certain minuscule objects called quantum bits, or qubits, can exist in two states at once. Physicists have connected multiple qubits with each other to share one overall "entangled" state. Using entanglement, rudimentary quantum computers can run multiple calculations at once and solve simple problems like factoring 15 into 3 and 5 (*SN: 3/10/12, p. 26*). Each additional qubit doubles a device's processing power, so quantum computers should complete tasks far more rapidly than conventional machines do.

But quantum states are easily shattered, especially as the number of entangled qubits increases. Theorists in the 1990s suggested that qubits arranged in a checkerboard could overcome this fragility by monitoring and correcting errors in their neighbors, creating communal stability. Even in this scheme, however, individual qubits' states would need to come out correctly after at least 99 out of 100 state-changing computations; otherwise, errors would multiply throughout the grid.

Seeking to make an unflappable qubit, John Martinis, a physicist at the University of California, Santa Barbara, and colleagues report in the April 24 *Nature* that they built electrical circuits, each roughly the size of a grain of sand, from superconducting aluminum wire and ultrathin barriers of aluminum oxide. When cooled to 30 thousandths of a degree Celsius above absolute zero, electrons slosh back and forth, or resonate, around the circuits without resistance. Information can be encoded in this resonance to make a qubit.

Using the grid-computing idea, Martinis and colleagues lined up five of their qubits and electrically linked each to its nearest neighbors. The researchers then etched larger circuits that allowed them to change individual qubits' states with tiny pulses of electricity. The scientists found they could control one qubit's state more than 99.9 percent of the time. For two entangled neighboring qubits, the fidelity dropped to 99.4 percent. When the team entangled all five at once, the researchers could control the qubits' state 81.7 percent of the time.



Tiny electrical circuits have given physicists unprecedented control over the quantum states of units of information called qubits. The circuits appear as five crosses (center).

Achieving such precise control in a system with so many qubits is "a great milestone for quantum information processing," says physicist Raymond Laflamme of the University of Waterloo in Canada. And Yale University's Robert Schoelkopf, who invented the sloshing-electron qubit, agrees. But he adds that a practical quantum computer would require even stabler qubits. ■

LIFE & EVOLUTION

Abandoned frog eggs can hatch early

If deadbeat dads among frogs shirk their parental duties, neglected egg clutches can respond by hatching early.

Eggs laid on the undersides of leaves by the glass frogs *Hyalinobatrachium fleischmanni* (shown) depend entirely on fathers for care. And, says Jesse Delia of Boston University, "some are just bad dads."

Males keep the eggs hydrated by releasing water to an egg clutch over the course of about 40 minutes. A diligent dad may make five or six water trips a night. But he also has to fight off rivals and court the mothers of his next egg batches.

Embryos neglected in his crowded schedule can eventually hatch early if they've had at least three days of care, Delia and his colleagues report in the June 22 *Proceedings of the Royal Society B*. Clutches hatched successfully as early as 12 days after being laid. Well-tended clutches take up to 27 days. The link between abandonment and early hatching shows up in the frogs' natural behavior in southern Mexico and in experiments in which researchers removed dads. Hatching early saves the embryos from drying out in their eggs but may not give them the best start to life outside the egg. —*Susan Milius*

FROM TOP: ERIK LUCERO/UCSB; COURTESY OF J. DELIA

HUMANS & SOCIETY

Row arises over *Homo erectus* height

Doubt over whether Turkana Boy could have hit modern stature

BY BRUCE BOWER

A Stone Age boy stands at the center of a controversy over when members of the human evolutionary family first reached heights and weights comparable to those of modern human adults.

All that remains of the ancient, approximately 8-year-old *Homo erectus* boy is his nearly complete roughly 1.5-million-year-old skeleton. Excavations in 1984 near Kenya's Lake Turkana yielded the find.

When he died, "Turkana Boy" stood roughly 5 feet, 3 inches. A study from 1993 estimated that, had the boy lived, he would have grown to a height of 6 feet, 1 inch. To reach such a height, the boy would have to have been destined for an adolescent growth spurt on par with modern humans'. And a transition to humanlike growth and development would have to have occurred surprisingly early in hominid evolution.

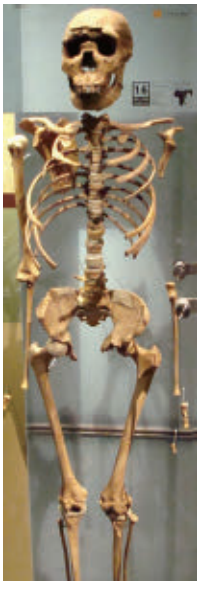
New comparisons of Turkana Boy's teeth with those of modern chimpanzees and gorillas at various ages indicate that the child would have reached an adult height of 5 feet, 9 inches to 5 feet, 11 inches, reported Christopher Ruff on April 10. That estimate should be seen as a minimum, said Ruff, of the Johns Hopkins University School of Medicine. In his view, Turkana Boy demonstrates that *H. erectus* took a major step toward the extended developmental period of modern humans.

Ruff's work revises downward only slightly the estimate that he and Alan Walker of Penn State University proposed over 20 years ago. However, the earlier conclusion rested on the assumption that *H. erectus* grew much as modern humans do, getting considerably taller and heavier during adolescence.

Now, researchers assume that *H. erectus* growth patterns fell somewhere between those of *Homo sapiens* and relatively faster-developing chimps. A team led by Ronda Graves, then at Florida Atlantic University in Boca Raton, estimated in the November 2010 *Journal of Human Evolution* that Turkana Boy would have reached an adult height of 5 feet, 4 inches, just a tick taller than when he died. That analysis hinged on growth curves calculated to lie between those of modern humans and chimps.

But between 8 years of age and maturity, even chimps get considerably taller and heavier than Graves and her colleagues say Turkana Boy did, Ruff said, a sign that Graves' team underestimated adolescent growth in *H. erectus*.

Ruff concluded that Turkana Boy's height would have fallen within the range of previously estimated heights of adult *H. erectus* individuals derived from 1.5-million-year-old footprints in Kenya (*SN: 3/28/09, p. 14*).



NIEL R/FLICKR (CC BY-NC 2.0)

Clashing analyses conclude that 1.5-million-year-old Turkana Boy, whose nearly complete skeleton was found in 1984, would have grown to nearly 6 feet tall or reached only about 5 feet, 4 inches.

In a new set of growth curves for Turkana Boy presented on April 10, Deborah Cunningham of Texas State University in San Marcos — a coauthor of Graves' 2010 paper — reaffirmed that the child would have been shorter as an adult than Ruff's estimate and would have weighed between 138 and 147 pounds.

Bernard Wood of George Washington University in Washington, D.C., commented that he didn't understand why Ruff's and Cunningham's growth estimates diverge so greatly. ■

MEETING NOTES

Laetoli footprints show signs of unusual gait

Hominids that left footprints in volcanic ash at Laetoli, Tanzania, 3.6 million years ago walked differently than people today do, Kevin Hatala, an anthropologist at George Washington University in Washington, D.C., reported on April 11. His conclusion challenges a recent study suggesting that Laetoli folk took humanlike strides (*SN Online: 3/22/10*). Hatala compared measures of the depth and shape of Laetoli prints with similar measures of footprints made in moist soil by men from a Tanzanian community of herders and farmers who rarely wear shoes. Ancient Laetoli individuals flexed their big toes more when pushing off and extended their hips less than the African men did, Hatala said. *— Bruce Bower*

Earliest case of a battered child found in Greece

A pit where Athenians living 2,200 years ago often deposited fetuses and babies who had died of natural causes contained a grim surprise for Maria Liston, an anthropologist at the University of Waterloo in Canada. There, she found the skeleton of a roughly 1-year-old child who was probably beaten to death before being thrown into the pit. The unfortunate youngster represents the earliest documented case of severe child abuse, Liston said on April 10. The battered child's remains include a partially healed skull fracture probably caused by a deliberate blow to the head that the youngster survived for about a week. Other abuse markers include fractures to ribs and at the front and back of the jaw, irregular bone growth due to leg and neck injuries and a break at the end of the upper arm bone that is usually caused by violent twisting. *— Bruce Bower*

LIFE & EVOLUTION

Mimicry lets birds keep cheating

Drongos borrow other species' sounds to freshen up their fraud

BY SUSAN MILIUS

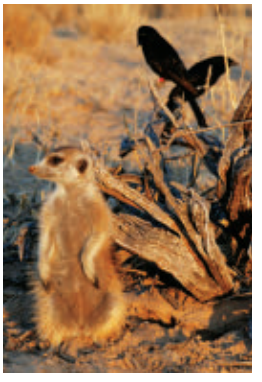
Avian masters of deception mix things up to keep their scam going, researchers have found.

When food gets scarce, African birds called fork-tailed drongos (*Dicrurus adsimilis*) watch for a meerkat or other forager to find desirable prey. The drongo calls out an alarm as if a predator were approaching. The forager often drops its prize and dashes away. Then the drongo swoops in and steals lunch.

If drongos faked one alarm too often, victims could learn to ignore it, says Tom Flower of the University of Cape Town in South Africa. Drongos get around this dilemma by borrowing other species' alarm sounds and varying what noise they make in the scam, Flower and his colleagues report in the May 2 *Science*.

Researchers in the arid Kalahari region of South Africa recorded drongos, each of which made 9 to 32 kinds of alarm calls. The sounds unique to drongos are "sharp and harsh and grating," Flower says. But the species can also make 45 more sounds that mimic other animals' warning calls, such as the piping or barks that meerkats give when spotting danger. Drongos often do give honest warnings of danger.

But when the birds steal food, they mimic alarms of other species more than 40 percent of the time, often using the victim's own alarm. The mimicry works. The researchers played recorded alarms for birds called pied babblers, a target of the drongos' fraud. Mimicked alarm calls of the babblers or of another bird distracted the babblers for longer than plain drongo alarms.



Drongos perch near a meerkat, perhaps readying their next cheat.

Variety also works. The same call lost some of its power to fool the babblers on the third iteration, the researchers found. But switching that third phony alarm to a different kind sent babblers fleeing as swiftly as ever.

Analyzing 688 drongo attempts at theft in the Kalahari revealed that the master tricksters switch it up. Compared with a drongo that has succeeded in scaring away a forager with an alarm call, a bird that has failed is more likely to switch to a different call for the next attempt. And switching made the next attempt more than four times as likely to succeed.

Documenting flexible deception in mimicry like the drongos' is extremely unusual, says behavioral ecologist Rose Thorogood of the University of Cambridge. Plenty of organisms lie and cheat for a living, but they face limits on their foolery that drongos have pushed back. ■

BODY & BRAIN

Material induces muscle regrowth

Noncellular pig tissue attracts stem cells to fix injuries

BY NATHAN SEPPA

Badly injured patients can regrow lost muscle with help from implanted sheets of pig tissue. An experimental treatment worked well for three of five volunteers and showed some benefit in a fourth, researchers report in the April 30 *Science Translational Medicine*.

"This is five patients, and that's not huge. But it's a benchmark," says George Christ, a physiologist at Wake Forest School of Medicine in Winston-Salem, N.C. "It's good to see studies out there trying to address this huge gap in medical knowledge and treatment."

Large-volume losses of muscle don't fully recover. To encourage regrowth, the scientists used pig bladder tissue with all of its cells removed, leaving a sterilized matrix sheet of collagen and other compounds common to mammals. Implanted in sites of muscle loss in mice, the material gave off chemical signals that attracted stem cells. The tissue sheets also served as a scaffold on which those cells grew and took on characteristics of muscle cells, says study coauthor Brian Sicari, a researcher at the University of Pittsburgh School of Medicine.

A larger, multilayer version of this scaffold was implanted in five men who had lost muscle tissue in either the thigh or lower leg and had endured physical therapy and various surgeries to remove scar tissue in failed attempts to regrow lost muscle. Their injuries had occurred one to seven years before the study.

"Most of these patients have been through hell," says coauthor Stephen Badylak, a physician and researcher also at Pittsburgh. A day or two after undergoing surgery to implant the scaffold material at the injury site, all five went into rigorous physical therapy. Such movement, Badylak says, instructs stem cells attracted to the scaffold's chemical cues that they should become muscle cells. Biopsies of the implant site showed muscle regrowth in all five patients.

Each patient also underwent tests of everyday movements such as getting up from a chair, standing balanced on the injured leg with eyes closed, jumping on that leg, squatting or reaching forward and backward while standing. Three patients passed all tests relevant to their injuries 24 to 28 weeks after implantation. Another patient passed six of seven tests but failed a standing balance test. Although one patient experienced little physical improvement, Badylak says this is the first study to show this degree of regrowth in multiple people with extensive muscle loss. ■

COURTESY OF T. FLOWER

Listen to drongos' mimicry at **bit.ly/SN_drongos**

Most extreme female penis is found on cave lice

Insect's organ can be 15 percent the length of the body, extract sperm from males

BY SUSAN MILIUS

The most dramatic genital-shape reversal known — females with long, insertable organs and males with corresponding pouches — has turned up in bark lice living in Brazilian caves.

A female in each of four *Neotrogla* species extends a skinny structure up to 15 percent the length of her body to retrieve sperm from the male's body, reports entomologist Kazunori Yoshizawa of Hokkaido University in Sapporo, Japan. Depending on the species, a female bark louse can spend up to 70 hours extracting sperm. Males have penislike remnants but can't deliver sperm with them.

Male sperm packages look as if they could be nutritional bonanzas in dry caves where the insects otherwise rely on bat guano and the occasional carcass, Yoshizawa says. The food value of sperm may change the balance of various evolutionary pressures and end up favoring the evolution of female penises and male vaginas, the researchers suggest in the May 5 *Current Biology*.

"Absolutely amazing," said Menno Schilthuizen of Leiden University in the Netherlands after a first look at the paper's anatomical illustrations. The female organ, he says, "has even copied the penis spines that are so common in many male animals."

Spines may help a female louse anchor her organ inside the male, Yoshizawa says. In three species, males have pouches, and bulging spots accommodate the spines and may reduce damage to the males. When the female inserts the structure, it inflates and remains firmly attached. Once, when researchers tried to separate a coupled pair, the male's body broke in two but male and female genitals remained connected.

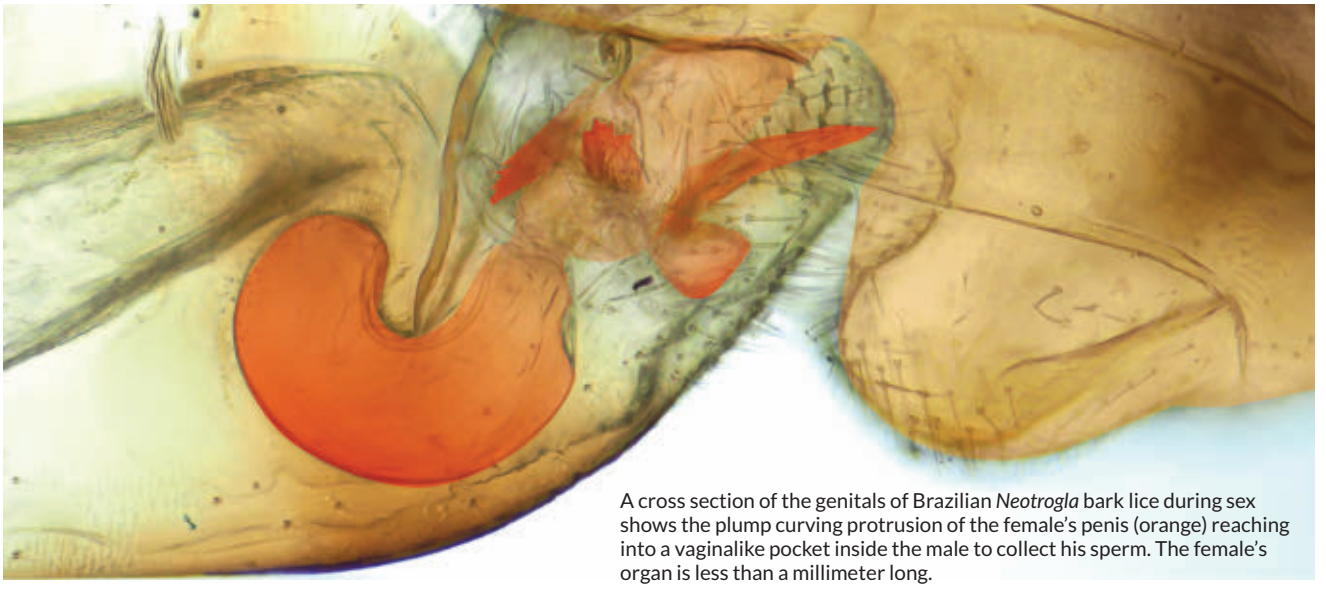
> "The female organ has even copied the penis spines that are so common in many male animals."
>
> **MENNO SCHILTHUIZEN**

The gripping power is just one of the features that distinguish the cave louse penis from the few other known examples of insertable female organs, Yoshizawa says. A female sea horse inserts a tube into a male's pouch but she's not retrieving sperm, just inserting eggs for the male to fertilize and carry to term. Some female scirtid beetles can push out a bit of the ducts leading to their sperm-storage organs, and female astigmatan mites extend a tube that is "quite long, actually," Yoshizawa says. "The *Neotrogla* female penis is the spiniest."

Neotrogla is a recent addition to the world's known insect genera, described in 2010 based on specimens collected from harsh, dry caves in eastern Brazil explored by Rodrigo Lopes Ferreira of the Federal University of Lavras in Brazil. "They live in such a severe condition that only a few species can survive," he says.

Its wow factor aside, Schilthuizen calls the genital role reversal "important because it is the exception that proves the rule of sexual selection." How much each sex invests in reproduction affects how choosy that sex is. If male cave lice are bundling a lot of their tiny sperm and extras into huge, nutritious packages in a nearly barren environment, the male could become the choosy one and the female the wanton and sexually more aggressive one.

Striking as the cave lice are, he says, "there are still so many unstudied insects out there that I wouldn't be surprised if more examples turn up sooner or later." ■



COURTESY OF K. YOSHIZAWA

A cross section of the genitals of Brazilian *Neotrogla* bark lice during sex shows the plump curving protrusion of the female's penis (orange) reaching into a vaginalike pocket inside the male to collect his sperm. The female's organ is less than a millimeter long.

HUMANS & SOCIETY

Students retain information better with pens than laptops

When it comes to taking notes, the old-fashioned way might be best. Students who jotted down notes by hand remembered lecture material better than their laptop-wielding peers did, researchers report April 23 in *Psychological Science*. People taking notes on laptops have a shallower grasp of a subject than people writing with their hands, and not just because laptops distract users with other activities such as web surfing, the new study suggests. Students from Princeton and UCLA watched videos of TED talks or of a graduate student delivering a lecture. Students who wrote in longhand before a quiz performed better on conceptual questions than did those who typed notes. Pen users' notes included around 100 to 150 fewer words than those of people who typed and were less likely to include what the lecturer said verbatim. The finding indicates that pen users reframed concepts in a more meaningful way, the authors suggest. — *Laura Sanders*

Massachusetts insurance mandate lowers death rate

After 2006, when Massachusetts put in place a policy aimed at universal health insurance, mortality rates among those affected by the law fell by 2.9 percent, researchers report in the May 6 *Annals of Internal Medicine*. The law, enacted when Mitt Romney was governor, is widely seen as a model for the national Affordable Care Act, sometimes called Obamacare. The Massachusetts law mandated coverage and offered subsidized private insurance and expanded Medicaid coverage. Researchers compared mortality for people ages 20 to 64 from 2007 to 2010 with death rates in the five years preceding the law's enactment. The 2.9 percent decline was the average, with the greatest effect seen in previously uninsured people. The researchers calculated that Romneycare yielded one fewer death for every additional 830 adults covered. Greater coverage led to more clinic visits resulting in better overall health, the authors suggest. — *Nathan Seppa*

EARTH & ENVIRONMENT

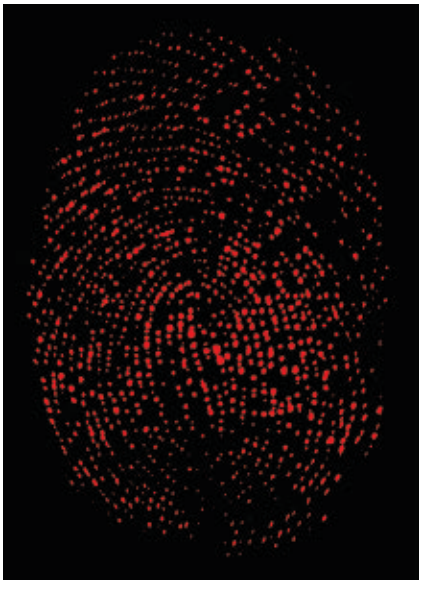
Viruses buoy life at hydrothermal vents

In the deep ocean, viruses have won safe harbor through thievery. With stolen genes that make sulfur-digesting enzymes, viruses provide metabolic backup to bacteria feasting on the sulfur plumes of hydrothermal vents, researchers propose May 1 in *Science*. Researchers know little about the bacteria-infecting viruses, called bacteriophage, that invade sulfur-oxidizing bacteria. These bacteria are key sources of energy for organisms in hydrothermal vents. Geomicrobiologist Gregory Dick of the University of Michigan in Ann Arbor and colleagues spotted the genetic looters in samples from vents in the western Pacific Ocean and the Gulf of California. By sequencing DNA in each sample, the team found the genomes of sulfur-oxidizing bacteria and 18 types of viruses. Fifteen of these viruses, the researchers found, had snatched and held onto bacterial genes involved in converting elemental sulfur to sulfite, a step in energy production that could bolster the host bacteria's energy output. — *Beth Mole*

MATTER & ENERGY

Color-changing polymer maps fingerprints

Sweaty fingers make tidy prints. Beads of perspiration seeping from a person's pores can leave detailed maps of the fingertips (one shown), and a new technique can detect the sweat. Materials scientist Jong-Man Kim of Hanyang University in Seoul, South Korea and colleagues created color-changing polymers that snap from blue to red when they touch tiny droplets. The polymer subunits look like teeny tadpoles, with bulbous heads and skinny tails. When packed tightly together, they form stacked sheets that appear blue. But water twists the crowded sheets apart, making them absorb shorter wavelengths. Pressing a finger to a polymer-coated film instantly colored it with red dots, Kim's team reports April 29 in *Nature Communications*. Kim thinks the polymers could improve existing fingerprinting, which analyzes impressions left by finger ridges' loops, arches and whorls. Pores speckle these ridges, creating unique dot patterns that match up with traditional fingerprints. Forensics teams can pick up 10-year-old dots of sweat left on a piece of paper, Kim says. — *Meghan Rosen*



COURTESY OF KIM *ET AL*

LIFE & EVOLUTION

Submariners' 'bio-duck' is probably a whale

It quacks like a duck, sort of. But the mystery creature of the Antarctic is more likely a whale. Submariners in the 1960s recorded strings of quick heartbeat-like pulses and nicknamed the unknown source a "bio-duck." Whatever it is sounds off mostly in winter and spring in the Weddell Sea off Antarctica and the waters off Western Australia. The sound is "way too loud for a fish," says marine biologist Denise Risch of Integrated Statistics in Falmouth, Mass. Listeners have proposed sources from military hardware to marine mammals such as minke whales. Very little is known about these whales' vocalizations. In 2013, researchers for the first time placed acoustic tags on the Antarctic minke (*Balaenoptera bonaerensis*). Over the course of 18 hours, one of the tags picked up bio-duck beats before and during a whale's feeding dive. Because researchers following the whales saw no other marine mammals nearby, Risch and colleagues conclude April 23 in *Biology Letters* that minke whales are the bio-ducks. — *Susan Milius*

Listen to minke whales' weird sounds at **bit.ly/SN_bioduck**

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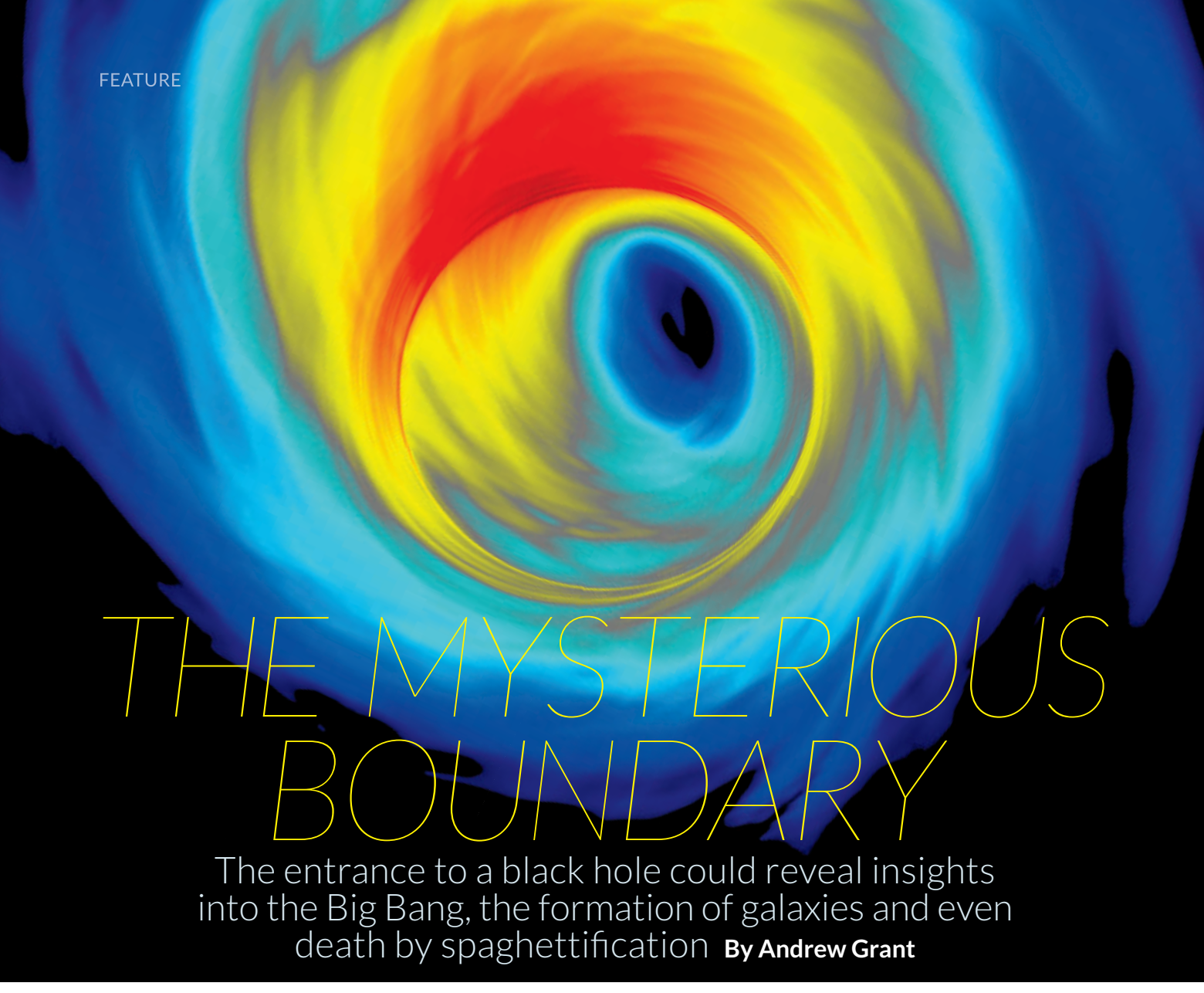


THE MYSTERIOUS BOUNDARY

The entrance to a black hole could reveal insights into the Big Bang, the formation of galaxies and even death by spaghettification

By Andrew Grant

A black hole's event horizon is a one-way bridge to nowhere, a gateway to a netherworld cut off from the rest of the cosmos.

Understanding what happens at that pivotal boundary could reveal the hidden influences that have molded the universe from the instant of the Big Bang.

Today some of the best minds in physics are fixated on the event horizon, pondering what would happen to hypothetical astronauts and subatomic particles upon reaching the precipice of a black hole. At stake is the nearly 100-year quest to unify the well-tested theories of general relativity and quantum mechanics into a supertheory of quantum gravity.

But the event horizon is more than just a thought experiment or a tool to merge physics theories. It is a very real feature of the universe, a pivotal piece of cosmic architecture that has shaped the evolution of stars and galaxies. As soon as next year, a telescope the size of Earth may allow us to spot the edge of the shadowy abyss for the first time (See sidebar, Page 20).

By studying the event horizon through both theory and observation, scientists could soon figure out how the universe began, how it evolved and even predict its ultimate fate. They'd also be able to answer a crucial question: Would a person falling into a black hole be stretched and flattened like a noodle, dying by spaghettification, or be incinerated?

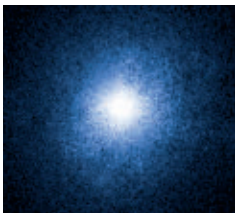
The event horizon is framed by the bright ring in this black hole simulation. Color represents the intensity of light emitted by hot gas circling the horizon; red is brightest, blue dimmest.

SCOTT NOBLE/RIT

Gravitational gusto

Scientists thought about the possibility of black holes and event horizons long before either term existed. In 1783, British geologist and astronomer John Michell considered Newton's work on gravity and light and found that, in theory, a star with 125 million times the mass of the sun would have enough gravitational oomph to pull in any object trying to escape — even one traveling at light speed.

Although stars can never attain that much mass, Albert Einstein's 1916 general theory of relativity put Michell's hunch about supermassive objects onto solid theoretical ground. Later that year, German astronomer Karl Schwarzschild used general relativity to show that some stars could collapse under their own gravity and create a deep pit in the fabric of spacetime. Anything, including light, that came within a certain distance of the collapsed star's center of mass could never come out. That point of no return became known as the event horizon.



Discovered in 1964, Cygnus X-1 (seen here in X-rays) became the first astronomical object to be classified as a black hole.

Confirmation for the existence of black holes came decades later. In 1974, scientists detected a heavy dose of radio waves emitted from the center of the Milky Way, about 26,000 light-years away. They eventually concluded that there must be a black hole there. Today, astronomers know that virtually every galaxy harbors a giant black hole at its center, shaping the formation of millions of stars and even neighboring galaxies with its immense gravitational influence. Galaxies also contain millions of small- and medium-sized black holes, each with an event horizon past which light is never seen again.

But the repercussions of black holes' extreme gravity eventually led to conflicts with one of the keystones of 20th century physics: quantum mechanics. The trouble began in the mid-1970s, when University of Cambridge physicist Stephen Hawking proposed that black holes are not eternal. In the far, far future, when black holes have devoured almost all the matter in the universe, leaving little else to consume, energy should slowly leak out from their event horizons. That energy, now known as Hawking radiation, should continue seeping out until each black hole evaporates completely.

Hawking quickly realized the drastic consequences of his proposal. In a chaos-inducing 1976 paper, he explained that if a black hole eventually disappears, then so should all the information about all the particles that ever fell into it. That violates a central tenet of quantum mechanics: Information cannot be destroyed. Physicists could accept that all the properties of all the particles within a black hole were locked up, forever inaccessible to those outside a black hole's event horizon. But they were not OK with that safe vanishing without a trace. "It violated everything I knew about quantum mechanics," says Stanford theoretical physicist Leonard Susskind, who heard Hawking's ideas at a conference in 1981. "It couldn't be right."

Violating theories

Susskind dug into this black hole information paradox, and by the turn of the century he thought he had resolved it with a proposal called complementarity. In essence, he argued that information can simultaneously cross the event horizon and never cross the event horizon, so long as no single observer can see it in both places.

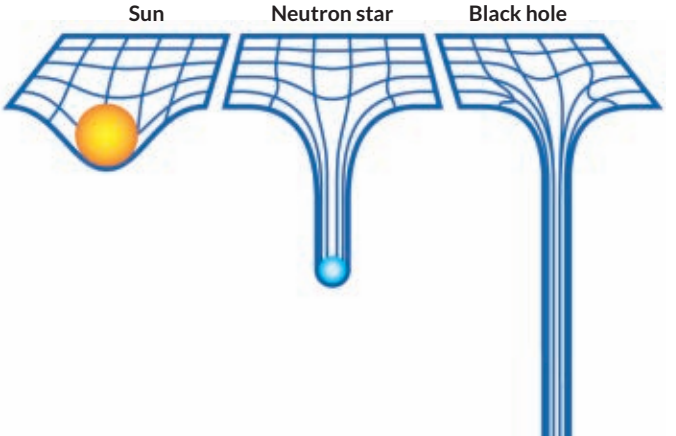
If a particle were to fall into a black hole, an astronaut falling alongside it would see nothing special happen as both coasted across the event horizon and into the black hole's interior. But another astronaut watching from outside would never see his friend or the particle pass the event horizon; from his point of view, the particle would get perilously close to the horizon but never quite cross it. Eventually, as the black hole evaporated perhaps a trillion trillion trillion trillion years later (astronauts in thought experiments have remarkable longevity), the astronaut outside the black hole would see the Hawking radiation associated with the infalling particle.

Susskind's explanation is unintuitive, but at least it's elegant. For both observers, information is preserved (*SN: 9/25/04, p. 202*). Plus, the outside astronaut can potentially piece together everything that fell into the vast black hole interior just by monitoring the event horizon. This idea, proposed by Juan Maldacena at the Institute for Advanced Study in Princeton, N.J., is called the holographic principle: Just as a two-dimensional hologram can depict a three-dimensional object, the surface of a black hole theoretically reveals everything inside of it.

But in 2012, a quartet of physicists including Joseph Polchinski from the University of California, Santa Barbara reignited the black hole information paradox by demonstrating that in solving one problem, Susskind and Maldacena had created another. The issue centers on another facet of quantum mechanics called entanglement, which intertwines the properties of multiple particles regardless of the distance between them. Susskind and Maldacena's complementarity relies on entanglement to preserve information. As the proposal goes, particles of Hawking radiation are linked to each other so that over time an observer could measure the radiation and piece together what's inside the black hole.

In yet another thought experiment, Polchinski and his team pondered what would happen if just one of a pair of entangled particles near a black hole's event horizon fell in, while the other escaped as Hawking radiation. According to complementarity, the escaping particle would also have to be entangled with another Hawking particle. But that's a no-no in quantum mechanics: Particles entangled with each other

Stretching spacetime According to general relativity, the sun's mass makes an imprint on the fabric of spacetime that keeps the planets in orbit. A neutron star leaves a greater mark. But a black hole is so dense that it creates a pit deep enough to prevent light from escaping.



FROM TOP: CXC/SAO/NASA; JAMES PROVOST

Pasta or Barbecue?

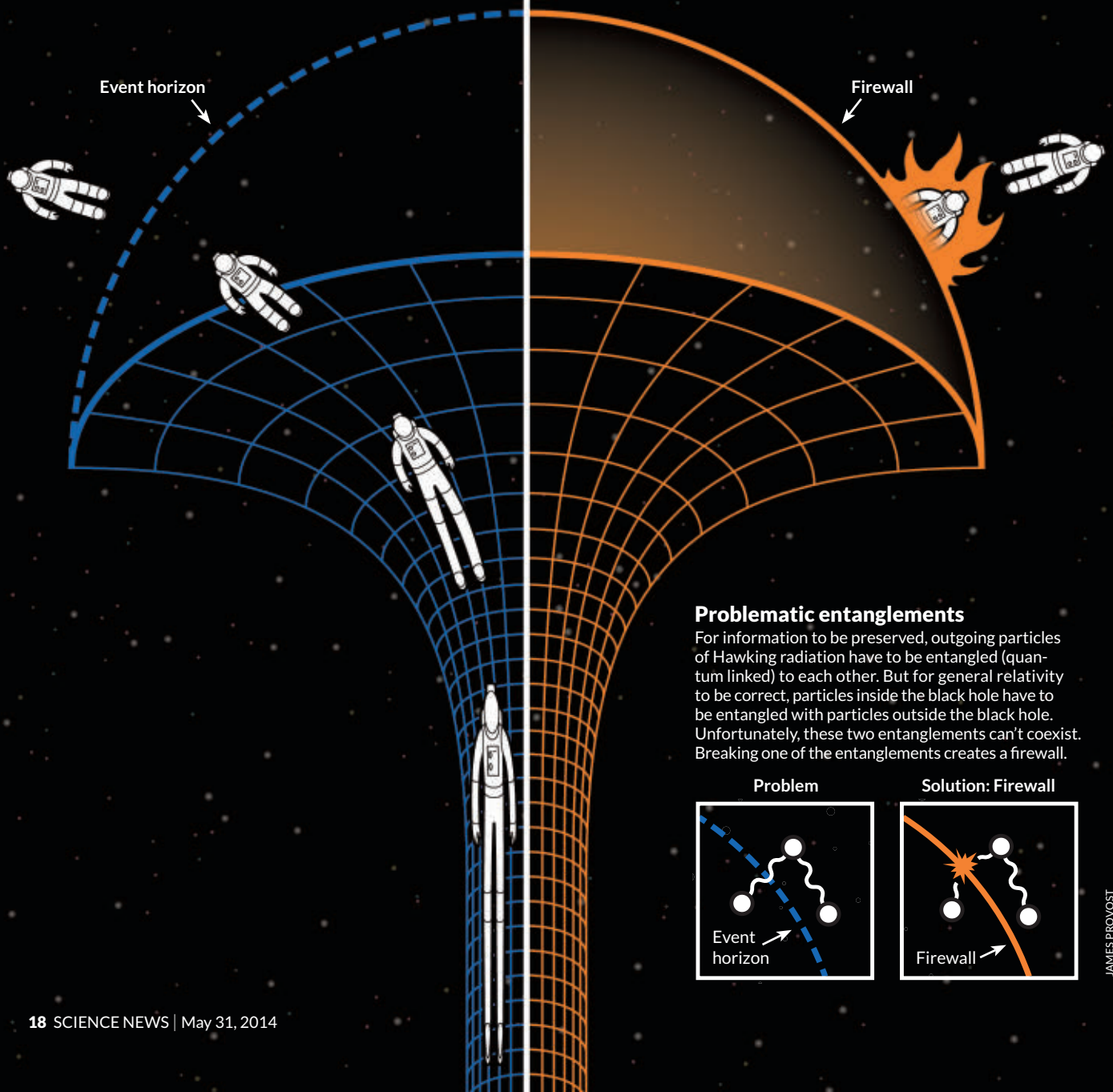
Since the 1970s, physicists have had trouble coming up with a proposal that describes the fate of something, or someone, falling into a black hole that doesn't violate well-tested theories. Until 2012, complementarity (left side of image) seemed to do the job. It said that an astronaut falling into a black hole won't notice anything special as he crosses the event horizon. Yet someone outside will never see his friend reach the horizon. Information is preserved for both observers. But complementarity breaks another rule of quantum mechanics (see "Problematic entanglements," below right). Some argue that walls of radiation along event horizons incinerate incoming matter (right side of image).

Complementarity

An astronaut falling into a black hole crosses the event horizon without incident, satisfying a prediction of general relativity. The astronaut continues floating along until, approaching the black hole's center, he is spaghettified.

Firewall

A wall of radiation incinerates the unlucky astronaut and blocks entry into the black hole. Information is preserved in this scenario (you can theoretically piece together the astronaut from his ashes), but general relativity is violated.



Problematic entanglements

For information to be preserved, outgoing particles of Hawking radiation have to be entangled (quantum linked) to each other. But for general relativity to be correct, particles inside the black hole have to be entangled with particles outside the black hole. Unfortunately, these two entanglements can't coexist. Breaking one of the entanglements creates a firewall.

JAMES PROVOST

outside a black hole cannot also be entangled with particles inside the black hole. Physicists call this forbidden arrangement entanglement polygamy.

To remedy this violation of quantum theory, Polchinski's team took its thought experiment a step further and tried severing the entanglement spanning the event horizon. The result: An impenetrable wall of energy formed at the event horizon, incinerating and shutting out any object big or small that tried to pass. They called this unforgiving boundary a firewall.

Unfortunately, while the firewall would play by the rules of quantum mechanics, it would violate Einstein's theory of general relativity. According to Einstein, an astronaut should not notice anything unusual as he crosses the event horizon; in fact, he shouldn't even know he's crossed it until later, when he begins getting spaghettified, or stretched like a noodle, from the extreme gravity of the black hole's interior and realizes that even a light-speed escape attempt would do no good. A firewall, on the other hand, would provide a pretty noticeable hint that the astronaut had reached the event horizon: He would fry instantly. If firewalls exist, then general relativity requires tweaking.

> "The event horizon is where gravity... rips off the Clark Kent business suit and starts to become as strong as the other forces."
>
> SHEPERD DOELEMAN

This firewall problem once again pits general relativity against quantum mechanics, and it has sparked new interest in thinking about the strange physics taking place at the event horizon. "I don't even see a good framework of an idea to solve the problem," Polchinski says.

Astronomical stakes

These thought experiments may seem academic, but the implications go well beyond the fates of a handful of particles. Event horizons seem to be the best theoretical test bed for combining general relativity and quantum mechanics into a unified theory of quantum gravity. "The last frontier for fundamental physics is quantum gravity," says Janna Levin, an astrophysicist at Columbia University's Barnard College. "And this one puzzle is offering us a chance to see the key elements."

Physicists have had trouble developing a theory of quantum gravity because compared with the universe's other three forces — strong, weak and electromagnetism — gravity is pathetically feeble. It's the only force that is negligible at the small scales dominated by quantum physics.

The quest for a theory of quantum gravity gained added significance after the recent discovery of ripples in spacetime dating back to a mere 10^{-36} seconds after the birth of the universe (*SN: 4/5/14, p. 6*). Understanding the universe so soon after the Big Bang is an amazing achievement, but a lot of interesting stuff happened in that trillionth of a trillionth of a trillionth of a second before those ripples cascaded through the infant cosmos.

If physicists are ever going to reach all the way back to the very beginning of the universe, Levin says, they will have to understand how the universe behaved when it was incredibly small and incredibly massive simultaneously. The best way to figure that out is to formulate a theory of quantum gravity by demystifying another such compact, massive environment: a black hole. "The event horizon is where gravity starts to come into its own," says Sheperd Doeleman, an astronomer at MIT's Haystack Observatory. "It rips off the Clark Kent business suit and starts to become as strong as the other forces."

With so much at stake, many prominent physicists are stepping up and throwing some intriguing ideas into the mix.

The all-star roster includes Hawking. In a brief, cryptic January posting to the physics preprint server arXiv.org, he suggested that event horizons are not the points of no return proposed by Schwarzschild nearly a century ago. If event horizons occasionally allow stuff inside the black hole to escape, Hawking argued, then firewalls need not exist. While Hawking's comments grabbed headlines — it didn't hurt that his write-up included the misleading phrase "there are no black holes" — nobody is quite sure what the black hole savant has in mind. "People want to know what Hawking thinks," says Sabine Hossenfelder, a cosmologist at the Nordic Institute for Theoretical Physics in Stockholm. "But practically, his paper has no use for me." She wants Hawking to release a comprehensive paper explaining his argument and the reasoning behind it.

Patrick Hayden, a Stanford quantum physicist, has an idea similar to complementarity. He agrees with the arguments laid out by Polchinski's team but suggests that it would be extremely difficult for a single observer to determine that a particle is engaged in entanglement polygamy. In fact, he says it would take a person so long to experimentally verify it that the black hole would have already evaporated. Once again, it may turn out that a black hole information paradox is allowed

Evolution of black hole theories

Black holes have given physicists headaches since Stephen Hawking proposed his eponymous radiation. A time line of proposals to prevent black holes from destroying information:

1916
Einstein's general theory of relativity lays a framework for existence of black holes, with massive gravity. Information stays safely locked inside.

1974-1976
Hawking shows that black holes evaporate over time. That means information inside disappears. Physicists are baffled.

Late 1990s
Complementarity, proposed by physicist Leonard Susskind, temporarily solves the problem of information loss.

2004
Hawking accepts Susskind and Juan Maldacena's assertion that black holes preserve information. General relativity and quantum mechanics are safe.

2012
Polchinski *et al* say complementarity violates rules of quantum entanglement. Implication: a wall of fire at the event horizon.

2014
Solutions put forth include fuzzy event horizons, a new take on complementarity and wormholes.

to exist for the simple reason that no one could ever detect it.

The most potentially paradigm-shifting idea comes from the dogged duo of Susskind and Maldacena. They address the firewall problem by combining entanglement, a mind-bending facet of quantum mechanics, with the sci-fi–sounding concept of wormholes. Wormholes are shortcuts through spacetime, the rough equivalent of crossing a mountain via tunnel rather than climbing over it. According to Susskind and Maldacena, every pair of entangled particles is connected by a wormhole, drastically shortening the distance between them.

Applying this to event horizons, they say that individual particles of Hawking radiation are linked via wormhole to the inside of the black hole. The proposal eliminates the need for firewalls by turning entanglement into a shortcut through spacetime rather than a mysterious long-distance link. In essence, the particles inside and outside the event horizon become one and the same.

Susskind and Maldacena's proposal, while pretty wild, is stirring cautious optimism. "As physicists, we often rely on our sense of smell in judging scientific ideas," Caltech theoretical physicist John Preskill wrote on his blog *Quantum Frontiers*. "At first whiff, [the wormhole proposal] may smell fresh and sweet, but it will have to ripen on the shelf for a while." If Susskind and Maldacena are right, it would mean that quantum mechanics determines not only the behavior of particles at very small scales but also the large-scale structure of the universe. "Entanglement creates the hooks that hold space together," Susskind says.

And in Susskind's mind, that's the beauty of the event horizon. A firewall proposal that he's sure is wrong but can't yet explain why may be the ticket to unraveling the great mysteries of the universe. Perhaps complementarity, wormholes or a mystery mechanism up Stephen Hawking's sleeve will simultaneously rectify the black hole information paradox and deliver a theory of quantum gravity. "Once in a while, a conflict comes along and completely changes the way we think about things," Susskind says. "This firewall story may be one of them."■

Explore more

■ J. Preskill. "Entanglement = Wormholes." http://bit.ly/SNentanglement

Picture perfect

With all the talk about hypothetical astronauts and entangled particles, it's easy to forget that black holes are actual objects in the universe. It may be up for debate whether matter falling in gets stretched or burned, but there's no doubt that throughout the cosmos incalculable amounts of gas and dust are flowing across the event horizons of black holes.

Astronomers know this because, despite the fact that no light can escape the event horizon, many black holes are fairly easy to detect. As the supergravity of a black hole reels in gas and dust, a traffic jam emerges near the event horizon. As matter bumps into other matter, it heats up and glows, emitting X-rays and other high-energy radiation. "Black holes are sitting in a luminous soup of billion-degree gas," MIT's Sheperd Doeleman says. Sometimes all that searing gas rockets away from the black hole in concentrated jets that can course more than a million light-years.

High-energy jets emanate from the central black hole of Centaurus A, a galaxy 12 million light years away.

Astronomers aren't sure why some galaxies' black holes are voracious eaters, glowing brightly, while others seem dark and inactive, Doeleman says. The Milky Way's central black hole, which weighs about 4 million times the mass of the sun, is relatively dormant. Astronomers are holding out hope that they'll get to see the local black hole light up over the next year as a large gas cloud called G2 swings perilously close to its event horizon (*SN: 8/24/13, p. 9*).

Doeleman has even greater ambitions. He leads a team that plans to directly image the event horizon of the Milky Way's central black hole. That's pretty hard to do: In fact, it requires a telescope the size of Earth.

So next year, Doeleman and his colleagues will unveil what amounts to an Earth-sized telescope.

The Event Horizon Telescope, the first instrument designed specifically for spying the structure of a black hole, combines multiple radio telescopes to achieve a resolution equivalent to that of a single one that is much larger (*SN: 10/9/10, p. 22*). This year, Doeleman is heading to the Atacama Large Millimeter/submillimeter Array in Chile, the world's most powerful radio telescope network, to install extraordinarily precise atomic clocks that will allow researchers to combine the Chilean telescopes' data with those from observatories in Hawaii, Spain and eventually the South Pole.

If all goes well, as early as next year a virtual telescope with the sensitivity of an Earth-sized radio dish will deliver images of a bright ring of hot gas surrounding a circular shadow: the heart of a black hole, bounded by the event horizon. "We've been working on this for a decade," Doeleman says. "It's exhilarating to be so close."

Theorists aren't as excited about the massive scope. After all, an Earth-sized telescope can't zoom in on a single particle and resolve the information paradox. But perhaps a photograph will provide some inspiration. For the first time they'll be able to take a good look at the mysterious boundary that has perplexed them for so long. — *Andrew Grant*

ESO/WFI (VISIBLE); MPIFR/ESO/APEX/A.WEISS *ET AL.* (MICROWAVE); NASA/CXC/CFA/R.KRAFT *ET AL.* (X-RAY)

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BIG BABIES

High birthweight might signal health risks later in life

By Nathan Seppa

We all come into this world with sealed orders, said 19th century philosopher Søren Kierkegaard. Although the great Dane lived at a time when much of science was still gauzy and life events were often ascribed to fate, the notion seems to hold true today. A quick scan of newborn babies snoozing in a maternity ward offers little hint of what their futures hold.

But medical researchers are now unsealing these orders by seizing on a simple clue — a newborn's weight. Having established that being too small at birth carries health risks down the road, researchers are also finding that high birthweight comes with baggage.

A stream of evidence has upended the long-held assumption that a big baby is a healthy baby. Newborns pushing 9 pounds face an increased risk of obesity, diabetes, heart disease, cancer and even neurological problems over a lifetime. They are more likely to run afoul of these conditions than are babies born in the "sweet spot" — not too big and not too small.

That much is clear, but details of how the tipped scales lead to later disease are still being sorted out. "High birthweight, in a way, is a proxy for a whole bunch of things going on," says David Hill, a physiologist at the Lawson Health Research Institute in London, Ontario. "It's like a lighthouse. You can see the light, but where are the rocks?"

Scientists suspect that high birthweight is a marker for unwanted fetal programming. Studies in animals suggest that too much nutrition triggers a collage of changes in a fetus' gene activation, organ function and production of insulin and other hormones. In a human pregnancy, these changes conspire to make a newborn too large for its own good.

The surge of big babies being born in the decades following World War II has leveled off, but about 8 percent of babies born in the United States are still too big. The external forces driving these births are apparent. In the past half-century, the West has embraced a more sedentary lifestyle and a diet larded with packaged and fast foods. Today, nearly 50 percent of U.S. women enter pregnancy either overweight or obese. And a woman who is heavy before pregnancy, who gains too much during those nine months or who has diabetes is substantially more likely to have a big baby than a nondiabetic woman who maintains a healthy weight during gestation.

The good news is that some of the problem is preventable, ideally through good prepregnancy health, controlled weight gain and exercise. But that's easier said than done. Many women still consider a big baby a sign of good health even as doctors are becoming more attuned to the risks of high birthweight.

High-birthweight newborns, such as this 4-day-old 19-pound baby (center) born to a diabetic mother, face health risks into adulthood.

ANDI ANSHARI/AP PHOTO

Are the days of eating for two gone? "I certainly hope they are," says Emily Oken, a physician at Harvard Medical School who works on women's health issues. In many cases, she says, "we think they should be eating for 1.1."

Metabolic mishaps

High birthweight is an informal classification that starts at 4 kilograms (8.8 pounds) for Western newborns, black or white, and, some suggest, 3.5 kilograms (7.7 pounds) for Asian babies. This doesn't include big babies who are born to naturally big people. Doctors call these babies "constitutionally large," says obstetrician Michael Ross of the UCLA School of Medicine. These infants are likely to be big-boned and long with plenty of muscle, he says. The high-birthweight babies to worry about are normal-sized newborns who carry extra fat mass, he says.

Of course, all women should gain some weight while pregnant. The Institute of Medicine, an advisory panel to the U.S. government, set down hard-and-fast ranges in 2009. Exceeding those ranges or carrying extra weight can distort mother-to-fetus communication.

"Fetus and mother are talking to each other through the placenta," says endocrinologist David Phillips of the University of Southampton in England. Nutrients such as glucose, fats, protein components and a few hormones pass from mom to fetus. "The mother is giving clues to the fetus, which responds accordingly."

This nutritional message includes lots of glucose, because all pregnant women experience some insulin resistance in the last two trimesters. Their cells resist insulin's effects and become less efficient at processing glucose for energy, leaving more of it available to the fetus, says Patrick Catalano, an obstetrician at Case Western Reserve University and MetroHealth Medical Center in Cleveland.

But for some women, this process goes into overdrive. If a woman is obese or diabetic during pregnancy, extra glucose passes through the placenta and the baby gets too much fuel, says Catalano, who served on the IOM panel. The same occurs if the mom has gestational diabetes, a temporary kind of diabetes that strikes only in pregnancy.

Inflammation may also boost this insulin resistance, says Fernando Guerrero-Romero, an internist and research scientist at the Mexican Social Security Institute in Durango. In obese women, fatty tissues act as a source of immune proteins called cytokines, which are chronic inflammation signalers. Inflammation exacerbates insulin resistance in a pregnant woman, he says. Insulin and some cytokines are too big to cross the placenta barrier, but excess glucose does, leading to an overfed fetus.

Ideal weight gain In 2009, the Institute of Medicine updated guidelines for weight gain during pregnancy, based on body mass index. The guidelines call for ample weight gain in thin or normal-sized women and less in heavier women.

Body type	Prepregnancy BMI (kg/m^2)	Recommended weight gain (lbs)	Recommended weight gain (lbs/wk)*
Underweight	<18.5	28–40	1 (1–1.3)
Normal weight	18.5–24.9	25–35	1 (0.8–1)
Overweight	25.0–29.9	15–25	0.6 (0.5–0.7)
Obese	≥30.0	11–20	0.5 (0.4–0.6)

*Mean (range) for 2nd and 3rd trimester

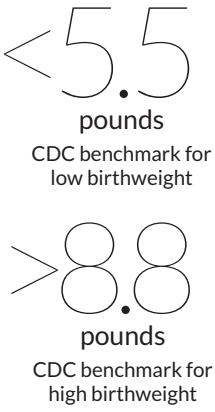
SOURCE: INSTITUTE OF MEDICINE

Women who are already obese before pregnancy tend to deliver a nutritional mix that is high in fats, Ross says. In women who gain excess weight during gestation, it's likely to be excess glucose. "With a diabetic mother," he says, "it's a little bit of everything." Those extra nutrients sent through the placenta trip hidden switches in the offspring that can lead to higher rates of obesity much later. Some combination of this poor nutrient mix "results in offspring with increased appetite and increased predisposition to fat deposition," Ross says. "They are just driven to store fat rather than break it down."

It's difficult to investigate how those changes happen in human fetuses, since invasive tests are out of the question. It's also tricky to try to assign pregnant women to experimental diets. But studies in animals shed light on the impact of excess nutrition in utero.

Some show that a faulty nutritional mix can cause DNA modifications, known as epigenetic changes, that modify genes and cells, sometimes for the long term, Ross says. Being awash in glucose, for example, might alter stem cells in a fetus as they change from nascent cells to cells with a more clearly defined role. In animals, stem cells with the blueprints to develop into the brain's neurons, for example, can be altered at key points, steering a neuron away from being one that induces satiety into one that provokes appetite.

Changes in the hypothalamus of the brain during late pregnancy are involved "in the programming of appetite and metabolism toward establishing an elevated body weight set point," Paul Taylor and Lucilla Poston of Kings College London suggested in *Experimental Physiology* in 2007.



25
percent
Fraction of U.S. women who enter pregnancy overweight

23
percent
Fraction of U.S. women who enter pregnancy obese

18
percent
Fraction of pregnant women worldwide with gestational diabetes

Regardless of how overfeeding in utero causes problems into adulthood, the consequences are becoming clear.

In adults ages 24 to 45 in Finland who were part of a health study, those born big were twice as likely to become obese as those of average birthweight, scientists report in *Arteriosclerosis, Thrombosis and Vascular Biology* in May. Another study shows that being born heavy, even without an obese mom, increases an adolescent's risk of obesity by 46 percent — implicating weight gain in pregnancy.

Birthweight is also tied to diabetes risk. Researchers at the University of Leipzig in Germany found in an analysis of 1,117 children with diabetes that these children had birthweights that were strikingly higher or lower than those of about 54,000 kids without diabetes.

Too much glucose

The finding suggests that access to too much or too little glucose in utero contributes to type 1 diabetes. What's more, women who were born big are roughly twice as likely to develop gestational diabetes during pregnancy as women who weren't, a Swedish team found in 2012.

The result of overnutrition in utero is measurable almost immediately. When scientists at the University of Chile in Santiago examined 84 infant girls, they found that high-birthweight girls had lower levels of adiponectin in the blood than those with average birthweights. This hormone helps to regulate glucose levels and break down fats. Low adiponectin is linked with insulin resistance in animals and people.

In Mexico, scientists examined 107 newborns and found that the 22 who were large, averaging about 9 pounds, were more apt to have higher blood levels of insulin, a sign of high blood glucose and insulin resistance, than average-weight babies, says Guerrero-Romero, who reported the findings in 2012 in *BMC Pediatrics*.

Brain puzzles

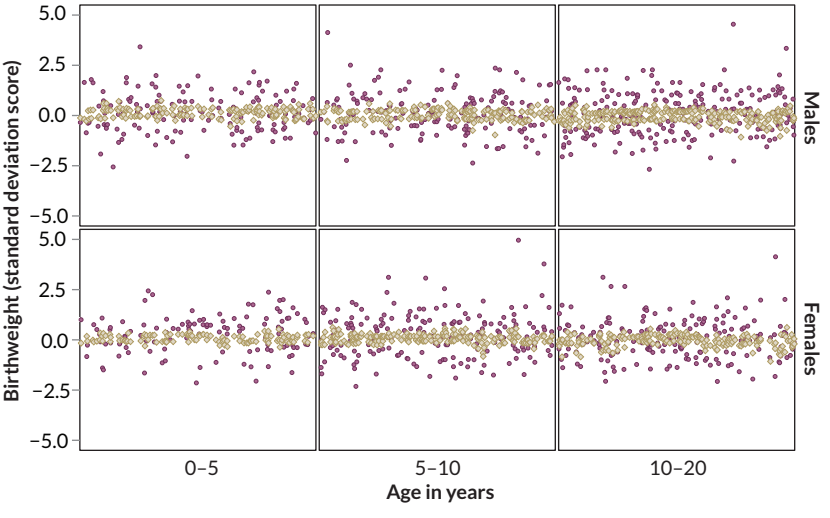
The impact of high birthweight goes beyond metabolic problems to include neurological predispositions that might be long-lasting. Tests in animals have shown that an adverse prenatal environment, whether due to overnutrition, undernutrition or other events such as psychological stress in the mother, can affect how the brain develops.

Phillips in the U.K. teamed with researchers in Finland in 2007 and found that adults who were born at either high or low birthweight had lower cortisol production during stress tests than normal-birthweight people. Cortisol is a powerful hormone with both beneficial and deleterious effects. Out-of-balance cortisol levels could be a sign of poor fetal programming, Phillips says.

He and his colleagues also tested elderly Britons for stress reactivity. In a 2013 study, they gave hundreds of people a standard stress test, asking how they would react in uncertain social situations. Answers to the questions can reveal how a person is hardwired to react to stress, with choices such as "I generally stay cool" or "I often feel warm." After accounting for other stressors in the volunteers' lives — recent and past — the researchers found that both low- and high-birthweight people reacted more strongly to stress in old age than those born within the normal weight range.

The ramifications of high birthweight might

Stacked deck
This chart shows birthweights of children and adolescents in relation to their diabetes status. The zero horizontal line marks a healthy birthweight, which is where nondiabetic children clustered. Kids who developed diabetes were more likely to have been born big or small.
SOURCE: V. KUCHLBAUER *ET AL/PEDIATRIC DIABETES* 2013



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stretch beyond stress to schizophrenia. In another Finnish study, people born at high-birthweight were 68 percent more apt to be diagnosed with schizophrenia than others their age, according to the 2011 report in *Psychiatry Research*. The authors suggest that a difficult delivery might play a role, but they also note that gestational diabetes could have been a contributing factor.

Cancer and heart disease

Scientists have known about a link between high birthweight and childhood leukemia since the 1960s. Other malignancies now tied to high birthweight include brain, colon, breast and prostate cancers in adulthood.

Less clear is the biology underpinning it all; insulin may play a role here as well. Twenty years ago Belgian researchers assessed fetal levels of an insulin building block called C-peptide and two growth factors called IGF-1 and IGF-2. Tests of umbilical cord blood from newborns showed some excess IGF-1 and C-peptide and very high levels of IGF-2 in high-birthweight babies. That report appeared in the *American Journal of Obstetrics and Gynecology*.

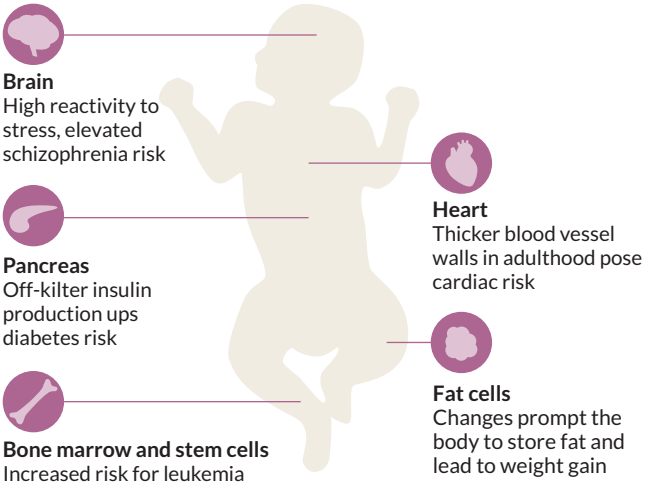
In lab animals, increased IGF-1 hikes colon cancer risk. Meanwhile, high insulin levels in the blood show up in cancer patients, and insulin itself seems able to promote tumor growth.

High birthweight might also contribute to cancer risk by adding to an individual's "stem cell burden." Because stem cells are self-renewing and long-living, the stem-cell burden hypothesis holds, having greater numbers of stem cells would increase the odds of cancerous changes arising at some point. Cristina Capittini and her colleagues at the IRCCS Policlinico San Matteo Foundation in Pavia, Italy, looked at stored umbilical cord blood samples from 1,037 full-term infants and tallied the population of stem cells, identifiable by the protein CD34. Writing in *Maturitas* in 2011, they reported that heavier babies had substantially more stem cells than average-weight or low-weight newborns.

But in some ways the cancer link to high birthweight appears to be an effect in search of a cause. "Birthweight is a marker for something," cancer epidemiologist Julie Ross of the University of Minnesota Medical School in Minneapolis asserted in a 2012 editorial in *Pediatric Blood Cancers*. She suspects IGFs getting activated in fetuses, and possibly altered levels of adiponectin and other hormones, account for some of it.

Although the cancer danger is real, the overall risk is low. The added risk of childhood leukemia resulting from high birthweight is around 25 percent, Julie Ross notes. Since the risk of developing childhood leukemia is minuscule, she calculates that high birthweight probably accounts for an extra 8 cases per million people per year.

Risk factors High birthweight can be a sign of altered fetal programming that can sabotage health later in several ways:



Heart disease is a lot more common than leukemia, and it might also get a leg up in utero. Heavy newborns grow up to have slightly thicker carotid artery walls, a risk factor for cardiovascular disease, than those with a normal birthweight, Michael Skilton, a vascular physiologist at the University of Sydney, and colleagues in Finland report in May in *Arteriosclerosis, Thrombosis and Vascular Biology*. Regardless of whether the adults were normal weight or overweight, if they were born big they were more likely to have more vessel thickening than if they weren't.

Fast-forward

Having large babies has little precedence in humans, says Michael Ross, because delivering them safely was harder before the advent of modern medicine. "Looking back over evolution, if you had too large a baby, you and your baby died."

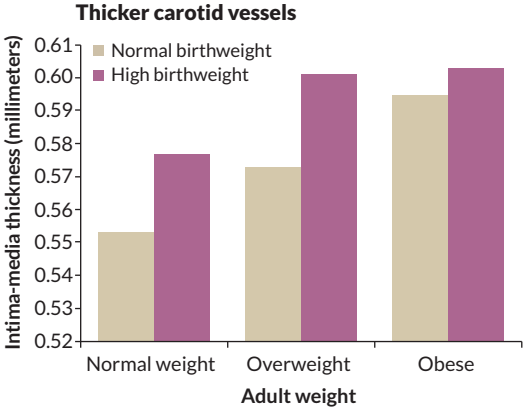
The problem for thousands of years was more likely too little nutrition, not too much. That may be why the impact of obesity and high birthweight shows up glaringly in cultures that historically faced food shortages but have recently run headlong into a Western diet and lifestyle. Ontario's David Hill points to studies of native peoples in the Canadian north who have seen obesity levels soar in a generation or two.

"You hear accounts of the day the satellite

E. OTWELL

Heart nemesis
Adults who were born at high birthweight have thicker carotid vessel walls, regardless of their current weight. A thicker intima-media, the innermost two layers of the vessel, is a warning sign for heart disease.

SOURCE: M.R. SKILTON *ET AL/ ARTERIOSCLEROSIS, THROMBOSIS, AND VASCULAR BIOLOGY*



dish came to town," Hill says. "Before that, kids ran about and played, then went home tired and slept." Now, adults and children alike watch television and consume foods that are often less healthy than what they had before. This lifestyle change is coinciding with higher birthweights in Cree Indian babies in Northern Canada, who are naturally big. A survey published in the January/February 2011 *American Journal of Human Biology* found that nearly 37 percent of Cree Indian newborns were high birthweight, higher than the 30 percent rate found in 1969.

A generational effect shows up in Cree girls. Those born at high birthweight in recent decades have been more likely to grow up obese and remain that way during their pregnancies, Hill says. They are more apt to develop gestational diabetes when they get pregnant and more likely to pass metabolic risks to their offspring.

Studies of the Pima Indians in Arizona show a similar trend. In the past, they led a spartan life with long stretches of scant food, Catalano says. The people who survived passed on their "thrifty genes," he says, which store fat efficiently for hard times — but can be detrimental in a modern world of abundance.

"It's a vicious cycle," says Guerrero-Romero. When he and his colleagues did their study in Mexico testing infants' umbilical cord blood, they had to enroll 800 pregnant women to find 150 who were normal weight. "Obesity is a problem in Mexico," he says, "and I don't think there is a simple answer to the problem of high birthweight."

What's a mother to do?

High birthweight would seem an implacable foe, "sealed orders" that can't be rescinded. But moms-to-be have some degree of control over their children's fate. Michael Ross suggests that women lose weight in anticipation of pregnancy. But he acknowledges that roughly half of the pregnancies in the United States are unplanned, and prepregnancy counseling is uncommon.

That leaves controlling weight gain during gestation and exercising. When 47 pregnant women were randomly assigned to spend up to 40 minutes a day on a stationary bicycle as part of a trial in New Zealand, the children born to the cycling women were slightly smaller (but not underweight) than babies born to 37 pregnant women not given a stationary bike. The babies of the exercising mothers also scored better on tests of IGF-1 and IGF-2 than the other babies, according to the 2010 report in the *Journal of Clinical Endocrinology & Metabolism*.

To protect offspring from arterial thickening that can lead to heart disease, Skilton suggests that pregnant women control their cholesterol as much as possible, ideally by diet rather than with medication. For very obese women, prepregnancy bariatric surgery can lead to weight loss, lower blood glucose and even an end to type 2 diabetes (*SN: 9/10/11, p. 26*). While drastic, such an approach has been shown to benefit offspring. A U.S.-Canadian team compared the school-age weights of children born to 113 obese women who had undergone bariatric surgery. The women had a total of 45 children before surgery and 172 after the operations. The kids born post-surgery were half as likely to be obese during their school years as the others, the researchers reported in *Pediatrics* in 2006.

"The majority of women are very receptive to the idea that they are responsible for the future health of their babies," Hill says. But some don't understand the risks. A 2013 report from Australia found that women had poor knowledge of the risks of being overweight in pregnancy. In a survey of pregnant women delivering at MetroHealth in Cleveland, Catalano found that at least half of overweight and obese women were gaining more than the IOM recommended amounts.

Education can help break this cycle, Hill says. "You can set a whole generation on a good trajectory." Intervention before and during pregnancy would help, he says, "but how effective you will be probably depends on how early you start." ■

Explore more:

■ S.A. Hopkins *et al.* "Exercise training in pregnancy reduces offspring size without changes in maternal insulin sensitivity." *Journal of Clinical Endocrinology & Metabolism*. May 2010.

E. OTWELL

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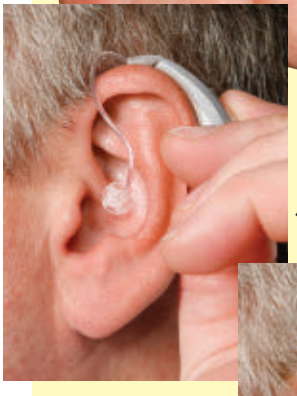

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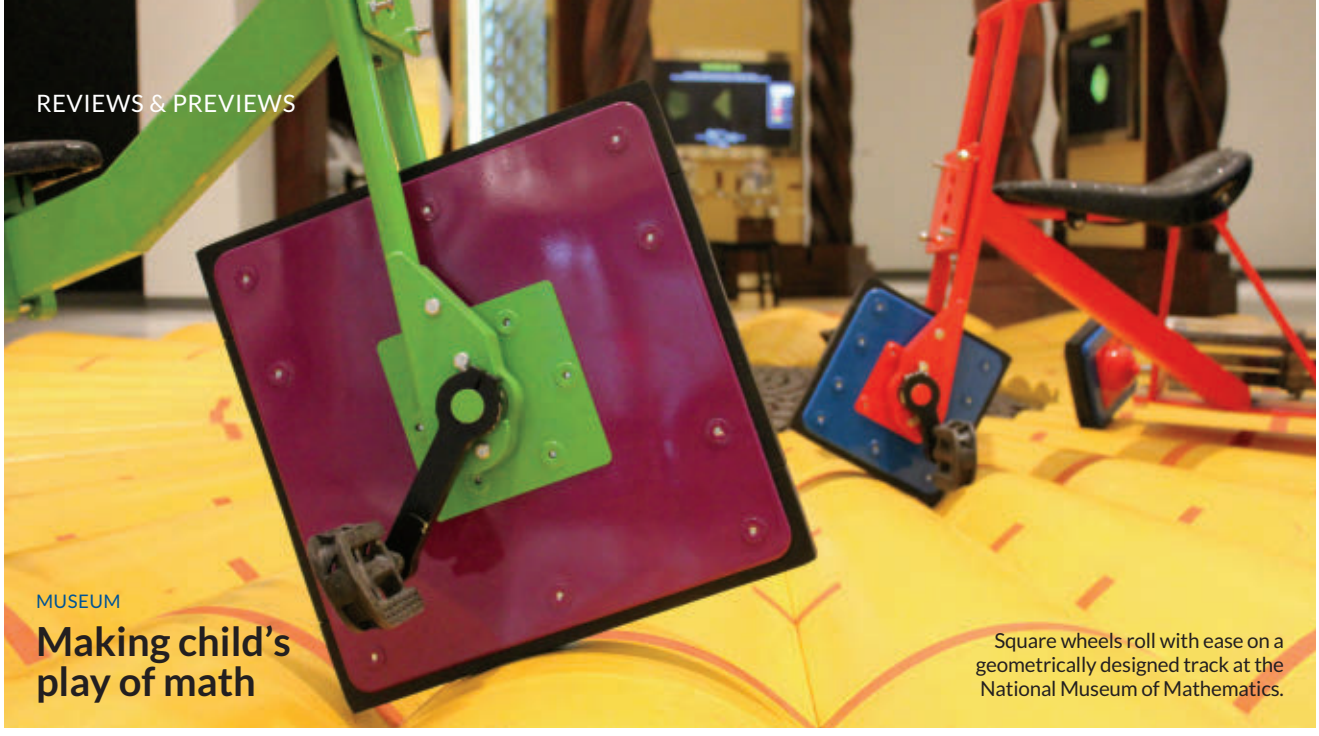


MUSEUM

Making child's play of math

Square wheels roll with ease on a geometrically designed track at the National Museum of Mathematics.

Few equations confront a visitor to the National Museum of Mathematics on Manhattan's East 26th Street. Instead, museumgoers find children — and adults — riding the Coaster Roller (below), a small platform that offers a surprisingly smooth ride over acorn-shaped balls. (The trick lies in the objects' diameter, which is the same in every direction.)

This physical, tactile, even rambunctious presentation of math is intentional, says museum cofounder Glen Whitney. Too many people think math is "boring, useless, too hard, irrelevant, stifling, something that people don't use," says Whitney, a former math professor and hedge fund analyst. He wants to show people "the breadth and the beauty and the creativity that are inherent in mathematics."

The museum, also known as MoMath, seems to be succeeding. School groups come through in waves. Preteen boys execute *Dance Dance Revolution*–style moves on a lighted grid where ever-shifting lines display the shortest path connecting everyone on the floor. High school students compete to see how many magnetic monkey shapes they can tessellate, or link together. At the Enigma Café no coffee is served, but plenty of geometrical games are; players are encouraged to sit and solve together.

> "We hope that by inspiring, we inspire education."
>
> CINDY LAWRENCE

Opened in late 2012, MoMath is a high-tech, high-concept playground. It is also the only math museum in the United States, where students' poor performance on international tests has inspired much hand-wringing among politicians and educators. Largely for this reason, the museum particularly targets kids in grades four through eight, a group known for finding math uncool. Still, cofounder Cindy Lawrence, a former accountant and curriculum developer, stresses that the museum's goal is not to replace classrooms.

"Do I think MoMath in and of itself is going to raise grades around country? No," Lawrence says. "We hope that by inspiring, we inspire education."

For those explicitly seeking math education, electronic screens scattered around the museum's two floors offer "More Math" lessons explaining underlying concepts such as why square-wheeled trikes require a track with bumps shaped like upside-down catenary curves. But at times the explanations can frustrate. Case in point: Each glowing orb in the exhibit "Harmony of the Spheres" plays a different chord when touched, but the text does little to illuminate how music relates to math or why certain chords sound more pleasing. "String Product," a two-story parabola meant to illustrate an early calculator, is hard to decipher. And the decision to forgo traditional signage can force visitors to alternate between interacting with an exhibit and tapping on a touch screen several feet away.

For most visitors, though, these occasional annoyances may not detract much. "I just want to make sure they're exposed to math as something fun," said one visitor, while her young sons explored a geometric proof of the Pythagorean theorem.

And lest you think math games are just for kids, another mom put that notion to rest: "I think my husband and I have more fun than they do."

— *Gabriel Popkin*

BOTH: MOMATH

For museum hours and admission, visit **http://momath.org**

BOOKSHELF

The Amoeba in the Room

Lives of the Microbes

Nicholas P. Money

Prochlorococcus is a little bacterium with a big job. Less than a micrometer in diameter, it's the most abundant photosynthetic organism on Earth, taking up carbon dioxide and releasing oxygen. If the octillion — that's a 1 followed by 27 zeros — or more *Prochlorococcus* currently adrift in the world's oceans were to disappear, writes mycologist Nicholas Money, air-breathing animals would suffocate.

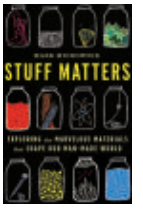
For far too long, Money argues, biology textbooks have focused on life that's visible to the naked eye. But the soil, seas and air abound with tiny living things that cycle nutrients and form the base of a food web supporting more familiar life-forms. Even the human gut teems with unseen hitchhikers. Money's book offers a glimpse into the lives of these often overlooked bacteria, fungi, amoebas and other microbes.

And what dramatic lives they lead. Money recounts brutal struggles between predator and prey, unusual methods of reproduction and seemingly unlikely alliances forged between species, all playing out under the microscope.

The cast is colorful, too, from armored amoebas to bacteria that withstand blasts of radiation more than a thousand times the dose that would kill a human. One interesting oddball is the dog lichen, a leafy-looking organism that's actually a three-way team-up between an alga, a bacterium and a fungus, all working together to ensure mutual survival.

Microbes are rarely allotted cute and easy-to-remember common names, so keeping up with the terminology in the book can be a mental workout. Money's light-hearted writing helps prevent the lingo from becoming overwhelming, though, and readers who can weather the tricky language will find a fascinating and strange new world. — *Allison Bohac*

Oxford Univ., $24.95



Stuff Matters

Mark Miodownik

From the reason glass is clear to what makes chocolate melt in your mouth, you'll find answers to all your questions about material science, plus some you've never thought of. *Houghton Mifflin Harcourt, $26*

The Soil Will Save Us

Kristin Ohlson

Rebuilding soil damaged by agriculture and urbanization can help to clean up waterways, reduce carbon emissions and lessen flooding, a journalist argues in a passionate defense of "dirt." *Rodale, $23.99*

The Extreme Life of the Sea

Stephen R. Palumbi and Anthony R. Palumbi

Marine biologist Stephen Palumbi and his son, a writer, team up to describe the fastest, deepest and other outliers of ocean life. *Princeton, $27.95*

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BOOKSHELF

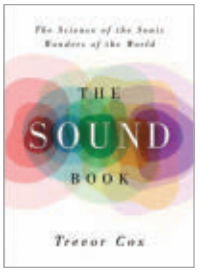
The Sound Book

The Science of the Sonic Wonders of the World

Trevor Cox

Most lists of the world's wonders include visually stunning attractions — the Grand Canyon or the pyramids of Giza, for example. Yet there's more to life than meets the eye, as acoustic engineer Trevor Cox reveals in this international tour of aural amazements.

Many of the marvels Cox describes are architectural, from domes and "whispering galleries" that reflect and focus even the tiniest murmurs to the most reverberant place in the world: a four-story-deep subterranean tank in Scotland that was built to hold strategic oil reserves during World War II. The echoes inside the tank are so strong and last so long because oil has soaked into the concrete walls, filling any pores where sound waves could infiltrate and be absorbed rather than reflected.



The author also visits natural wonders such as the singing sands of California's Kelso Dunes and the Stalacpipe Organ of Virginia's Luray Caverns, where cave formations are tapped like a huge xylophone to make musical tones. In various field experiments, Cox attempts to dispel the old wives' tale that "a duck's quack doesn't echo." (He's ultimately unsuccessful, but that's because of the sites he's chosen and not due to any supernatural characteristics of the waterfowl's vocal cords, he suggests.)

Throughout this charming book, Cox calls upon physics and the neuroscience of hearing to explain everything from how engineers successfully tweak the acoustics in concert halls to why it's so hard to hear in noisy restaurants.

From its first page to its last, *The Sound Book* invites readers to close their eyes and open their ears to the sounds, both normal and peculiar, that surround us all.

— *Sid Perkins*

Norton & Co., $26.95

APRIL 19, 2014

Lots of shots

Dose	Age
First	2 months
Second	4 months
Third	6 months
Fourth	15–18 months
Fifth	4–6 years

To keep whooping cough at bay, the Centers for Disease Control and Prevention recommends that children receive five doses of the acellular pertussis vaccine by age 6, on the schedule above. SOURCE: CDC

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Building a better vaccine

A whooping cough vaccine introduced in the 1990s has fewer side effects than its predecessor, but it may not protect against the disease as well, ***Nathan Seppa*** *reported in "Whooping cough bounces back"* (SN: 4/19/14, p. 22)*. The old vaccine used whole cells of the pertussis bacterium, while the new acellular vaccine uses only components of the disease-causing cells.*

Vaccinations are a hot-button topic, with some parents worried about possible side effects and others worried about the spread of illness from unvaccinated kids. Reader response to the whooping cough story reflected this growing unease. "Here's a novel idea: Give parents a choice of which vaccine to use," wrote **Kim Dominguez** on Facebook. "Many would choose the more effective one. Anyone who has seen someone suffer with whooping cough would choose to take the benefits of vaccination over the potential risks."

Ted Grinthal suggested a combination of both vaccines: "I wonder if we can have the best of both worlds. Would it be effective to use the acellular vaccine for the first three shots — until the child is 18 months old — and then give the old whole-cell vaccine? That way, we'd avoid the unpleasant side effects until the children and parents are more able to deal with them."

Pediatrician **Stanley Plotkin**, who helped develop the rubella vaccine, cautions that scientists don't know whether using the vaccines together would provide the needed protection. "The use of the whole-cell vaccine after the initial vaccination in the first year of life might be a good idea, but we don't know yet if that would correct the immunological defects of the acellular vaccine. And I doubt if American parents will accept the reactions, even later in life. I do not doubt that the whole-cell vaccine would be effective if enough doses were given, but I think the way forward is to improve the acellular vaccine. The acellular vaccine does protect infants when given in the first years of life; it just doesn't protect long enough."

On shaky ground

New early warning networks could provide alerts a few seconds before earthquakes hit, as ***Alexandra Witze*** *described in "Buying time"* (SN: 4/19/14, p. 16)*. These systems work by detecting the primary seismic waves, or P waves, that arrive before the more damaging secondary waves.*

Reader **David Reynolds** e-mailed the story of his frightening experience with a magnitude 9.2 earthquake, the second largest in recorded history, which led him to believe P waves could help provide early warnings. "I was at the corner of 15th Avenue and Juneau Street in Anchorage when the Good Friday quake struck in 1964. A week after the quake, I was working in an office with about 20 other people at Ft. Richardson when, without saying anything, everyone in the office suddenly jumped to their feet and started running out of the building. No noticeable shaking had started. About 15 or 20 seconds later, we had a 7.5 aftershock. Although none of us knew what we were experiencing at the time, I'm sure now that we must have been sensing the P waves."

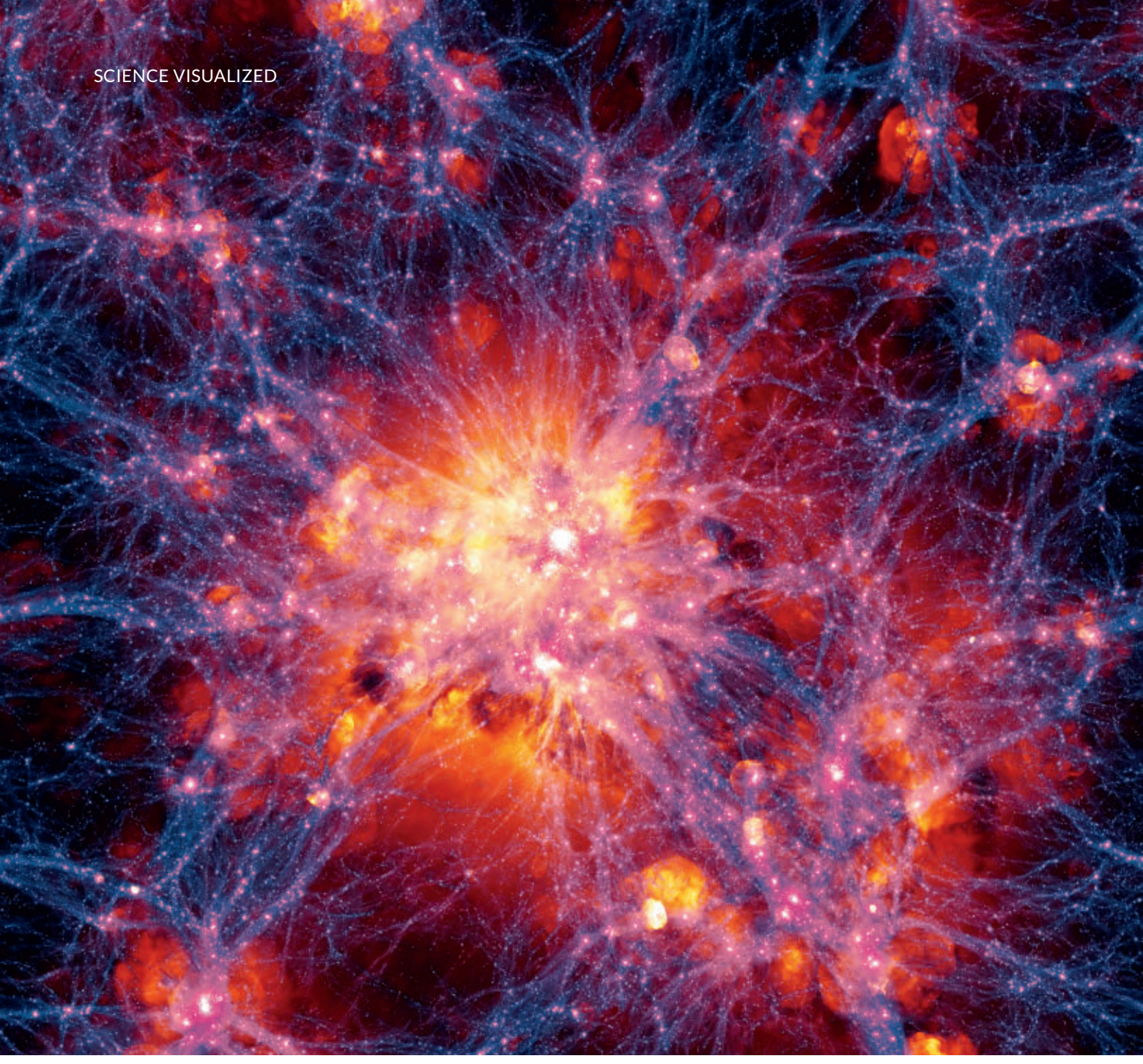
People can absolutely feel P waves, says **Witze**. "Trained seismologists in particular can detect them and they will start counting as soon as they feel them, to determine the seconds elapsed until the secondary waves arrive. This allows the researchers to calculate a rough distance to the epicenter."

The kangaroo solution

In "Kangaroo gut microbes make eco-friendly gas" (SN: 4/19/14, p. 10)*,* ***Beth Mole*** *described how bacteria called acetogens in the marsupials' guts outcompete methane-producing microbes, minimizing kangaroo's greenhouse gas emissions.*

"If cattle could tolerate a move to acetonic bacterial fermentation, we could revolutionize American beef production," **John Turner** wrote online. "Otherwise, why not cultivate red kangaroos instead? They're no less native to North America than our present beef cattle. We'd just need some serious stock fences, rather *Jurassic Park*–looking ones."

E. OTWELL



Virtual universe reconstructs over 13 billion years of history

"If you wish to make an apple pie from scratch," said Carl Sagan, "you must first invent the universe." A new simulation of the universe's evolution, called the Illustris Project, is a start. Led by Mark Vogelsberger, an astrophysicist at MIT, Illustris is the most detailed and comprehensive simulation of the universe to date and produces a cosmos that looks similar to today's. "The only way we can learn about the universe is to observe it through telescopes," Vogelsberger says. The way to test ideas about its evolution, he adds, is to build simulations. One of the simulation's insights, reported in the May 8 *Nature*, is the role that supermassive black holes must have played in shaping galaxies. As the behemoths swallow gas, they can belch out energetic gas bubbles (orange) that span hundreds of thousands of light-years. Without these eruptions, the universe would look different: Galaxies (pink, along blue filaments of dark matter) would be larger. Illustris tracks 12 billion grid cells in a cube nearly 350 million light-years on a side as the universe evolves from 12 million years after the Big Bang to the present. Running the simulation required 19 million central processing unit hours, or the equivalent of more than 2,000 years on one processor. — *Christopher Crockett*

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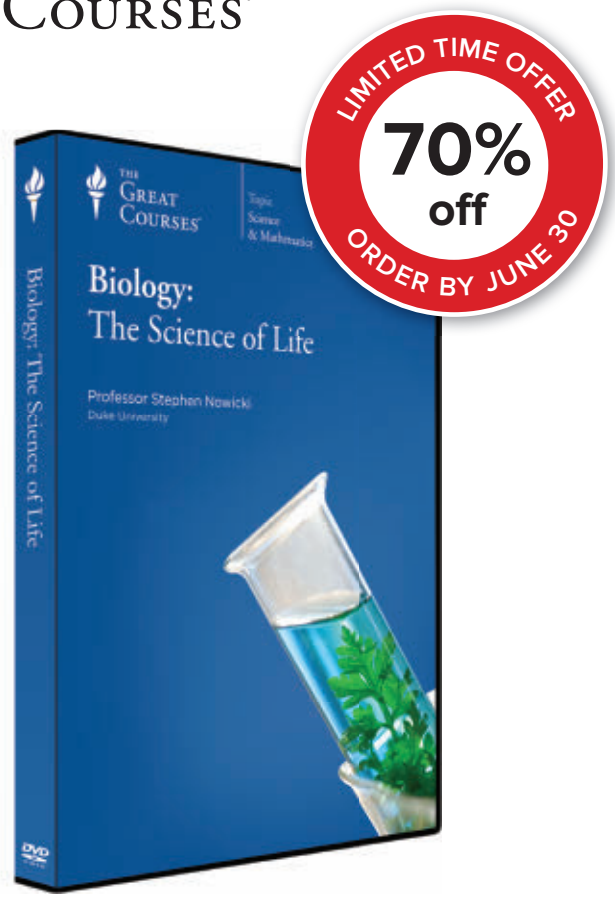

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What Stauer Clients Are Saying About Our Hybrid Watches

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"Great watch... an impressive piece straight out of the box."
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$49 Colossus Watch with FREE Sunglasses!

No More Mr. Nice Watch

*Forget sleek and subtle, the Stauer Colossus Hybrid is one tough timepiece…**now for less than $50!***

Never underestimate your competition. Just ask Demetrius, the unfortunate Greek general who set out to conquer Rhodes in 305 BC. He assumed that a massive force of 40,000 men, a fleet of Aegean pirates and an arsenal of wall-smashing war machines would be enough to crush the tiny Greek island. He was wrong. The Rhodians were tougher than he thought. And so is this watch. If you've always believed that the biggest, baddest watches had to cost big, bad money, the $49 Stauer ***Colossus Hybrid Chronograph*** is here to change your mind.

A monument to toughness. The people of Rhodes were ready for Demetrius and repelled his attack. To celebrate, they built the Colossus of Rhodes, a 107-foot bronze and iron giant that towered over the harbor like a ten-story trophy. It warned future invaders that "Rhodes is tougher than you think." You give the same message when you wear the Stauer ***Colossus***.

The timepiece that works twice as hard. The ***Colossus Hybrid Chronograph*** will keep you on schedule, but it's about much more than time. The imposing case features a rotating gunmetal bezel that frames the silver, black and yellow face. You'll find a battalion of digital displays on the dial arranged behind a pair of luminescent hands and a bold yellow second hand. Powered by a precise quartz movement, the watch is doubly accurate in analog and digital mode.

The ***Colossus*** is packed with plenty of handy extras including a bright green EL back-light for enhanced nighttime visibility, a tachymeter along the outer dial and a full complement of alarms and split-second countdown timers. It secures with a folded steel bracelet that highlights a row of striking dark center links. It's a rugged watch that's more than ready for your daily grind.

More watch for less money. Big-name watchmakers raise their prices because they can get away with it. But Stauer wants to turn luxury on its head. We sent the ***Colossus Hybrid*** to an independent appraiser who works with auction houses, luxury estate sales and insurance companies. He valued the watch at $199.* We thanked him for his professional opinion and then ignored it. Because we still want you to wear it for **ONLY $49**.

Your satisfaction is guaranteed. Wear the Stauer ***Colossus Hybrid Chronograph*** for 30 days and if you are not 100% thrilled with your purchase, return it for a full refund of your purchase price. But once you get a taste of more watch for less money, it's likely you'll be back for more... and we'll be waiting.

WATCH SPECS: -Easy-to-read analog/digital modes -Back-lighting and luminescent hands - Tachymeter, countdown timers and alarms -Folded stainless steel bracelet fits a 6 3/4"–9" wrist

Colossus Hybrid Digital/Analog Watch

Appraised at $199* — ~~$79~~

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