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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
JUNE 25, 2016

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COVER After five years of travel, Juno will soon reach Jupiter and begin its up-close investigations of the giant planet. *JPL-Caltech/NASA*

CLOCKWISE FROM TOP: JAMES GATHANY/CDC; J.T. CANTLEY (CC BY 4.0); ETIENNE FABRE/SSAC

On a mission for science, on Jupiter and on Earth

I am on a mission. I want everyone to appreciate and understand science — even those who assume (often based on the way they were taught in school) that they don't like it. Science is important, and frequently amazing. In this issue alone, you can read about the solar-powered spacecraft that, after a five-year journey, will soon arrive at Jupiter to discover what lurks beneath the planet's blanket of haze and clouds (Page 16). As NASA's Juno spacecraft settles into a cloud-skimming series of orbits around the gas giant, it will probe what makes up the planet, its origins and the nature of its core. Learn about efforts to develop vaccines for mosquito-ferried scourges, from Zika to dengue on Page 22. On Page 7, read about the latest volley in the confounding search for the cause of Alzheimer's and ancient cave circles built by Neandertals.

Luckily, I work for an organization with a mission aligned with my own. And Society for Science & the Public just got a big boost in its efforts to sow understanding and appreciation of science. On May 26, the Society announced a new sponsor of its flagship competition, the Science Talent Search. Like the science fair I wrote about in the last issue (*SN: 6/11/16, p. 2*), STS offers young scientists a national stage on which they can shine. Regeneron Pharmaceuticals Inc. of Tarrytown, N.Y., has stepped in to replace Intel, STS sponsor since 1998. (Founded by the Society in 1942, STS was originally sponsored by Westinghouse.)

Regeneron has also upped the game, pledging $100 million over 10 years and increasing the value of the scholarships and other awards to $3.1 million annually. The top student winner will now get $250,000, enough for a full-ride at many universities. "We are over the moon," Maya Ajmera, CEO and president of the Society and publisher of *Science News*, told the *Washington Post*. "Regeneron is truly helping the Society scale its work in an unprecedented way," she says.

Regeneron, founded in 1988, developed the cholesterol-fighting drug Praulent that went on sale last year and Eylea, used to treat vision diseases such as wet macular degeneration, among other products. Regeneron's chief scientific officer George Yancopoulos was a top-10 finalist in STS in 1976. Yancopoulos (a former trustee of the Society) and his fellow STS alum Leonard Schleifer, Regeneron CEO and president, now want to give back. "The Westinghouse was a game changer for me as a high school student," Yancopoulos says. "It truly set me on the path I am on today. I want to be able to grow that ability to motivate the best and the brightest to pursue careers in science."

Notably, the biotech firm will dedicate $30 million of the total to expand the Society's efforts in outreach and equity, designed to encourage more young people to engage in original research. In addition to better supporting educators using research-based approaches, the new funds will increase grants to teachers working with underserved students. It will also grow the *Science News* in High Schools program, sending the magazine to 4,000 more high schools and, I hope, inspiring students to make discoveries of their own.

We are also expanding efforts to get *Science News* to you. Look for our updated iPad app in July and, coming soon, apps for Android tablets, Kindle Fire and smartphones. — *Eva Emerson, Editor in Chief*

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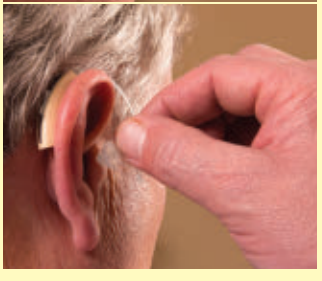

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Excerpt from the June 25, 1966 issue of *Science News*

50 YEARS AGO

Childhood fears are common, normal

Some behavior, such as nail biting, bed-wetting and fearfulness, may actually represent a temporary phase in normal development.... A most important finding [in a recent study] was that the fearful or anxious children, defined ... as those with seven or more worries, did not seem to be in any particular psychological trouble.... Anxieties may be part of normal child development.

UPDATE: Actually, there *is* reason to worry about anxious children. Kids with anxiety disorders, depression or behavioral problems are especially likely to develop a range of difficulties as young adults, say researchers who conducted a long-term study published in 2015. The same goes for kids whose anxiety, mood or behavior issues cause daily problems but don't qualify as psychiatric ailments. Problems that later dogged the study's troubled youngsters, who grew up in rural North Carolina, included drug addiction, teenage parenthood, dropping out of high school and criminal arrests.

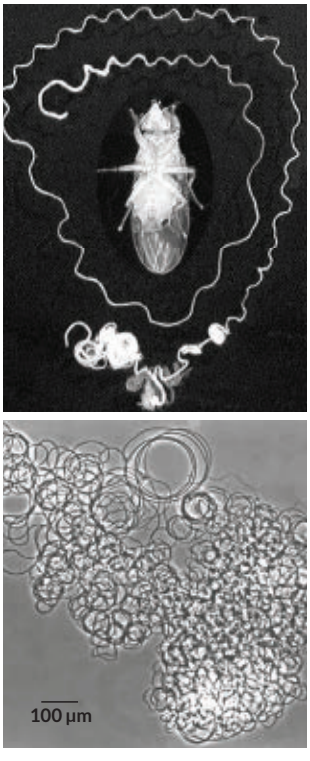
THE SCIENCE LIFE

People may wear their emotions on their breath

Researchers can tell if a movie scene is funny or suspenseful from chemicals that audiences exhale into theater air.

Spoiler alert: Scientists can gauge a film's emotional tenor from the gasps of its audience. Sure, the audible sounds are a cue, but so are the chemicals exhaled with each sigh and scream. These gases could point the way to a subtle form of human communication.

"There's an invisible concerto going on," says Jonathan Williams, an atmospheric chemist at the Max Planck Institute for Chemistry in Mainz, Germany. "You hear the music and see the pictures, but you don't realize there are chemical signals in the air."



The most oversized male sexual feature yet documented may be a fruit fly's giant sperm. A male (top), at 200 times magnification, is surrounded by a male reproductive tract. A sperm (bottom), at the same magnification, is from *Drosophila bifurca*.

THE -EST

Tiny fly, giant sperm

Forget it, peacocks. Nice try, elk. Sure, sexy feathers and antlers are showy, but the sperm of a fruit fly could be the most over-the-top, exaggerated male ornamentation of all.

In certain fruit fly species, such as *Drosophila bifurca*, males measuring just a few millimeters produce sperm with a tail as long as 5.8 centimeters, researchers write in the May 26 *Nature*. Adjusted for body size, the disproportionately supersized sperm outdoes such exuberant body parts as pheasant display feathers, deer antlers, scarab beetle horns and the forward-pointing forceps of earwigs.

Fruit flies' oversized sperm have been challenging to explain, says study coauthor Scott Pitnick of Syracuse University in New York. He and colleagues propose that a complex interplay of male and female benefits has accelerated sperm length in a runaway-train scenario.

Males with longer sperm deliver fewer sperm — just a few dozen to a few hundred per mating. (A common lab fruit fly transfers more than a thousand.) And as newly arrived sperm compete to displace those already waiting in a female's storage organ, longer is better. Fewer sperm per mating means females tend to mate more often, intensifying sperm-vs.-sperm competition. Females that have the longest storage organs, which favor the longest sperm, benefit too: Males producing greater numbers of megasperm, the researchers found, tend to be the ones with good genes likely to produce robust offspring. "Sex," says Pitnick, "is a powerful force." — *Susan Milius*

FROM TOP: ANDRESR/ISTOCKPHOTO; S. LÜPOLD *ET AL*/*NATURE* 2016

Williams started out measuring the air in a soccer stadium to see if human breath had a noticeable impact on the concentration of greenhouse gases in the atmosphere. The answer was no, at least on a small scale. But he noticed that levels of carbon dioxide and other gases fluctuated wildly whenever the crowd cheered. That got him wondering: Maybe humans' emissions are influenced by emotions. So he went to the movies.

Williams and colleagues measured air samples collected over six weeks in two movie theaters in Germany. Overall, 9,500 moviegoers watched 16 films — a mix of comedy, romance, action and horror that included *The Hunger Games: Catching Fire*, *Walking With Dinosaurs* and *Carrie*. The researchers classified scenes from the movies using such labels as "suspense," "laughter" and "crying." Then they looked for associations between movie scenes and hundreds of compounds in the air.

Certain scenes, primarily those that had people laughing or on the edge of their seats, had distinct chemical fingerprints, the researchers write May 10 in *Scientific Reports*. During screenings of *The Hunger Games: Catching Fire*, CO_2 and isoprene emissions consistently peaked at two suspenseful moments. Williams and colleagues attribute the spikes in CO_2 to increased pulse and breathing rate. The spikes in isoprene — a chemical associated with muscle action — were probably due to tense movie moments.

The researchers had to account for chemicals wafting into the air that may not have been a reaction to onscreen action. People emit chemicals from their perfume, shampoo and even the snacks they munch such as popcorn or beer. During screenings of *The Secret Life of Walter Mitty*, for instance, the researchers noticed a spike in ethanol corresponding with a scene in which Mitty orders a beer. Williams speculates that the scene reminded moviegoers to take a swig of their own alcoholic beverages.

Scientists need more data to make robust connections between human emotion and chemical emissions. But Williams sees potential practical applications. Marketers, for example, could quickly measure the air during consumer testing to see how people feel about products. He envisions future studies involving heart rate, body temperature and other physiological measurements.

"We have scratched the surface and it's made a funny smell," he says. "It's something to investigate." — *Cassie Martin*

FROM LEFT: J.T. CANTLEY (CC BY 4.0); KRISTIJAN ZONTAR/SHUTTERSTOCK

INTRODUCING

Scary tomato appears to bleed

A newly discovered species of tomato belongs in a haunted house, not on a sandwich.

Fruit from the bush tomato plant *Solanum ossicruentum* bears little resemblance to its cultivated cousins. The Australian tomato, about a couple centimeters wide, grows enclosed in a shell of spikes. These burrs probably help the fruit latch on to the fur of passing mammals, which then spread the tomato's seeds elsewhere, researchers at Bucknell University in Lewisburg, Pa., report May 3 in *PhytoKeys*.

Slice open the fearsome fruit and within five minutes, its sticky white-green flesh appears to bleed, flushing bright red to dark maroon in response to air exposure. One brave researcher tasted an unripe fruit and deemed it salty. The bush tomato becomes no more appetizing with time: Mature fruits harden into dry, bony nuggets.

The tomato's gruesome qualities inspired its name, courtesy of a group of Pennsylvanian seventh-grade science students: "Ossicruentum" combines the Latin words for "bone" and "bloody." — *Sarah Schwartz*

SCIENCE STATS

Earth is young at heart

Our planet's center is more than two years younger than its surface, according to new calculations.

In Einstein's general theory of relativity, massive objects warp the fabric of spacetime, creating a gravitational pull and slowing time nearby. So a clock placed at Earth's center will tick ever-so-slightly slower than a clock at its surface. Such time shifts are determined by the gravitational potential, a measure of the amount of work it would take to move an object from one place to another. Since climbing up from Earth's center would be a struggle against gravity, clocks down deep would run slow relative to surface timepieces.

Over the roughly 4.5 billion years of Earth's history, the gradual shaving off of fractions of a second adds up to a core that's 2.5 years younger than the planet's crust, researchers estimate in the May *European Journal of Physics*.

2.5
years
Age difference, by one estimate, between Earth's core and its surface

The new calculation neglects geologic processes, which have a larger impact on the planet's age. For example, Earth's core probably formed before the crust. Says study coauthor Ulrik Uggerhøj of Aarhus University in Denmark, the calculation serves as an illustration of gravity's influence on time — very close to home. — *Emily Conover*

GENES & CELLS

Jumping gene darkened moths

Genetics of classic example of natural selection explained

BY TINA HESMAN SAEY

Peppered moths and some copycat butterflies owe their color changes to a single gene, two new studies suggest.

A tweak in a portion of the *cortex* gene painted the speckled gray wings of peppered moths black, researchers report in the June 2 *Nature*. Genetic variants in DNA interspersed with and surrounding the *cortex* gene also helped some tasty species of *Heliconius* butterfly mimic unpalatable species, a second team of scientists reports, also in *Nature*.

In the often-told evolutionary tale, the peppered moths' color shift began as factories in Britain darkened the skies and trees with smoke during the Industrial Revolution in the 1800s. Naturalists took note as a new, all-black *carbonaria* form of peppered moths (*Biston betularia*) blended into sooty backgrounds; the light-colored *typica* moths were easily picked off by birds. By 1970, nearly 99 percent of peppered moths were black in some localities. As air pollution decreased in the late 20th century, black moths became more visible to birds. Now, *carbonaria* moths are rare.

The new research "begins to unravel exactly what the original mutation was that produced the black ... moths that were favored by natural selection" during much of the last century, says evolutionary biologist Paul Brakefield of the University of Cambridge. "It adds a new and exciting element to the story."

The molecular details behind the wing pattern changes have eluded scientists for decades. In 2011, researchers tracked the traits to a region of a chromosome that the moths and butterflies share (*SN: 9/24/11, p. 16*; *SN: 5/7/11, p. 11*). Which of the many genes in that region might be responsible remained a mystery.

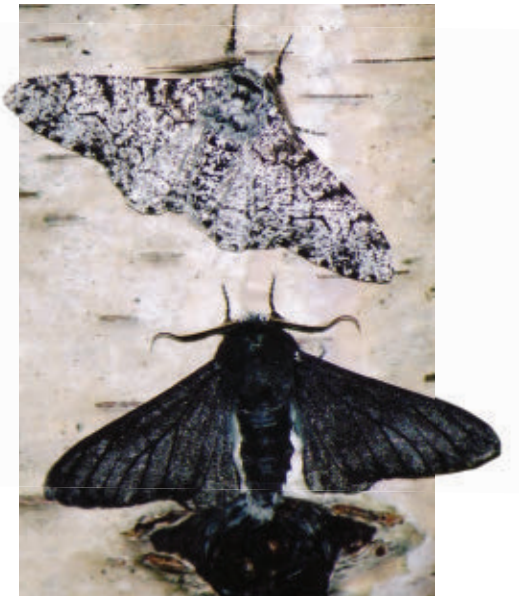
In peppered moths, the region of interest stretches over about 400,000 DNA bases and contains 13 genes and two microRNAs. "There aren't really any genes that scream out to you, 'I'm involved in wing patterning,'" says evolutionary geneticist Ilik Saccheri of the University of Liverpool in England.

Saccheri and colleagues compared that region in one black moth and three typical moths. The black moth differed from the light-colored moths in 87 places. Most of the differences were changes in just one or a few DNA bases — the information-carrying chemicals in DNA. One difference was the insertion of a 21,925-base-long stretch of DNA into the region. This big chunk contained multiple copies of a transposable element, or jumping gene. Transposable elements are viruslike pieces of DNA that copy and insert themselves into a host's DNA.

By examining the DNA of hundreds more *typica* moths and ruling out mutations one by one, the team ended up with one candidate: the large transposable element, which had landed in the *cortex* gene. But the jumping gene didn't land in the DNA that encodes the protein. Instead it landed in an intron, a stretch of DNA that gets chopped out after a gene is copied into RNA and before a protein is made.

The jumping gene first landed in the *cortex* intron in about 1819, the researchers calculated from historical measurements. That timing gave the mutation about 20 to 30 generations to spread through the population before people first reported sightings of the black moths in 1848. Saccheri and colleagues found the transposable element in 105 of 110 wild-caught *carbonaria* moths and none of the 283 *typica* moths tested. The remaining five moths were black because of another, unknown genetic variation.

Similarly, evolutionary geneticist Nicola Nadeau of the University of Sheffield in England and colleagues combed through over 1 million DNA bases in each of five species of *Heliconius* butterfly. The researchers were looking for genetic variants, called single nucleotide polymorphisms, associated with the presence or absence of yellow wing bands.



As soot settled onto trees in Britain during the Industrial Revolution, a black version of the peppered moth started to overtake the mottled-wing form. Scientists have now found the molecular source of the color shift.

I. SACCHERI

Nadeau's team found 108 such SNPs in all *H. erato favorinus* butterflies that have a yellow band. Most of those SNPs were in introns of the *cortex* gene or outside of the gene. Butterflies that lack the yellow band don't have those SNPs. Other changes caused yellow bars on the wings of different *Heliconius* species, suggesting that evolution acted multiple times on the *cortex* gene with similar results.

It's not obvious how *cortex* affects wing patterns, says Saccheri. But there's evidence that the gene helps determine when certain wing scales grow. In butterflies and moths, the timing of wing scale development affects wing color, says Robert Reed, an evolutionary biologist at Cornell University.

Yellow, white and red scales develop first. Black scales come later. *Cortex* is known to be involved in cell growth. So varying levels of protein may speed up wing scale growth, causing them to be colored, or slow their growth, allowing them to turn black, the researchers speculate. ■

BODY & BRAIN

Alzheimer's culprit may fight germs

Amyloid-beta protein attacks pathogens in mice, worms

BY LAURA SANDERS

A notorious Alzheimer's disease villain may also be a germ-busting superhero. Amyloid-beta gums up the brains of people with Alzheimer's but also takes out brain invaders, scientists report in the May 25 *Science Translational Medicine*.

As strong as steel, tough strands of A-beta protein imprison pathogens that threaten the body and brain, experiments in mice and worms show. Those results raise the possibility that A-beta plays a role in the immune system and its accumulation in Alzheimer's might be prompted by infection.

Earlier studies have shown that A-beta can kill germs in lab dishes, but the new experiment shows A-beta protection in living mice and worms. Mice engineered to have the human form of A-beta survived a brain infection of *Salmonella* bacteria better than mice without the human A-beta, Robert Moir and Rudolph Tanzi, both of Harvard Medical School, and colleagues found. In worms, A-beta helped stave off the yeast *Candida*.

When researchers injected *Salmonella* into mice's brains, A-beta quickly sprang into action in the hippocampus, a brain area damaged in Alzheimer's. A-beta swarmed the microbes and formed aggregates called fibrils and plaques. "Overnight you see the plaques throughout the hippocampus where the bugs were, and then in each single plaque is a single bacterium," Tanzi says. That rapid response was surprising, he says. "No one expected that."

And those prisons are probably permanent, Moir says. "In A-beta, those fibrils set like concrete, and the bugs have no chance of ever getting out."

Alzheimer's has been linked to a host of bacterial, fungal and viral infections, says immunologist Kevan Hartshorn of Boston University School of Medicine. That work, along with the new study, raises the possibility that Alzheimer's is spurred by an immune response to a pathogen.

That's "an extremely provocative and interesting hypothesis," says neuroscientist Berislav Zlokovic of the University of Southern California in Los Angeles. Zlokovic and colleagues recently found that the barrier between brain and blood weakens with age — a situation that could let more microbes into the brain and perhaps spur A-beta accumulation.

A-beta appears to be a general immune system fighter that's effective against many enemies. "This is a classical innate immune response, which means that whatever gets thrown at it, it does the same thing," Moir says. "So whether it's a herpesvirus, a spirochete or chlamydia, it's going to generate A-beta plaques."

A-beta's germ-fighting job might play a role in other diseases that come with amyloid accumulation, such as diabetes or heart disease, Moir says.

Finding this helpful role for A-beta may complicate a potential Alzheimer's treatment that attempts to use antibodies to reduce levels of the protein, says molecular pharmacologist Marina Ziche of the University of Siena in Italy. "I have always been very skeptical about that approach," Ziche says. The new results suggest that people benefit from some A-beta.

The next step is to see whether pathogens are entombed in A-beta plaques in the human brain, Tanzi says. He and colleagues have just begun a project to catalog the collection of microbes in healthy brains and in brains with Alzheimer's. ■

HUMANS & SOCIETY

Stone circles show Neandertals' skills

Ancient stalagmite structures found inside French cave

BY BRUCE BOWER

In at least one part of Stone Age Europe, Neandertals were lords of the rings. Humankind's close evolutionary cousins built large, circular structures out of stalagmites in a French cave around 176,500 years ago, researchers say.

Neandertal groups explored the cave's dark recesses, where they assembled stalagmite pieces into complex configurations, archaeologist Jacques Jaubert of the University of Bordeaux in France and colleagues report in the June 2 *Nature*. Two ring-shaped formations and four smaller stalagmite arrangements, situated 336 meters inside France's Bruniquel Cave, all display traces of ancient fires on stalagmite chunks.

Jaubert's team calculated the age of these creations based on the decay of uranium variants in six stalagmites from the two circular structures. Neandertals inhabited Europe and Asia from around 400,000 to 40,000 years ago. *Homo sapiens* did not leave Africa until about 60,000 years ago. That leaves Neandertals as the only candidates for builders of the circles.

The structures provide more evidence that Neandertals' social and technical skills roughly equaled those of African *H. sapiens* living at the same time

A researcher takes measurements of a circular arrangement of stalagmites created by European Neandertals about 176,500 years ago.

ETIENNE FABRE/SSAC

(*SN: 4/18/15, p. 7*), Jaubert says. His group will investigate whether the constructions served ritual or practical purposes.

Additional finds are also needed to determine whether Neandertals regularly made stalagmite structures in caves, archaeologist Marie Soressi of Leiden University in the Netherlands writes, also in *Nature*. ■

GENES & CELLS

Mitochondrial therapy has risk

'3-parent-baby' technique may fail in some instances

BY TINA HESMAN SAEY

A new study sounds a cautionary note for a controversial procedure for creating "three-parent babies."

That procedure replaces defective mitochondria, the energy-generating organelles in cells, with healthy ones. But even a tiny amount of defective mitochondria carried over in a transfer may replicate and take over the cell, researchers report in the June 2 *Cell Stem Cell*. Exactly which mitochondria can stage a comeback and when is unpredictable, say stem cell biologist Dieter Egli of the New York Stem Cell Foundation and colleagues.

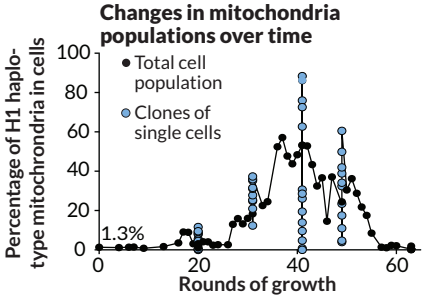
Mitochondrial replacement therapy is designed to prevent women from passing diseased mitochondria to their children. Mutations in mitochondrial DNA can impair energy generation, starving some organs, such as the brain and muscles, and have been linked to a number of diseases. Scientists designed a work-around in which they could transfer an egg cell's nucleus from a would-be mother carrying a mitochondrial disease into the shell of a donor egg containing healthy mitochondria (*SN: 11/17/12, p. 5*). Fertilization by sperm would create a three-parent baby who gets most of his or her DNA from the mother and father but mitochondrial DNA from the donor woman.

Researchers have always known that the therapy could fail if too many of the unhealthy mitochondria were transferred along with the mother's nucleus. "It was assumed that if the level of carryover was initially very low — on the order of 1 percent — then this ought to be inconsequential," says mitochondrial biologist Vamsi Mootha of Harvard Medical School. "The current paper demonstrates that even trace levels of carryover can get amplified to alarmingly high levels. This is a real concern."

Egli and colleagues transferred nuclei from eggs of women with healthy mitochondria to eggs of women containing a different variety of healthy mitochondria. The team created cells with different combinations of mitochondrial varieties, with one type in each cell making up 2.2 percent or less of the mitochondrial population of the cell.

Carrying over a bit of mitochondria was usually not a problem. But in a few cases, mitochondria could balloon from less than 1 percent to become the only type of mitochondria in the cell. One lineage of cells initially contained 1.3 percent of a particular mitochondrial DNA variety, called the H1 haplotype. After 36 rounds of growth in lab dishes, the H1 mitochondria made up 53.2 percent of the mitochondrial population. But after 59 rounds, they dwindled again to 1 percent. Individual cells removed from the dish at various time points and grown as clones in separate dishes contained between 0 and 90 percent H1 mitochondria. Those and other instances of shifting mitochondria happened at random.

Up and down Random chance can change the amount of certain mitochondria varieties (haplotypes). In a cell population created by mitochondrial replacement (black dots), the H1 haplotype started at a low level, rose and dwindled. At various times, clones of individual cells (blue dots) had varying amounts of H1.



More research is needed to determine how high the risk of resurgence is, says Philip Yeske, the science officer for the United Mitochondrial Disease Foundation in Pittsburgh.

Improved transfer techniques and other advances might reduce the chance of mutant mitochondria staging a coup, says Caltech mitochondrial biologist David Chan. "We should find a way to move forward, but it should be done cautiously."

Others, including stem cell researcher Paul Knoepfler of the University of California, Davis, hope scientists hold off on human clinical trials until more data are collected on replacement techniques and mitochondrial function in human embryos. The technique was approved last year in the United Kingdom, but no three-parent babies have been born yet. In the United States, federal laws would need to change before researchers could conduct clinical trials. ■

EARTH & ENVIRONMENT

Plate tectonics could grind to a halt

Shifting crust just 1 stage in Earth's life cycle, study suggests

BY THOMAS SUMNER

Earth's plate tectonics could be a passing phase. After simulating rock and heat flow throughout a planet's lifetime, scientists have proposed that plate tectonics is just one stage of a planet's life cycle.

In the simulation, the Earth's interior was too hot and runny at first to push around giant chunks of crust, researchers report in the June *Physics of the Earth and Planetary Interiors*. After the interior cooled for about 400 million years, tectonic plates began shifting and sinking, though the process was stop-and-go for about 2 billion years. The simulation suggests that Earth is nearly halfway through its tectonic life cycle, says study coauthor Craig O'Neill, a planetary scientist at Macquarie University in Sydney. In about 5 billion years, plate tectonics will grind to a halt as the planet's interior chills.

The long delay before full-blown plate tectonics hints that the process could one day begin on currently stagnant planets, says Julian Lowman, a geodynamicist at the University of Toronto

M. YAMADA ET AL/CELL STEM CELL 2016

MATTER & ENERGY

Schrödinger's cat in 2 boxes at once

Entangled microwaves offer benefits for quantum computing

BY EMILY CONOVER

Schrödinger's cat can't seem to catch a break. The unfortunate imaginary feline is famous for being alive and dead at the same time, as long as it remains hidden inside a box. Scientists have now gone one step further, splitting one living-dead cat between two boxes.

Animal lovers can relax — there are no actual cats involved. Instead, physicists used microwaves to mimic the cat's weird quantum behavior. The new advance, reported in the May 27 *Science*, brings scientists a step closer to building quantum computers out of such systems.

Schrödinger's cat is the hapless participant in a hypothetical experiment dreamed up by physicist Erwin Schrödinger in 1935. He imagined a cat in a closed box with a lethal poison that will be released if a sample of radioactive material decays. After any given amount of time passes, quantum math can provide only the odds that the material has decayed and released the poison. So from the quantum perspective, the cat is in a state of superposition — both dead and alive. It remains in limbo until the box is opened, and out comes a purring kitty or a lifeless corpse (*SN: 11/20/10, p. 15*).

In a lab version of the experiment, microwaves inside a superconducting aluminum cavity take the place of the cat. The microwaves' electric fields can be pointing in two opposing directions at the same time — just as Schrödinger's cat can be simultaneously alive and dead. These are known as "cat states." Now, physicists have created such cat states in two linked cavities, thereby splitting the cat into two "boxes" at once.

Though the idea of one cat in two boxes is "kind of whimsical," says study coauthor Chen Wang of Yale University, it's not that far off from the real-world situation. The cat state "is shared in two boxes because it's a global quantum state." In other words, the cat stretches out to occupy both boxes.

Because the states of the two boxes are linked — or in quantum parlance, entangled — if the cat turns out to be alive in one box, it's also alive in the other (*SN: 11/20/10, p. 22*). Wang compares it to a cat with two symptoms of life: an open eye in the first box and a heartbeat in the second box. Measurements from the two boxes will always agree on the cat's status. For microwaves, this means the electric field will always be in sync in both cavities. The scientists measured the cat states produced and found a fidelity of 81 percent — a measure of how close the state was to the ideal cat state. This fidelity is comparable to that achieved in similarly complex systems, the researchers say.

The result is a step toward quantum computing with such devices. The two cavities could act as two quantum bits, or qubits. One stumbling block for quantum computers is that errors inevitably slip in to calculations due to interactions with the outside environment that muck up the qubits' quantum properties. The cat states are more resistant to errors than other types of qubits, the researchers say, so the system could lead to more fault-tolerant quantum computers.

"They've made some really great advances," says Gerhard Kirchmair of the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences in Innsbruck. "They've come up with a very nice architecture to realize quantum computation."

Sergey Polyakov of the National Institute of Standards and Technology in Gaithersburg, Md., says, "the next step would be to demonstrate that this approach is actually scalable" by adding more cavities to the mix to build a bigger quantum computer. ■

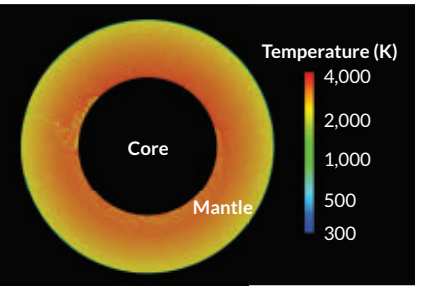


Plate tectonics on Earth may end in a few billion years, as the planet's interior cools. A computer simulation calculated how heat flows inside a planet's interior, including this snapshot during a period of active plate tectonics.

C. O'NEILL *ET AL/PHYSICS OF THE EARTH AND PLANETARY INTERIORS* 2016

Scarborough who was not involved in the research. "There is a possibility that plate tectonics could start up on Venus if conditions were right."

Plate tectonics regulates a planet's climate by adding and removing carbon dioxide from the atmosphere. This climate control helps maintain Earth's habitability. Plate movement is driven by heat flow through the planet's interior. Simulating that heat flow requires complex calculations. Previous, simplified simulations typically considered only snapshots of Earth's history.

O'Neill and colleagues simulated Earth's full tectonic life span, starting with the planet's formation about 4.5 billion years ago and looking to about 10 billion years in the future. Even using a supercomputer and simulating only a two-dimensional cross section of the planet, the calculations took weeks.

The new timeline suggests that plate tectonics is a midpoint in Earth's evolution between two stagnant states. Planets with different starting temperatures than Earth's follow different trajectories, the team found. Colder planets may exhibit plate tectonics throughout much of their histories; hotter planets could go for billions of years without plate tectonics.

Just because a planet currently lacks plate tectonics doesn't make it inhabitable, O'Neill says. Life may have appeared on Earth as early as 4.1 billion years ago, when Earth lacked full-blown plate tectonics, according to the simulation. "Stagnant planets, depending on when they are in their history, can be equally likely of supporting habitable conditions" as planets with plate tectonics, O'Neill says. ■

MATH & TECHNOLOGY

New method creates real randomness

‘Extractor’ removes bias from computer-generated numbers

BY EMILY CONOVER

Ask a computer to pick a random number and you’ll probably get a response that isn’t completely unpredictable. Because they are deterministic automatons, computers struggle to generate numbers that are truly random. But a new advance on a method known as a randomness extractor makes it easier for machines to roll the dice, generating truly random numbers by harvesting randomness from the environment.

The method improves on previous randomness extractors because it requires only two sources of randomness, and those sources can be very weak. “It’s a big breakthrough on a fundamental problem,” says computer scientist Dana Moshkovitz of MIT.

Eshan Chattopadhyay and David Zuckerman, computer scientists at the University of Texas at Austin, were scheduled to present the new randomness extractor June 20 in Cambridge, Mass., at the Symposium on the Theory of Computing.

For computers, random numbers are a precious resource, essential for encrypting sensitive information such as credit card numbers, for instance. But computers typically fail at generating truly random numbers. Many computer applications instead rely on “pseudorandom” numbers. These are generated in a reproducible way, relying on an algorithm, and therefore aren’t really random.

Deviations from true randomness can create security holes. “A common way for hackers to break into systems is to exploit the fact that people don’t use high-quality randomness,” says Zuckerman.

To sidestep computers’ predictable natures, computer scientists have devised ways of harvesting randomness from the environment, using input from the mouse or the keyboard, for example. The computer might sample the mouse’s coordinates at several points in time and convert these values into a string of numbers. But this still falls short of being truly random. If the mouse is on the left of the screen one moment, it’s less likely to be all the way on the right in the following instant. So successive numbers could be correlated or biased toward certain values, making them only weakly random.

Randomness extractors excavate the randomness from these weak sources, throwing away the predictable junk to create a truly random number. “Randomness is a resource — it’s just like gold that you mine,” says Moshkovitz. “You take the sources that you have and you just purify the gold out of them.”

The new randomness extractor combines two independent sources of weakly random numbers into one set that is nearly random, with only minor deviations. Then the researchers use a “resilient function,” a method of combining information, to turn the string of numbers into one truly random bit — a 1 or 0.

Resilient functions combine information in a way that can withstand a certain amount of bias. For example, in an election, some number of malicious voters might collude to sway it in one direction. A resilient function can protect honest voters. Rather than taking the majority vote, election officials could group voters into threes and take the majority of each group, then group those results into threes and take the majority and so on. This method allows the election to tolerate a larger number of bad apples — or, in random number generation, it can filter out the effect of the biased numbers.

Compared with previous state-of-the-art randomness extractors, which required input that was already very close to random, the new method can mine sources that are “much, much, much, much weaker,” says computer scientist Avi Wigderson of the Institute for Advanced Study in Princeton, N.J. The new extractor is a “substantial improvement over the previous results, and it’s very close to the best you can hope for.” ■

MATH & TECHNOLOGY

Insect-sized bot is first to both fly and land

HARVARD MICROROBOTICS LAB/HARVARD UNIV.

Houseflies stretch their legs to land. Bumblebees hover, then slowly descend. Now, a roughly bee-sized flying robot has a way to stick the landing.

The bot (dubbed RoboBee) uses static electricity to cling to a leaf and perch on other materials. RoboBee is the first of its size that can fly, perch and take off again, Robert Wood of Harvard University and colleagues report in the May 20 *Science*. (RoboBee is shown flying, then clinging to a leaf in a time series image.)

The researchers made an “electrostatic adhesive” patch with electrodes that can be charged, letting the patch stick to different surfaces, like a balloon sticking to the wall after being rubbed on hair. Switch the electrodes on and the patch, on top of the bot, helps RoboBee hang out on overhanging pieces of glass or plywood. Switch the electrodes off and the bot detaches. The patch lets RoboBee rest between flights: The bot used about a thousandth as much energy perching as it did hovering. This energy-saving feat could one day extend mission time in search and rescue operations. — *Meghan Rosen*

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ATOM & COSMOS

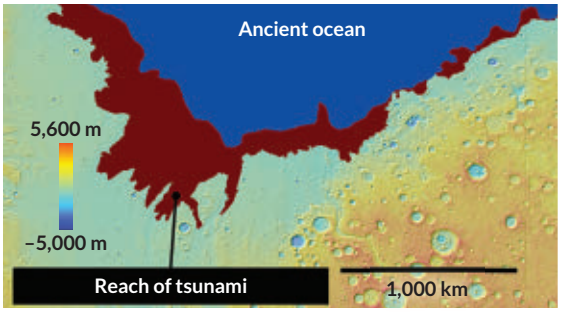
Tsunamis reshaped Martian landscape

Signs of waves shore up evidence for past ocean on Red Planet

BY THOMAS SUMNER

Massive meteorite impacts may have once made waves on the Red Planet. The resulting tsunamis towered nearly as tall as the Great Pyramid of Giza and reshaped the coastline of an ancient ocean, researchers propose.

By scrutinizing satellite images of Mars, planetary scientist Alexis Rodriguez and colleagues conclude that tsunamis could have sent water hundreds of kilometers inland and carved the region's odd geography. The team reports the findings May 19 in *Scientific Reports*.



Meteorite impacts could have generated tsunamis on Mars that reshaped the coastlines of an ocean about 3.4 billion years ago. The dark red region shows the reach of one potential tsunami.

The work supports the idea that an ocean covered Mars' northern lowlands around 3.4 billion years ago. While other evidence backs up this claim, the ocean's existence has nonetheless been disputed due to a lack of shoreline features.

"It's remarkable that as we look closer and longer at the geology of Mars, we see more and more evidence that Mars once had an ocean," says MIT planetary scientist Taylor Perron.

Mars is mostly parched now, but some scientists think that as much as a third of the planet's surface was once covered in water and ice. Water-carved channels hint that groundwater outbursts flooded the northern lowlands, forming an ocean.

The surrounding landscape doesn't contain definitive traces of a shoreline, but the area shows evidence that fluids once flowed uphill. A visit to Japan after the 2011 tsunami made Rodriguez, of the Planetary Science Institute in Tucson, wonder whether waves could have reshaped Mars' shorelines.

Meteorite impacts big enough to blast out 30-kilometer-wide craters would have hit early Mars every 2.7 million years on average, Rodriguez and colleagues estimate. These impacts could have generated tsunamis up to 120 meters tall that could have flooded as much as 1 million square kilometers of land.

Studying Mars' geography, Rodriguez and colleagues found signs of at least two tsunamis millions of years apart. The first tsunami pushed boulders as large as buses into strange places and shifted sediments, obscuring the ocean coastlines.

During the time between the tsunamis, the climate chilled, the researchers think. When the second tsunami struck, its ice-rich waters froze before retreating, leaving behind icy bloblike formations. Sampling these formations could allow scientists to glean the chemistry of the ancient ocean, Rodriguez says. ■

ATOM & COSMOS

Young sun's flares nurtured early life

Solar blasts could have helped warm Earth and seed DNA

BY THOMAS SUMNER

Solar outbursts may have supplied early Earth with the right stuff for life.

Based on observations of young sunlike stars, researchers estimate that "super" solar flares bombarded Earth with energetic particles daily around 4 billion years ago. Collisions between the particles and molecules in Earth's atmosphere produced nitrous oxide, a greenhouse gas, and hydrogen cyanide, a component for building DNA, the researchers propose May 23 in *Nature Geoscience*.

The compounds warmed and fostered life, says Vladimir Airapetian, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Md. "Our sun," he says, "wasn't just a source of warmth; it also produced ingredients for life."

Life's earliest traces date back to around 4.1 billion years ago, when the sun was about 25 to 30 percent dimmer than today — too faint to keep Earth's temperatures above freezing without the help of additional greenhouse gases (*SN: 5/4/13, p. 30*). Simulating the early sun using star data collected by the Kepler space telescope, Airapetian's team found that while dim, the sun was probably wilder in its youth. Solar flares probably erupted more often and with more ferocity.

The storms temporarily squeezed the magnetosphere, the protective magnetic bubble surrounding Earth, to one-sixth its normal height, the researchers suggest. That squashing allowed more solar particles to rain into the atmosphere. The particles ionized and broke apart nitrogen molecules in the air. Those molecules reassembled into new ones such as hydrogen cyanide, which can produce DNA bases and amino acids.

Another product, nitrous oxide, is a greenhouse gas nearly 300 times as potent as carbon dioxide. The additional nitrous oxide could have kept Earth from freezing, the researchers propose.

The interactions create the right molecules but in the wrong place, says Cornell University astrobiologist Ramses Ramirez. The molecules would have originated in the upper atmosphere, not near the surface where most greenhouse warming takes place and where life would have taken root. While the idea is plausible, he says, some other mechanism is needed to "get the molecules down so the critters can utilize them." ■

A. RODRIGUEZ

LIFE & EVOLUTION

Pygmy blue whale 'moans' deepen

Scientists can't explain drop in vocalization frequency

BY MEGHAN ROSEN

In the Indian Ocean off the coast of Sri Lanka, pygmy blue whales are changing their tune.

From 2002 to 2012, the frequency of one part of the whales' calls steadily fell, marine bioacoustician Jennifer Miksis-Olds reported May 25. But another part of the calls stayed the same.

"I've never seen results like this before," said Leanna Matthews, a marine bioacoustician at Syracuse University in New York. The findings add a new twist to theories about blue whale vocalizations and spark questions about what the animals are doing, she said. "It's a huge mystery."

Over the last 40 to 50 years, blue whale calls around the world have been getting deeper. Researchers have reported frequency drops in populations from the Arctic Ocean to the North Pacific.

Some researchers think that today's blue whales are just getting bigger, said Miksis-Olds, of the University of New Hampshire in Durham. Whaling isn't as common as it used to be, so whales have been able to grow larger — and larger whales have deeper calls. Another theory blames the changes on an increasingly noisy ocean. Whales could be adjusting their calls to be heard better, like people raising their voices at a party, she said.

But if the whales were just getting bigger, you'd expect all components of the calls to be deeper, said acoustics researcher Pasquale Bottalico of Michigan State University in East Lansing.

Miksis-Olds and her colleague, marine bioacoustician Sharon Nieukirk of Oregon State University in Newport, also discovered that the ocean's average daily sound levels at two of the whale call frequencies — 100 and 60 hertz — didn't increase during the study period. So the noisy ocean theory doesn't seem to explain why the whales are making deeper calls either.

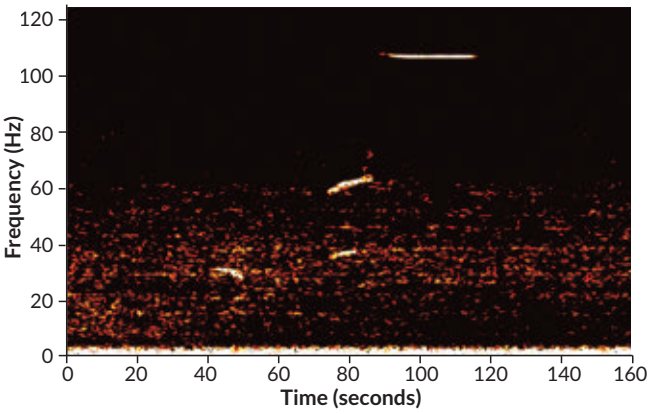
"No one can say for sure why they're doing it," Miksis-Olds said, but perhaps it's intentional. Deeper calls could attract mates. Or the whales could be learning the deeper calls from other whales.

The calls of pygmy blue whales (*Balaenoptera musculus brevicauda*) have three main parts, at about 100, 60 and 40 hertz. For humans, that's barely audible. "All you hear is a low moan," said Miksis-Olds.

She picked out moans in data recorded by underwater microphones. The highest part of the calls dropped about 0.5 hertz per year, from around 107 hertz in 2002 to around 100 hertz in 2012. It's like the difference in a teenage boy's voice before and after puberty, Miksis-Olds said. For blue whales, it's the biggest rate of decrease ever reported.

But the component at 60 hertz stayed constant. (The team didn't analyze the 40 hertz component because it was difficult to distinguish from background noise.)

Why the whales are tweaking just one part of the call is puzzling. "We're seeing an evolution of some type," Miksis-Olds said. "We just don't know what aspect of the environment they're adapting to." ■



Call of the whale
The calls of Sri Lankan pygmy blue whales have three major components, around 100, 60 and 40 hertz. In this spectrogram, recorded in 2002, white represents the loudest sounds and black the quietest. Other colors represent background noise. The frequency of the highest part of the call has dropped in recent years.

J. MIKSIS-OLDS/UNH, S. NIEUKIRK/OREGON STATE UNIV., NOAA PMEL

MEETING NOTE

Crashing empty fuel tank on Europa could help scientists study ice

A literal moon shot just might reveal the thickness of Europa's icy crust.

Launching an SUV-sized rocket canister at Jupiter's frigid moon could shake the surface so much that the tremors would be visible from space, mechanical engineer T.J. Campbell of the Catholic University of America in Washington, D.C., said May 24.

A spacecraft overhead could record the tremors, which would help reveal how thick Europa's ice shell is, Campbell and colleagues proposed. Estimates range from a few kilometers to more than 30 kilometers (*SN: 5/17/14, p. 20*).

NASA has a concept for a Europa mission, which could launch in the 2020s. The plan is to use ice-penetrating radar to probe the shell (*SN Online: 5/26/15*), but that might not work on ultrathick ice, Campbell said. So his team came up with a seismic approach. Instead of discarding the empty propellant tank needed to blast the spacecraft to Jupiter, the team wants to crash it into Europa.

Campbell and colleagues estimated that the tank would slam into Europa's crust at about 15.7 kilometers per second (roughly 60 times as fast as the cruising speed of a 747 airplane). Such an impact would gouge out a crater and send waves of energy racing through the ice like the tremors of an earthquake. The slower the waves, the thicker the ice.

NASA typically avoids crashing objects into places where life might thrive for fear of contamination. A propellant tank sent to smash into Europa would have to be heavily sterilized first. — *Meghan Rosen*

HUMANS & SOCIETY

Some Stone Age humans ventured back to Africa

DNA from an ancient woman who lived in what is now Romania indicates that people in Asia trekked to Africa starting between 45,000 and 40,000 years ago.

Evidence for this back-to-Africa trip comes from the partial remains of a 35,000-year-old human discovered in a cave more than 60 years ago. A distinctive pattern of alterations to mitochondrial DNA extracted from two teeth are similar to alterations seen in mitochondrial DNA of present-day North Africans, signaling an evolutionary connection, researchers in Europe say May 19 in *Scientific Reports*.

After evolving in Africa around 200,000 years ago, human populations spread beyond the continent by 50,000 years ago. The ancient Romanian woman's DNA came from a maternal line that originated in West Asia after humans initially left Africa but then ended up in North Africa, the scientists propose. — *Bruce Bower*

DNA from a woman who lived in what is now Romania around 35,000 years ago indicates that Stone Age humans migrated to North Africa from West Asia. The ancient woman's skull is shown here.

EARTH & ENVIRONMENT

Tiny plastics cause big problems for perch, lab study finds

Microscopic pieces of plastic rule Earth's oceans, with numbers in the billions — possibly trillions. These tiny plastic rafts provide homes to microbes (*SN: 2/20/16, p. 20*), but their ecological effects remain murky.

In a lab at Uppsala University in Sweden, researchers exposed European perch (*Perca fluviatilis*) larvae to a microplastic called polystyrene to see how they might react. The exposure triggered a slew of potentially negative effects: Fewer eggs hatched, growth rates dropped and feeding habits changed, with some larvae preferring polystyrene to more nutritious food options. Exposed larvae were also sluggish in responding to scents that signal approaching predators in the wild, the team reports in the June 3 *Science*.

European perch, a keystone species in the Baltic Sea, have recently experienced a population dive. Because the drop has been linked to juvenile feeding issues, the researchers argue that microplastics could be to blame. — *Helen Thompson*

BODY & BRAIN

Wiping out gut bacteria impairs brain

Obliterating bacteria in the gut may hurt the brain, too.

In mice, a long course of antibiotics that wiped out gut bacteria slowed the birth of new brain cells and impaired memory, scientists write in the May 31 *Cell Reports*. The results reinforce evidence for a powerful connection between the brain and bacteria in the gut (*SN: 4/2/16, p. 23*).

After seven weeks of drinking water spiked with a cocktail of antibiotics, mice had fewer newborn nerve cells in a part of the hippocampus, a brain structure important for memory. The mice's ability to remember previously seen objects also suffered.

Further work revealed one way gut bacteria get signals to the brain. After antibiotics, levels of immune cells called Ly6C^{hi} monocytes were lower in the brain, Susanne Wolf of the Max Delbrück Center for Molecular Medicine in Berlin and colleagues found. Injections of the monocytes increased counts of new nerve cells.

Exercise and probiotic treatment with eight types of live bacteria also increased the number of newborn nerve cells and improved memory in mice treated with antibiotics. The results help clarify the toll of prolonged antibiotic treatment and hint at ways to fight back, the authors write. — *Laura Sanders*

GENES & CELLS

Bacterial enzymes can destroy biofilms

What builds up can also tear down, a new study of bacteria suggests.

Bacteria build biofilms, communities of the microorganisms encased in a protective goo that shields the microbes from antibiotics and immune system attacks. But the very enzymes bacteria use to construct that shield can also destroy some of its molecules and strip away the protection, researchers report May 20 in *Science Advances*.

"We're weaponizing the bacteria against themselves," says structural biologist P. Lynne Howell of the Hospital for Sick Children in Toronto. Howell and colleagues studied *Pseudomonas aeruginosa* bacteria, which can cause pneumonia and other infections and are particularly problematic for people with the lung disease cystic fibrosis.

Two enzymes, called PelA$_h$ and PslG$_h$, that the bacteria use to build two different sugar polymers can degrade those same polymers, the researchers discovered. That delete function, supplied by parts of the enzymes known as glycoside hydrolase domains, normally helps correct mistakes or prevents buildup of the sugar chains inside bacterial cells, Howell says.

In laboratory tests, synthetic versions of the glycoside hydrolase domains applied to *P. aeruginosa* cultures stopped the bacteria from forming new biofilms and melted existing ones. Stripping away sugar polymers did not kill the bacteria but did make them more vulnerable to antibiotics and immune cells. Human lung cells grown in dishes containing the enzymes suffered no harm, suggesting the enzymes wouldn't damage human tissues.

Animal tests are needed to determine whether the enzymes are safe and can fight biofilm infections in the body, Howell says, and then human tests will be needed too. Similar enzymes from other bacteria and fungi may also fight biofilm infections caused by those organisms, she says. — *Tina Hesman Saey*

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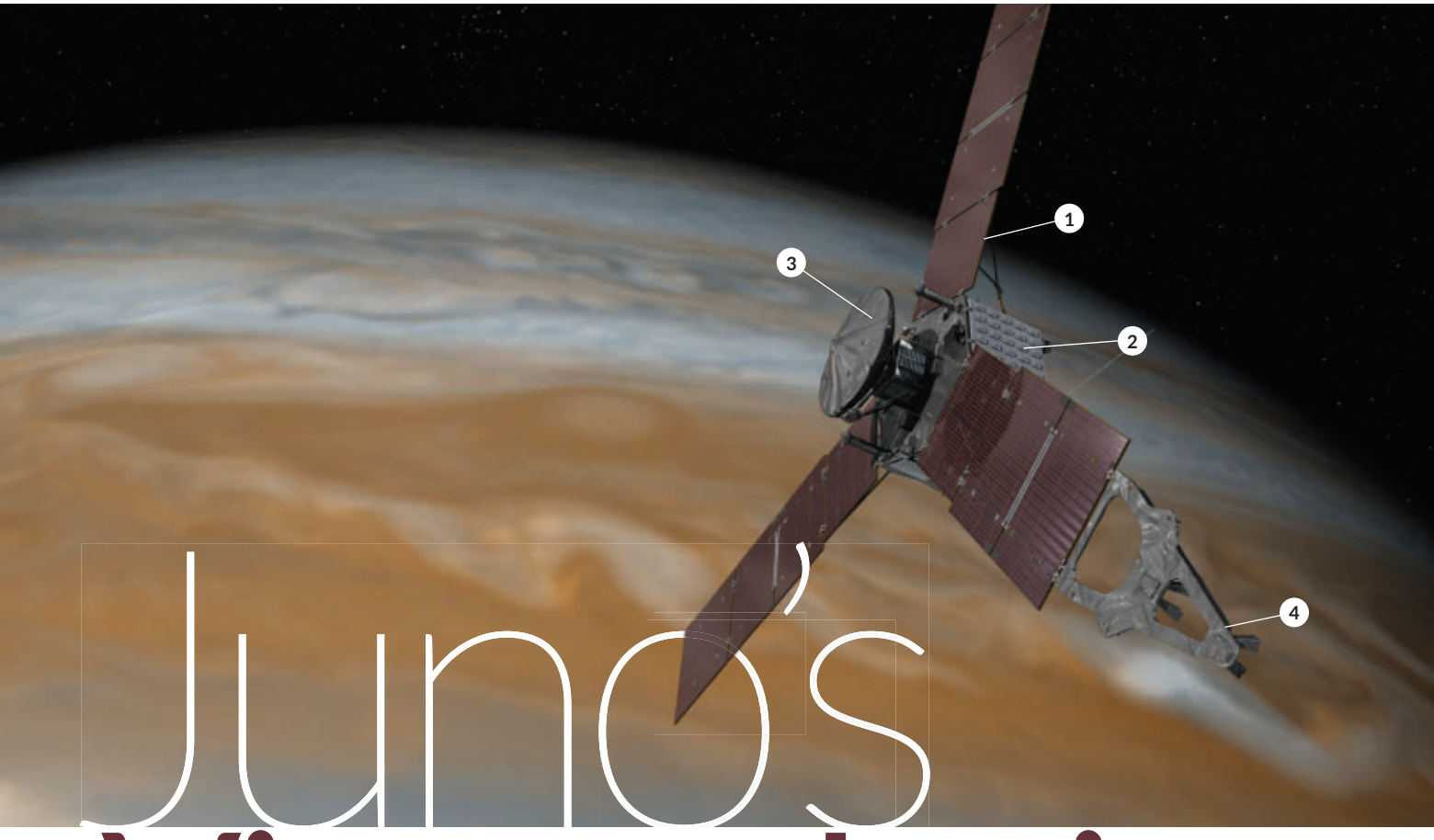


Juno's View to Jupiter

After almost 5 years in flight, the space probe is about to meet its planet

By Christopher Crockett

Ancient stargazers chose well when they named the solar system's largest planet, Jupiter, after the king of the Roman gods.

With more than twice the mass of all the other planets combined, Jupiter reigns supreme. It's the most influential member of our planetary family — after the sun. Jupiter might have hurled the asteroids that delivered water to Earth, robbed Mars of planet-building material and nudged Uranus and Neptune to the planetary hinterlands. It's also a massive time capsule, a ball of gas that records what conditions were like when the planets formed over 4 billion years ago.

And yet, despite over four centuries of intense scrutiny, including visits by eight spacecraft, there's still much that scientists don't know about Jupiter. Thick clouds conceal what goes on deep within the planet.

NASA's Juno spacecraft, set to arrive at the giant world on July 4, is about to break through the haze.

"We're going to see beneath the cloud tops for the very first time," says Scott Bolton, a planetary scientist at the Southwest Research Institute in San Antonio and head of the Juno mission. "We don't know what the inside of Jupiter is like at all."

Juno gets its name from Jupiter's wife, a goddess who peered through a veil of clouds and saw the deity's true nature. Launched on August 5, 2011, the probe has traveled about 2.8 billion kilometers to spend 20 months orbiting

JPL-CALTECH/NASA

Onboard instruments On July 4, NASA's Juno spacecraft arrives at Jupiter to begin a 20-month investigation of what lies beneath the planet's thick clouds.

1. Solar panels Juno's solar panels are the largest flown on an interplanetary spacecraft; at Jupiter's distance from the sun, probes normally use a nuclear power source to generate electricity.

2. Titanium vault Most of Juno's scientific instruments sit inside a 200-kilogram titanium vault, which will protect the electronics during repeated dives through harsh radiation belts that encircle the planet.

3. Radio link Juno's radio link to Earth doubles as a scientific experiment. Doppler shifts in the radio waves will show how the spacecraft accelerates in response to Jupiter's gravity, revealing how mass is spread out within the planet.

4. Magnetometers As Juno cartwheels through space, magnetometers on the end of a 4-meter-long boom will measure Jupiter's magnetic field, which is probably generated by metallic fluid hydrogen swirling deep beneath the clouds.

and scrutinizing the gas giant. If all goes well, Juno will measure how much water lurks beneath the clouds, map Jupiter's interior and deliver humankind's first good look at the planet's polar regions.

Jupiter is no stranger to robotic explorers, but most have come and gone quickly. Many probes use Jupiter's gravity to pick up speed on their way to the outer solar system. Even the Ulysses spacecraft, which was headed toward the sun, went the long way around, using Jupiter in 1992 to get thrown over the poles of the sun. When possible, the probes do some scientific sightseeing while passing by (see Page 32).

Galileo, which reached Jupiter in 1995, was the only spacecraft to orbit the planet. But a few technical difficulties — a malfunctioning antenna and a broken tape recorder — forced Galileo to spend most of its time observing the four largest of Jupiter's 67 moons rather than the planet itself.

"There's been a crying need to go back to Jupiter and actually study Jupiter," says Jonathan Lunine, a planetary scientist at Cornell University.

Planet of extremes

Jupiter is extreme in every way. "I often think of it as a planet on steroids," Bolton says. If Jupiter were a hollow shell, about 1,000 Earths could squeeze inside. Despite its size, it's the fastest spinning planet in the solar system: One day lasts just under 10 hours. In its turbulent atmosphere, storms come and go, although at least one has raged for centuries. Its famous Great Red Spot, a storm more than twice as wide as Earth, has churned for at least 150 years. Temperatures near the Jovian core may exceed 20,000° Celsius — more than three times as hot as the surface of the sun. And even though it's made predominantly of the lightweight elements hydrogen and helium, Jupiter is 318 times as massive as Earth. The weight of all that gas generates pressures near the center that are millions of times greater than anything people experience.

At Earth's surface, the atmosphere pushes against every square inch with 14.7 pounds of force. "That's like having four people standing on your shoulders," says Fran Bagenal, a planetary scientist at the University of Colorado Boulder. You don't feel it because you're used to it.

At Jupiter, pressure at the cloud tops would feel comfortable. But as you fell — and you would keep falling because there's no surface to stand on — you'd plummet to crushing pressures. To imagine it, replace the four shoulder-balancing people with a thousand elephants, Bagenal says, "and the bottom elephant is standing on one heel."

Much of what scientists know about Jupiter comes from gazing at its clouds with telescopes and spacecraft; the interior is left mostly to speculation. There might be a solid core, a seed from which the planet grew — or there might not. There might be an ocean of metallic fluid hydrogen swirling around that core, a gargantuan electrical conductor that generates Jupiter's far-reaching magnetic field. There might be abundant stores of water vapor beneath the clouds.

Mission timeline

August 5, 2011
Launch

August–September 2012
Deep space maneuvers

October 2013
Earth flyby gravity assist

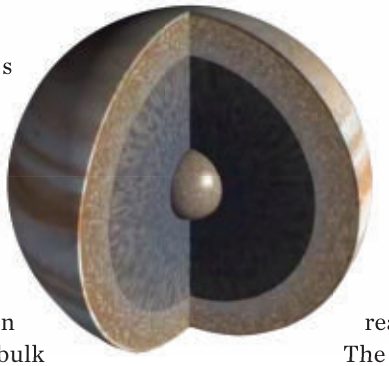
July 2016
Arrival at Jupiter

For 20 months Juno will orbit Jupiter 37 times

February 2018
End of mission (plunge into Jupiter)

Jupiter by the numbers

Mass	Volume	Length of day	Length of year	Number of moons
318 x Earth	1,321 x Earth	9.9 hours	11.9 Earth years	67



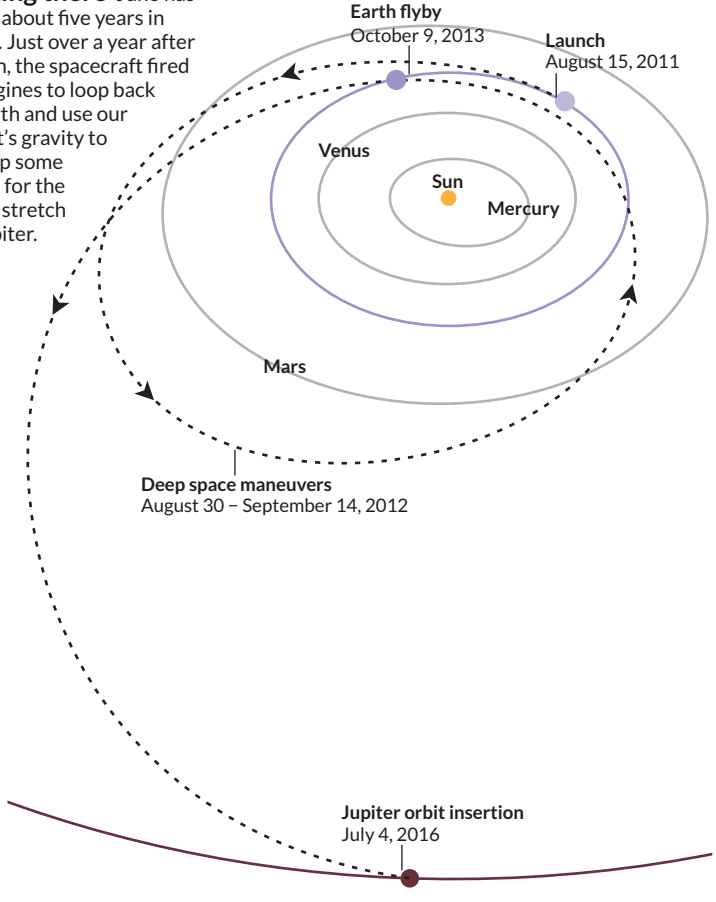
A layered planet Jupiter might have a core of rock and ice that sits below a layer of metallic fluid hydrogen (dark gray). Hydrogen and helium gas (brown) might sit atop the liquid hydrogen, just below the clouds. Or the core might not be solid at all.

Those are the mysteries that Juno will investigate. They address how Jupiter works today and how the planet first came together 4.6 billion years ago.

Researchers think that when Jupiter formed, it hoovered up all the gas within reach. That gas is what the bulk of Jupiter is made of — samples of the material that swirled around the infant sun, now stored in a planet-sized warehouse. Measuring the water abundance of that gas could tell researchers where the planet formed and what the environment was like in the solar system's early days.

"Water plays a key role in the formation of the planet," Bagenal says. Far from the sun's heat, temperatures were cold enough for water to freeze and provide lots of the solid particles from which giant planets could grow. Jupiter might have started as a ball of rock and water ice several times as massive as Earth that then pulled in all the nearby hydrogen and helium to make a giant planet.

Getting there Juno has spent about five years in space. Just over a year after launch, the spacecraft fired its engines to loop back to Earth and use our planet's gravity to pick up some speed for the home stretch to Jupiter.



"Until we measure the water, we really don't know," Bagenal says.

The Galileo spacecraft tried to figure out how much water is in Jupiter's atmosphere. As it sidled up to the planet, Galileo sent a probe into the atmosphere that measured temperatures, pressures and chemical abundances. The probe worked flawlessly, descending far deeper than researchers had hoped. But it went in at an unlucky place and its water measurement came up dry.

Galileo's probe dropped into what researchers call a "hot spot," a clearing in the clouds where thermal downdrafts drag dry air deep into the atmosphere. "They went into the Sahara desert of Jupiter," Bolton says. The probe stopped transmitting before traveling deep enough to get a realistic measure of Jupiter's water.

NASA scientists thought that they should try again, perhaps with a mission that could drop multiple probes around Jupiter and to much greater depths, Bolton says. "But that's a very expensive and challenging proposition."

Deep dives

So Bolton and colleagues came up with another idea, one that would become the Juno mission. Jupiter glows with microwave radiation as it continues to cool from its long-ago formation. And water excels at absorbing specific microwave frequencies. If a ship could orbit Jupiter and measure to what extent those frequencies were being absorbed, researchers could figure out how much H_2O was hiding beneath the clouds. To measure the microwaves, Juno will loop around the planet many times and record the intensity of multiple frequency bands.

But water alone doesn't tell everything about how the planet was born. For the rest of the story, researchers need to know if Jupiter has a solid core.

One theory for how giant planets form is that they start with a seed of rock and ice that attracts a puffy atmosphere. Another idea is that they form when a blob of hydrogen and helium gas collapses under its own weight, skipping the creation of a solid core entirely.

FROM TOP: JPL-CALTECH/NASA; E. OTWELL

Juno could resolve this debate. As the spacecraft loops around the planet, it will speed up and slow down in response to subtle changes from one spot to another in Jupiter's gravitational pull. By tracking these accelerations, researchers will be able to figure out how mass is distributed deep inside, including whether the mass is concentrated in a core or not.

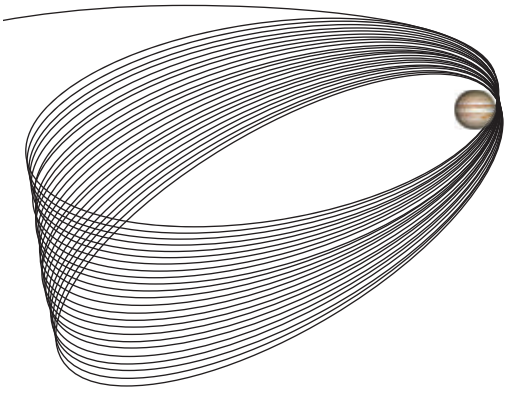
One advantage Juno has over previous spacecraft is its orbit: Juno will circle perpendicular to the equator, flying from pole to pole as it skims the cloud tops. Galileo, by contrast, usually kept its distance from the planet and never strayed far from the equator. Getting in close will allow Juno to make detailed measurements, and the north-to-south flight path lets the spacecraft scan all latitudes and get a global view of the planet's interior. Still, Jupiter doesn't make that easy.

"We're going into a very hazardous region," Bolton says, "probably the most hazardous region in the solar system outside of doing a dive bomb into the sun." Belts of high-energy radiation and charged particles encircle the planet — belts that are not friendly to spacecraft electronics. To survive, Juno's instruments are sealed inside a 200-kilogram titanium vault, speaking to the outside world through heavily shielded cables. "We're like an armored tank going to Jupiter," Bolton says.

That tank carries a camera, spectrometers, magnetometers, plasma and particle detectors, a microwave sensor and a radio antenna. The plan is to repeatedly get in close to the planet and then get far away fast. Once Juno settles into its routine, each orbit will take 14 days. Most of that time will be spent far from the planet, outside the radiation belts. Because of the planet's rotation, each time Juno swoops in, it will scan a different longitude. During those deep dives, the probe will fly just 5,000 kilometers above the cloud tops and gravity will accelerate it to roughly a quarter of a million kilometers per hour, setting a new spacecraft speed record. At that speed, Juno could go from Boston to Los Angeles in one minute.

The poles

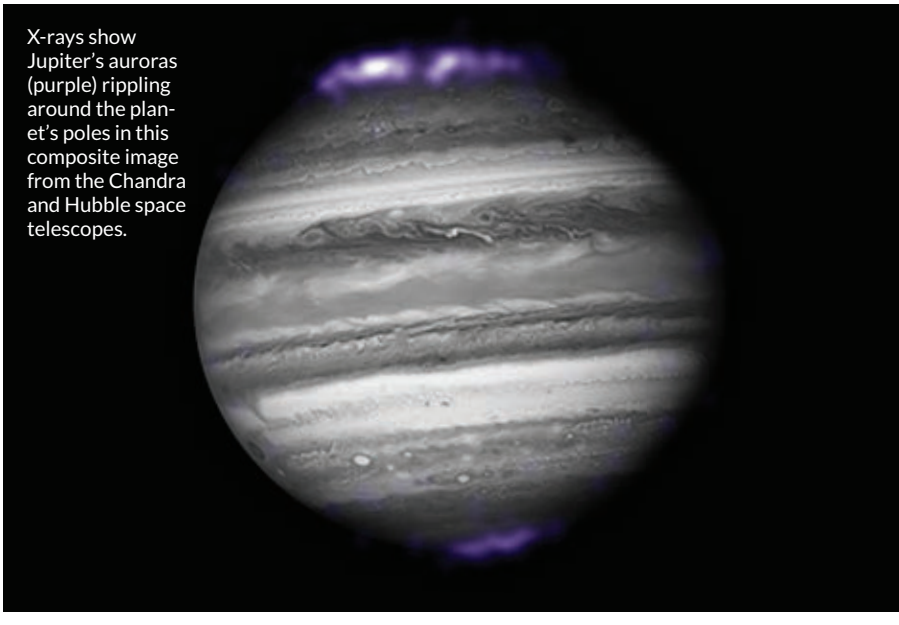
In the hours before and after each close brush with the planet, Juno will fly over Jupiter's mysterious north and south poles. "This is terra incognita for planetary scientists," says Leigh Fletcher, a planetary scientist at the University of Leicester in England. Jupiter doesn't have seasons; its axis is almost perpendicular to its orbit. That means the poles are practically invisible from Earth. Most other spacecraft have stayed near Jupiter's equator. Pioneer 11 captured a fuzzy parting shot of the north polar region as it departed Jupiter for Saturn. The Ulysses solar probe flew over the poles en route to the sun, but it didn't carry a camera nor did it get as close as Juno will.



Juno will travel on a series of elongated 14-day orbits. Its trajectory will repeatedly take the craft over Jupiter's poles and keep it away from the radiation belts most of the time.

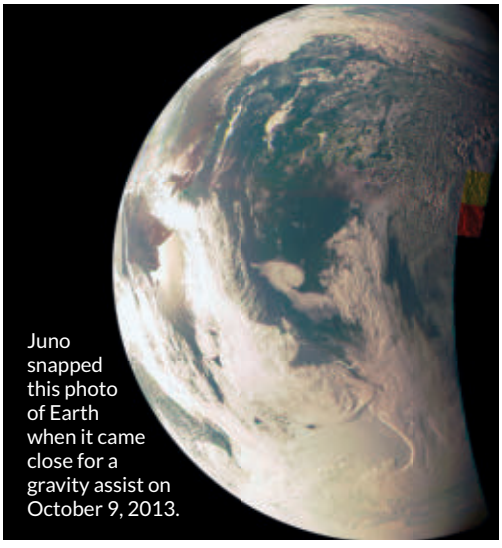
At the poles, Juno will give researchers a close look at Jupiter's auroras, the Jovian equivalent of Earth's northern and southern lights. Jupiter's lights are just one of the tools scientists will have for investigating the planet's magnetic field. Most of what researchers already know about the auroras comes from observatories closer to home, such as the Hubble Space Telescope. These dancing ribbons of light are about 1,000 times as powerful as Earth's and are longer than our planet is wide.

If the Cassini spacecraft's visit to Saturn is any indication, there might be surprises waiting at Jupiter's poles. Cassini found hurricane-like vortices swirling around Saturn's poles. "It's like we're looking into a plughole draining down into Saturn," says Fletcher. "We don't know if that's a common



X-rays show Jupiter's auroras (purple) rippling around the planet's poles in this composite image from the Chandra and Hubble space telescopes.

FROM TOP: E. OTWELL, NASA; X-RAY: CXC, SWRI, R. GLADSTONE *ET AL*/NASA.; OPTICAL: ESA, HUBBLE HERITAGE (AURA/STSCI)/NASA



Juno snapped this photo of Earth when it came close for a gravity assist on October 9, 2013.

Point and shoot

Juno is carrying a citizen-science camera. "We're inviting the public into the room," says planetary scientist Candice Hansen, who is in charge of the aptly named JunoCam.

Juno's mission didn't require pictures. "But we didn't want to fly to Jupiter without a camera," says Hansen, of the Planetary Science Institute in Tucson, Ariz. Because JunoCam is an add-on, there is just a skeleton crew working the camera. So Juno's "team" is the public. Anyone will be able to go online and mark spots on Jupiter they'd like to see photographed (http://bit.ly/Junocam).

Jupiter enthusiasts are already uploading images from backyard telescopes to a periodically updated global map that showcases the latest goings-on in Jupiter's atmosphere. Each time Juno swoops in close, the popular vote will help decide where its camera lens will point. Unfortunately, Juno wasn't equipped with an extendable arm, so there won't be any Curiosity-like selfies (*SN: 5/2/15, p. 24*). — *Christopher Crockett*

feature of giant planets or unique to Saturn."

Excitement as July 4 approaches is tempered by a further wait. Juno's arrival in July won't be heralded with new pictures; the instruments will be switched off as the spacecraft whips around the planet and begins its first orbit. Juno's next close approach — with accompanying snapshots — won't happen until late August. After two 53-day loops around Jupiter, Juno will settle into its normal routine in November.

As Juno investigates, telescopes around the world and in space will be keeping an eye on Jupiter as well. When the probe buzzes the clouds, it can see only a sliver of the planet at one time. An international observing campaign calls on large observatories in Chile and Hawaii, backyard amateur telescopes and orbiting instruments such as Hubble to see what's going on in the rest of Jupiter's atmosphere.

"If you add them all together, you have a much richer and more extensive science return," Fletcher says. "Everybody is trying to make the most of this moment in time when all eyes are going to be on Jupiter."

About 1.5 years after its arrival, in February 2018, Juno will plunge to its death in Jupiter's atmosphere. Galileo's mission ended the same way in 2003. Scientists don't want to risk a run-in between Juno and any of the icy moons, such as Europa, which could conceivably harbor life in its buried liquid water ocean. Juno was not sterilized before launch, and if Earth microbes have hitched a ride, then a crash landing on Europa could contaminate an alien ecosystem.

Europa is the next target for Jupiter-bound missions. A NASA spacecraft is planned for launch in the early 2020s on a mission to repeatedly fly by the ice-encrusted satellite. And the European Space Agency's Jupiter Icy Moons Explorer, or JUICE, is scheduled to leave Earth in June 2022 (arriving at Jupiter in 2030) to study the potentially habitable Jovian satellites and eventually orbit Ganymede, the largest satellite in the solar system.

> "This is our big generational opportunity to learn something fundamentally new about Jupiter."
>
> **LEIGH FLETCHER**

Until then, Jupiter is in Juno's hands. "This is our big generational opportunity to learn something fundamentally new about Jupiter," Fletcher says.

And the mission's legacy could extend beyond the giant planet to encompass aspects of the origins of life on Earth. When Galileo's probe dived into Jupiter, it found that there are more heavy elements such as carbon and nitrogen in its atmosphere than are found in the sun. Those elements are also key ingredients for life.

"The stuff that Jupiter has more of is what we're made of," Bolton says. What happened in the early solar system to concentrate life's building blocks out among the planets? "It's a profound question," he says. "I'm not saying we're going to answer it, but we're going to get a piece of that puzzle." ■

Explore more

■ The Juno mission: www.missionjuno.swri.edu

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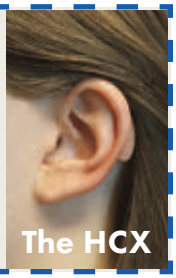

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Swat that VIRUS

Researchers aim to take the sting out of mosquito-carried diseases

By Laura Beil

Hospital patients recover from dengue virus infection under bed nets in Asunción, Paraguay, in 2012. The following year, the country hit a high of more than 144,500 reported cases.

Humans can't easily protect themselves from the most dangerous species on Earth. The predator slips invisibly into homes, quietly stalks its prey and bites before a victim knows what happened. There's little chance of escape.

The attacker is *Aedes aegypti*, a mosquito that has, over time, developed a taste for people. It's a city dweller that hovers in undisturbed crannies and can breed in a mere capful of water. Unlike some mosquitoes, which help themselves to a good meal and fly off satisfied, *Ae. aegypti* is a serial biter that can work through an entire family in minutes.

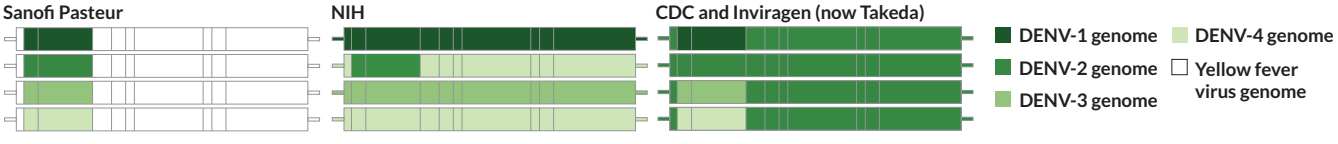
The lingering itch isn't the problem; it's the saliva transferred with each bite that could be loaded with thousands of virus particles, ready to multiply in the human body with little to stop it.

In the early 1900s, yellow fever, named for its hallmark jaundice and temperature spikes, was the most feared consequence of an *Aedes* bite. Outbreaks of the viral disease flared up with regularity in major port cities, and even delayed construction of the Panama Canal. After an effective vaccine was developed in the 1930s, yellow fever subsided and an emerging threat took its place: dengue, a flulike sickness so painful that it's known as "breakbone fever." For decades, dengue has reigned as the biggest *Aedes*-carried menace, now estimated to infect more than 50 million people a year in the Americas and almost 400 million worldwide.

Scientists are finally on the brink of introducing promising vaccines that might help control dengue, as well as newer mosquito-borne viral risks that now dominate public attention: Zika and chikungunya.

In December 2013, *Ae. aegypti* began spreading chikungunya virus in the Caribbean; by January 2015, an estimated 1 million people were infected in the Americas (*SN: 6/13/15, p. 16*). Then another worrisome *Aedes* hitchhiker, the Zika virus, began

Three dengue vaccines It's been a long road to a dengue vaccine. A recently approved, but less-than-perfect, version made by the company Sanofi Pasteur starts with the yellow fever genome used in the yellow fever vaccine and adds genes from dengue virus types 1–4. Other vaccines in development, by NIH and CDC researchers and others, contain different mixes of the four dengue virus genomes. SOURCE: A.L. ROTHMAN/*NAT. REV. IMMUNOL.* 2011



NORBERTO DUARTE/AFP/GETTY IMAGES

cutting a wide swath through South and Central America, causing devastating birth defects (*SN Online: 4/13/16*). So far, as many as 1.4 million people in Brazil alone may have contracted Zika.

For each of these infections, all doctors have to offer is pain relief and support. Although scientists are working on ways to remove disease-carrying mosquitoes (*SN: 4/2/16, p. 30*), controlling growing mosquito populations is looking less like a realistic option, according to reports from a March meeting of the World Health Organization: "There's no evidence that any recent vector-control interventions, including massive spraying of insecticides, have had any significant effect on dengue transmission."

In the absence of effective mosquito control, vaccines provide the best hope of winning the long game. Of the vaccines under study, the most challenging — and the one currently of broadest need — is dengue, which has proved exceptionally difficult to develop. After 70 years of effort, a dengue vaccine was approved in December for use in Mexico, the Philippines and Brazil. In April, the WHO threw its support behind the dengue shot. The vaccine has some shortcomings, but improved versions are not far behind. "I'm very optimistic — and I say this not just because I've been working on this for 16 years," says Anna Durbin, a dengue vaccine researcher at the Johns Hopkins Bloomberg School of Public Health.

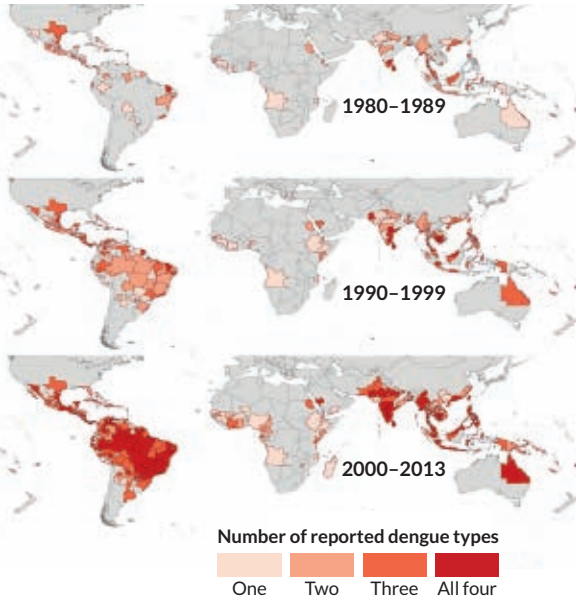
For the two infections that have the public on edge, Zika and chikungunya, vaccine development may be more straightforward. This fall, human tests should start of a vaccine that enlists just two Zika virus proteins to stimulate the immune system to fight the disease. One scientist calls the approach "simple and easy to manufacture."

Dengue dangers

Although less of a headline grabber today, dengue has a long history of causing human suffering. Even Albert Sabin, famed developer of the oral polio vaccine, got involved in dengue vaccine development in the 1940s, just as the disease began its worldwide march.

Dengue is now thought to infect people in more than 100 countries (far more than Zika). Once bitten by an infected mosquito, a person's symptoms can range from nothing at all, to tender, bloody splotches under the skin, to cardiovascular collapse and death.

Vaccine development is tricky because dengue is caused by four viruses, each slightly different but all capable of causing disease on their own.



Quadruple threat
Over the last few decades, all four dengue viruses have spread globally, creating challenges for vaccine development. A second infection from a different dengue virus can lead to more serious disease and even death.

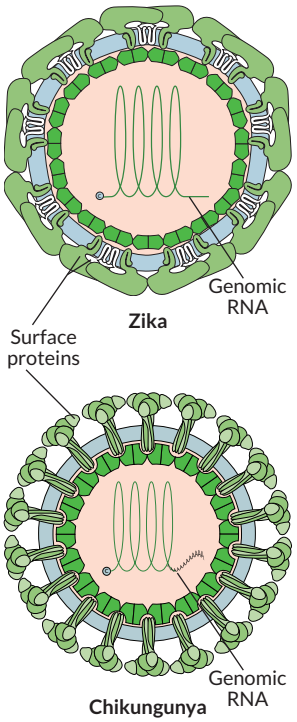
J.P. MESSINA *ET AL/TRENDS IN MICROBIOL.* 2014

While infection with one version, called a serotype, is thought to confer lifelong immunity against that serotype, a subsequent infection from a different serotype can be worse than the first. The second time around, leftover antibodies from the first episode can sometimes turn traitor, enhancing growth of the virus inside the body.

This one-two punch can lead to unyielding forms of dengue, including potentially fatal hemorrhagic fever. "In 95 percent of people who have very severe disease, it's because they've gotten a second infection of a different type," says Stephen Thomas of the Walter Reed Army Institute of Research in Silver Spring, Md. "If you get infected with dengue 1, and five years later you get another dengue 1, we believe you'll be protected. If you get infected with dengue 2, there are biological processes that increase your chances of severe disease." The same goes for types 3 and 4. And the risk probably lasts a lifetime — or until a person is infected with all four serotypes.

Scientists have attempted to develop a dengue vaccine that both simultaneously and evenly provides immunity to all four dengue viruses. "Most people say if a vaccine works even just a little bit, it's better than nothing," Durbin says. In the case of dengue, however, "a bad vaccine can be worse than no vaccine. You may actually predispose people to more severe disease."

About half a dozen dengue vaccines are in development. The first approved vaccine is Dengvaxia, made by French pharmaceutical manufacturer Sanofi Pasteur. The vaccine is built on a "backbone" of the yellow fever virus vaccine, drawing



Similarities Zika virus (top) is a flavivirus, in the same genus as dengue and yellow fever. ("Flavi" is Latin for "yellow.") Chikungunya (bottom) is in the togavirus family, which includes the rubella virus. Both Zika and chikungunya vaccines aim to stimulate an immune response using genes for proteins from the surface of the virus.

on that shot's long history of success. In 25 clinical trials involving more than 40,000 participants, protection against dengue ranged from 77 percent against dengue serotype 4, to 43 percent against serotype 2, which is considered the hardest to guard against.

The vaccine is far from ideal. It is only for people ages 9 to 45 in dengue-hit areas. Yet small children bear a huge burden of disease. In Asia, where dengue has a long history, a study published March 24 in the *New England Journal of Medicine* found 10 percent of all fevers in children ages 2 to 16 were due to dengue; 19 percent of those required hospitalization.

But the vaccine may put some children in danger. In one clinical trial, immunization appeared to increase the risk of younger children going to the hospital for dengue the following year. Writing in the January issue of *Nature Reviews Microbiology*, Sanofi scientists hypothesized that the immune response from the vaccine mimicked a first infection in some of the littlest patients, predisposing them to the dangers of a second round of illness.

Other vaccines in the pipeline, such as one by the U.S. Centers for Disease Control and Prevention and Inviragen (now Takeda Pharmaceuticals), use a weakened form of the four live dengue viruses. In December 2015, researchers writing in the *Journal of Infectious Diseases* described a human test of the vaccine in Puerto Rico, Colombia, Singapore and Thailand. Among 148 volunteers ages 1 to 45, one or two doses of vaccine produced an immune response against all four types that ranged from 72 to 100 percent protection, based on the level of antibody present in the bloodstream. Even in volunteers who had been infected with dengue in the past, the vaccine did not raise safety concerns.

A dengue vaccine developed at the National Institutes of Health and tested at Johns Hopkins and the University of Vermont is in phase III trials, the last and largest phase of experimental testing. That vaccine is also made from a weakened version of live dengue viruses and requires only one dose. In early studies, the vaccine appeared to confer only weak protection to serotype 2, which might leave a gaping hole in immune defense.

However, a reassuring study was published in March in *Science Translational Medicine*. Durbin and colleagues gave 21 volunteers the NIH dengue vaccine. Six months later, they gave dengue 2 virus to the vaccinated group, as well as 20 volunteers who were not immunized. None of the vaccinated volunteers showed signs of virus in their blood, or a rash. Yet all 20 unvaccinated volunteers had positive blood tests and 80 percent had a rash. "We knew the dengue 2 component was weaker," Durbin says. "Our question was, 'Are we going to protect people from dengue 2?' Challenge study said 'yes.'"

Activating against Zika

In the current Zika epidemic, some scientists have theorized that dengue and Zika may be partners in crime, interacting in some way that allows the Zika virus to cross the placenta. For all its mysteries, this much is known: Before the Zika virus arrived in Brazil, it was not known to cause birth defects.

Although Zika virus has caused sporadic outbreaks since the 1940s, starting in Uganda, the numbers were small, and the disease was considered minor. Zika did not become a public health emergency until it crossed the ocean in 2014. Upon reaching Brazil in 2015, the virus spread explosively. It became linked to neurological problems (*SN: 4/2/16, p. 29*) and tragedies such as microcephaly in newborns (*SN: 4/2/16, p. 26*). Before Zika, the incidence of microcephaly in Brazil was 0.5 per 10,000 births. Today, the birth defect occurs in 20 of every 10,000 births, although those estimates are inexact because of unclear reporting before Zika.

"We were surprised when we saw what a devastating disease it was," says Jorge Kalil, director of the Butantan Institute in São Paulo, Brazil's premier institution for vaccine research and development. "Why do we have it? We still don't know."

On the vaccine front, there is reason for optimism. For one, after the infection clears, a person is thought to have lifelong protection against Zika, so lasting immunity appears possible. The Zika virus is made up of 10 proteins, but the immune system mostly responds to just two that protrude from the virus's outer surface. Scientists at the National Institute of Allergy and Infectious Diseases in Bethesda, Md., are making a vaccine that consists of the genes that encode these two proteins. In theory, once inside the body, a person's own cells would manufacture copies of the two Zika proteins, assemble them and trigger an immune response.

"It's like you're making your own viruslike particle," says Julie Ledgerwood, chief of the clinical trials program at the NIH's vaccine research center. The particle looks like a piece of virus — called an antigen — that is just enough to activate the immune system but not enough to cause disease. It's a straightforward technology successfully

VIRALZONE, SIB SWISS INSTITUTE OF BIOINFORMATICS

tested against West Nile virus, another mosquito-borne infection, and described in a study published in 2011 in the *Journal of Infectious Diseases*. In that experiment, 30 volunteers received a vaccine that contained the genes for the outer coat of West Nile and their bodies began making antibodies to the virus.

Still, even if human testing of a Zika immunization begins this fall, a vaccine could take years to work through the approval process. Kalil says that Butantan researchers in Brazil need options sooner, especially for pregnant women. Instead of asking the body to develop antibodies in response to a vaccine, the researchers are investigating whether laboratory-made antibodies that fight Zika, when given to an infected pregnant woman, might shield her baby from infection. It's an unorthodox approach, he says, but his agency feels an urgency to protect infants who can't wait for the vaccine research to run its course.

"Time is crucial," Kalil says. Already, Brazilian health authorities have confirmed more than 1,100 cases of microcephaly tied to Zika exposure. If a woman received a vaccine after she was already infected, her body would not have enough time to develop her own antibodies before the fetus is damaged, he says.

His institute is also developing a vaccine with whole, killed Zika virus. "It's very basic, and we know it is safe," he says, because the virus is dead. The killed virus may eventually be combined with a dengue vaccine.

Ready for chikungunya's resurgence

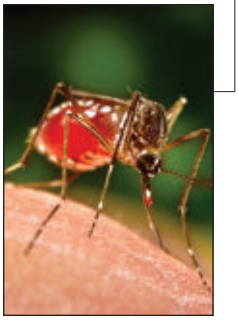
As with Zika, experts believe one infection from chikungunya leaves lasting protection — a key reason that the epidemic in the Americas has largely subsided for now.

Chikungunya virus was first identified in the 1950s on the Makonde Plateau in Africa. Its name is roughly translated as "that which bends up," a reference to the excruciating joint pain that can accompany infection. In December 2013, for reasons still not known, it leaped to another hemisphere, quickly spreading to South and Central America, lapping at the U.S. border. While rarely fatal, the disease can cause sore joints and arthritis long after a person's initial recovery.

More than 15 different chikungunya vaccines are in various stages of development, employing almost every known approach to vaccine innovation, according to researchers from the University of Texas Medical Branch in Galveston writing in March in the journal *Vaccine*. The field has

Timeline: Viruses march on

Philadelphia physician Benjamin Rush, a signer of the Declaration of Independence, wrote of bleeding his patients and giving large amounts of mercury to treat yellow fever.



Aedes aegypti mosquitoes were pegged as the carriers of yellow fever in the late 1800s.

Blood is tested for dengue fever in New Delhi. Yearly outbreaks come after the mosquito-heavy monsoon season.

1600s
Yellow fever virus is imported to the Americas on slave ships from Africa.

1771
A physician at a military hospital in Puerto Rico uses "quebranta huesos," or "break bones," to describe a disease (later called dengue) afflicting troops.

1793
Yellow fever sweeps through Philadelphia, killing about 10 percent of the population.

1873
Dengue strikes about 40,000 in New Orleans.

1881
Carlos Finlay correctly identifies mosquitoes as the source of yellow fever. His theory is ridiculed.

1937
Max Theiler at the Rockefeller Institute develops a yellow fever vaccine, which wins him a Nobel Prize in 1951.

1947
Scientists doing yellow fever surveillance in the Zika forest of Uganda isolate Zika virus from a monkey.

1952
The first chikungunya outbreak is documented in the border region of Mozambique and Tanzania.

1960s
The U.S. military begins work on a chikungunya vaccine, as the infection circulates in Asia, where soldiers are stationed. As cases fall, interest wanes.

2010
Dengue infections in the Americas triple since 1970.

October 2013
A traveler arriving on the Caribbean island of St. Martin introduces chikungunya to the Western Hemisphere, touching off an epidemic that infects more than a million people over the coming year.

May 2015
Brazil confirms the first report of locally acquired Zika disease in the Americas.

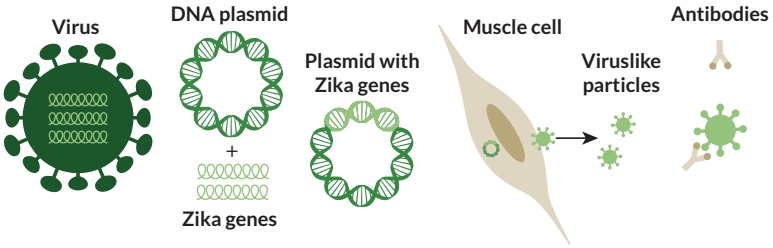
October 2015
Brazil reports an unusual increase in the number of cases of microcephaly among newborns. By the end of the year, more than 1,000 Brazilian babies have been born with confirmed microcephaly.

December 2015
As dengue spreads globally, the first vaccine is approved in Mexico, the Philippines and Brazil.

January 2016
Zika hits more than 26 nations and territories.

May 2016
Amid a vaccine shortage, the yellow fever epidemic in Angola is the worst outbreak in more than 30 years.

FROM TOP: BOSTON MEDICAL LIBRARY IN THE FRANCIS A. COUNTWAY LIBRARY OF MEDICINE; JAMES GATHANY/CDC; MANISH SWARUP/AP IMAGES



Zika hope A vaccine being developed at NIH contains genes for two outer proteins of the Zika virus inserted into a circular piece of DNA called a plasmid. Once injected into muscle, the vaccine stimulates the body to make particles that may look enough like the virus to trigger a protective immune response. SOURCE: NIAID

suffered some disappointments. The first vaccine to be tested in people used a weakened live version of the virus. Its development was halted in the early 2000s. Some early volunteers experienced joint pain, and studies raised concerns that the virus could gain strength — perhaps easier for chikungunya than other viruses because it can do so with just a few mutations.

The majority of chikungunya vaccines involve the use of weakened or killed virus. Only two have been tested in humans, and just one of those is currently in clinical trials.

The human trial in progress, led by NIH's Ledgerwood, tests a vaccine similar to the Zika vaccine. Her team is injecting just a few genes from the chikungunya virus's outer coat, allowing the body's own cells to make a piece of virus. The tricky part of the technology, she says, is to make sure that the three proteins coded by the viral genes get assembled in the correct order so the immune system mistakes them for an actual virus.

Among 25 people who received three doses of the vaccine, two doses triggered a vigorous immune response, the researchers reported in *The Lancet* in 2014. No one developed serious side effects. The NIH team is recruiting 400 volunteers in the Caribbean — half will receive the vaccine and be compared with their unvaccinated neighbors.

Scott Weaver, director of the Institute for Human Infections and Immunity at the University of Texas Medical Branch at Galveston, is heading a team investigating a newer version of a live, weakened virus. Tests indicate that the virus used in this vaccine is more genetically stable than many strains, and unlikely to strengthen over time. Last year, in *PLOS Neglected Tropical Diseases*, Weaver and colleagues reported that in animal tests, the virus passed through five different generations of mice and did not show signs of mutating into a more virulent form. Weaver hopes the results help clear the way for studies in people.

The current chikungunya epidemic has been waning, causing just over 100,000 suspected cases this year in the Caribbean and Latin America. With little disease to protect against, a vaccine trial is hard to conduct. But most predict that the lull is only temporary.

"Chikungunya is not going away," Weaver says. "We are on the back end of the current epidemic, but there will be another one coming, and we hope to have a vaccine ready in time."

Extra hurdles

If the epidemics aren't brought under control, there's fear that the viruses could migrate from *Ae. aegypti* into its cousin *Aedes albopictus*, the Asian tiger mosquito, which is more widespread in the cooler climates of the United States (*SN Online: 5/16/16*; *SN: 6/29/13, p. 26*). Asian tiger mosquitoes have already shown they are capable of spreading Zika, as they did in a 2007 outbreak in Gabon. They also spread chikungunya in an outbreak on the island of Réunion in 2005.

If there is one lesson from yellow fever, it is that science is not the only hurdle. Vaccines must overcome tests of logistics, politics and economics. After generations of control, yellow fever emerged in Angola and other parts of Africa in January and is spreading. As of June 1, Angola had 2,893 suspected cases and 325 people had died. Yellow fever vaccine is in short supply, and it's unclear how soon manufacturers can ramp up production.

Writing in *JAMA* on May 9, two professors from Georgetown University's O'Neill Institute for National and Global Health Law asked the WHO to "urgently convene an emergency committee to mobilize funds, coordinate an international response and spearhead a surge in [yellow fever] vaccine production."

While not declaring the yellow fever escalation an emergency, Margaret Chan, WHO's director-general, told the United Nations general assembly on May 23 that the spread of Zika, dengue and chikungunya are the price being paid for policies that dropped the ball on mosquito and disease control.

"The lesson from yellow fever is especially brutal," she said. "The world failed to use an excellent preventive tool to its full strategic advantage." After all, a vaccine is no good if the people in need don't receive it. ■

Explore more

■ David Olagnier. "Dengue virus immunopathogenesis: Lessons applicable to the emergence of Zika virus." *Journal of Molecular Biology*. April 2016.

E. OTWELL

Silent Sparks
Sara Lewis
PRINCETON UNIV., $29.95

BOOKSHELF

Fascinating world of fireflies illuminated

Kids are fascinated by fireflies. So are scientists, who, despite decades of research, are still perplexed by many of the mysteries posed by "lightning bugs." In *Silent Sparks*, biologist Sara Lewis explores both the cultural and scientific fascination with these marvelous beetles.

Many creatures can manufacture their own glow, Lewis notes, but fireflies are some of the few that can readily turn their lamps on and off. Not all of the world's nearly 2,000 firefly species light up as adults. But all of their larvae do, which suggests that the bioluminescence may have first evolved in a dinosaur-era ancestor as a "Don't eat me! I'm toxic!" signal to predators. Only later would adults have co-opted this glimmer for the mating displays that most people are familiar with.

Some of the most impressive firefly shows involve the synchronous flashing of thousands of insects. Each mating season, these Christmas tree–like spectacles draw thousands of tourists to locales as diverse as Tennessee and Malaysia. Although researchers have a fairly good idea of *how* the fireflies synchronize their flashings — in some species, males continually adjust their flashing rate based on their neighbors' activity — scientists still haven't figured out *why* they do so.

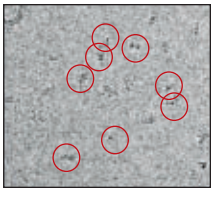
Fireflies aren't just pretty; they're useful. For instance, food inspectors monitor food contamination by taking advantage of the chemical reactions that the insects use to signal their mates. These reactions occur only in the presence of ATP, an energy-storing chemical found in all living cells, making the glowing substances a keen detector for food-tainting bacteria such as *Salmonella* or *E. coli*.

Silent Sparks is at its best when Lewis describes her own experiences in the field, such as lying on her back on the forest floor while flickering fireflies wafted mere inches above her nose. For readers who would like their own experience, Lewis includes a field guide to the most common species found in the southeastern United States (the hot spot of North American firefly diversity).

So grab a copy of the book, along with a net, jar and kid you love, and relive fond childhood memories while inspiring a few new ones. — *Sid Perkins*

SCREENTIME

Help scientists see proteins in 3-D



Researchers are calling on citizen scientists to find proteins (a few circled) in micrographs.

J. BRUGGEMANN

Microscopy Masters asks one thing of citizen scientists: Find proteins in electron microscope images. The task will probably give participants new appreciation for biologists who decipher the structures of teeny, tiny molecules. It's not easy.

The goal of the online project, created by researchers at the Scripps Research Institute in La Jolla, Calif., is to improve biologists' ability to construct detailed, three-dimensional models of proteins.

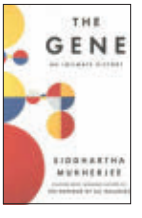
Using cryo-electron microscopy — which involves freezing, then imaging a sample — the researchers have taken thousands of photos of their current target, a protein complex involved in breaking down other, unwanted proteins. Each image contains 10 to 100 copies of the complex. It takes that many images to capture a protein from every angle. Once the 2-D images are stitched together, researchers can reconstruct the protein's globular, 3-D shape at near-atomic resolution.

Microscopy Masters enlists volunteers to do the necessary first step of combing through the photos to find the protein molecules — a time-consuming job that people do better than computers. The task may feel daunting, as each black-and-white image resembles a fuzzy TV screen. Only some of the dark smudges in any given image will be molecules of interest; others will be actual smudges or globs of proteins too jumbled to be of use. Fortunately, a practice tutorial offers a crash course in protein identification. And each image will be classified by many users, alleviating some of the pressure of worrying about marking the wrong thing.

Data from the project will help researchers improve protein-picking computer algorithms, says project member Jacob Bruggemann. That way computers can take over the painstaking work. — *Erin Wayman*

Search for proteins at **bit.ly/MicroscopyMasters**

BOOKSHELF



The Gene
Siddhartha Mukherjee
With his gifts of observation and depth of research, the physician and Pulitzer Prize–winning author offers a comprehensive look at "one of the most dangerous ideas in history."
Simon & Schuster, $32

Being a Beast
Charles Foster
Informed by scientific research, a writer attempts to live like a badger, otter, fox, deer and swift to get a sense of how various wild animals experience the world around them.
Henry Holt and Co., $28

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Regeneron selected as new sponsor of the Science Talent Search

Regeneron Pharmaceuticals, Inc. is the new title sponsor of the Science Talent Search (STS), the Society for Science & the Public announced at a special event held May 26 at the American Museum of Natural History in New York City. Regeneron, the third sponsor in the 75-year history of the nation's oldest and most prestigious high school science competition, is committing $100 million to support STS and other Society programs through 2026. The Society selected Regeneron as the sponsor through a competitive process that garnered interest from the nation's leading companies and philanthropists.

As part of its commitment, Regeneron is nearly doubling the overall STS award distribution to $3.1 million annually, increasing the top award to $250,000 and doubling the awards for the top 300 young scientists to $2,000 for each semifinalist and $2,000 for their school. As a key component of the sponsorship, $30 million will be dedicated to scaling Society initiatives focused on increasing outreach and equity for students across the United States to nurture their interest in the sciences.

Regeneron is led by two STS alumni: Chief Executive Officer Leonard Schleifer and Chief Scientific Officer George D. Yancopoulos. A leading science-based biopharmaceutical company based in Tarrytown, N.Y., Regeneron discovers, invents, develops, manufactures and commercializes medicines for the treatment of serious medical conditions.

For more information on the new Science Talent Search sponsor, visit student.societyforscience.org/regeneron-sts

HANNAH MAXWELL

Opposite page: 2016 Science Talent Search finalists Andrew Amini and Augusta Uwamanzu-Nna speak at the American Museum of Natural History launch event.

Top: George Yancopoulos and astrophysicist Neil deGrasse Tyson talk about the sponsorship at their alma mater, Bronx High School of Science. Center, from left: Leonard Schleifer lauded STS as an "unrivaled program" that "provides important motivation and reinforcement for talented young people to stay this course"; A student presents research at Bronx High School of Science; Maya Ajmera, President & CEO of the Society, calls Regeneron's founders "one of us" — scientists and STS alumni. Bottom: Yancopoulos describes Regeneron's sponsorship of STS as a "no-brainer."

APRIL 30, 2016

SOCIAL MEDIA

Tully monster mash

An ancient creature that defied identification for decades may be a distant relative of modern-day lampreys, **Meghan Rosen** reported in "True nature of 'Tully monster' revealed" (*SN: 4/30/16, p. 5*). Readers on Facebook poked fun at its odd appearance.

"Looks like a creature from a Tim Burton movie."
Juliet Fischer

"Looks like a great fishing lure."
Michael Park

"I thought it was a squid with a beak on an appendage."
Paul Fabiniak

"Who's that Pokémon?!"
Emada R. Evets

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All about aliens

New telescopes and spacecraft will soon help researchers scour our galaxy for signs of extraterrestrial life. But what might aliens look like? And if they do exist, why haven't they returned our calls? These are just some of the questions addressed in the Science News *special report "In Search of Aliens"* (SN: 4/30/16, p. 24).

Readers enjoyed **Tina Hesman Saey's** feature "Will we know ET when we see it?" (*SN: 4/30/16, p. 28*) and described what they think aliens might look like.

"The search for extraterrestrials is a subject which needs to be taken more seriously by mainstream science. Thanks for looking at it and please have more on the topic," **Wade Carmen** wrote. He suggested aliens might look similar to creatures that dwell in the deep ocean. "H.G. Wells did it right by envisioning Martians as cephalopods in *War of the Worlds*," he added. "The first extraterrestrial forms of life likely to be encountered are microbes or even something amorphous like the Blob."

Other readers thought the search for ET might require new definitions for life: "Maybe ribose is ET," said **Cabell Smith**, drawing a connection between the special issue and **Christopher Crockett's** "Ribose could have formed in space" (*SN: 4/30/16, p. 18*), which reported that the key sugar in RNA can form in lab-made "interstellar" ice. **Annselm Morpurgo** took the idea a step further. "I am still waiting for some astrophysicist to declare that there may even be life on the surface of the sun," she wrote. "Forget biology. Information exchange between self-replicating structures of any kind, such as electromagnetic 'bumps' in a chaotic 'soup,' might also qualify."

Great Plains shake-up

Earthquakes are no longer just a natural hazard. For the first time, the U.S. Geological Survey included human-made earthquakes from activities such as wastewater injection in its annual hazard forecast, ***Thomas Sumner*** *reported in "Quake risk high in parts of central United States"* (SN: 4/30/16, p. 20).

Online reader **Pro-Marx** wondered if more frequent small, human-made earthquakes could relieve built up stress and prevent the occassional massive quake.

Smaller earthquakes can relieve stress on a fault but not enough to reduce the intensity of big quakes, **Sumner** says. As earthquakes' magnitudes increase, the energies they release rise drastically. A magnitude 6 earthquake, for instance, releases nearly 32 times as much energy as a magnitude 5 quake and about 32,000 times as much energy as a magnitude 3 earthquake, according to the USGS. Scientists do not consider triggering artificial quakes a good prevention strategy. "Accumulating all of those smaller quakes would be a tall task, especially when you run the risk of accidentally triggering a damaging quake," **Sumner** says.

Salamander insights

Europe's spookily pale and blind cave salamanders, called olms, include a dark form with what look like functional eyes, ***Susan Milius*** *reported in "What's odd about a dark, big-eyed salamander"* (SN: 4/30/16, p. 4).

Online reader **John Turner** wondered why dark olms evolved those traits. "Maybe every few generations, every few tries, a pigmented and sighted salamander makes it across open ground from one cave system to another cave system to spread the species," he wrote. "That would be the reward for keeping a few black sheep in the family, no?"

The evolution of dark skin and vision likely resulted from olms spending more time in shallow caves where it's lighter, says olm researcher **Stanley Sessions** of Hartwick College in Oneonta, N.Y. Their evolution, of course, "does not have a 'purpose' such as allowing [olms] to migrate over the surface," he says. Although spring floods occasionally wash both dark and light olms aboveground, "they are all thoroughly aquatic with delicate gills, and die very quickly if they are exposed to air for long," he says.

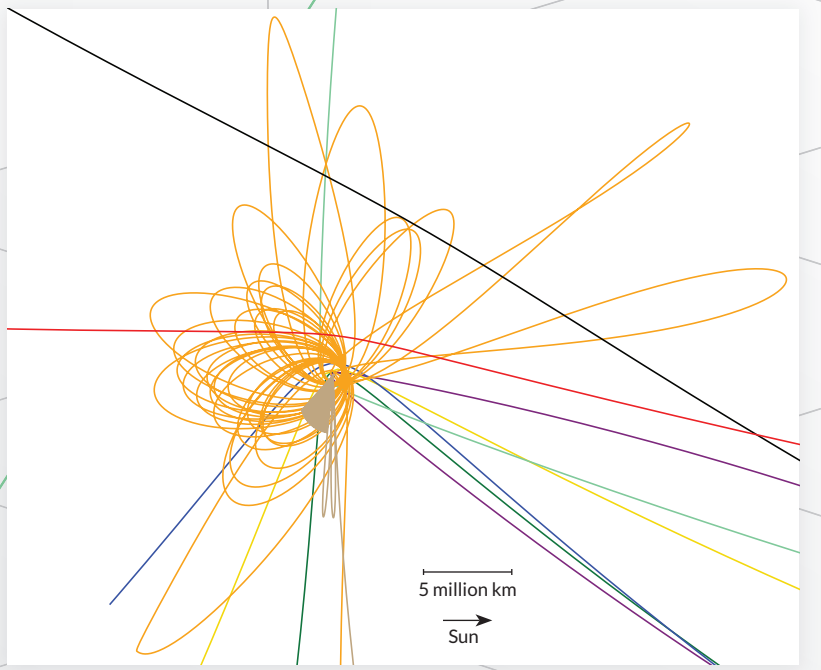
PAUL MAYER/FIELD MUSEUM OF NATURAL HISTORY

Pioneer 10 —1973
Pioneer 11 —1974
Voyager 1 —1979
Voyager 2 —1979
Ulysses —1992
Galileo —1995–2003
Cassini —2000
New Horizons —2007
Juno —2016–2018

Dates note year(s) of flyby or orbit

Grid lines represent 3.6 million km

Sun



Plotting a course around Jupiter

Since 1973, eight spacecraft have flown past or orbited Jupiter. On July 4, NASA's Juno probe will become the planet's ninth visitor (see Page 16). Juno's trajectory is different than all others, as seen in the 3-D plot above. For 20 months, Juno will repeatedly skim the cloud tops, looping over the poles on orbits that are almost perpendicular to Jupiter's equator, as seen at left in a two-dimensional view looking down on the north pole. Most other spacecraft zipped by, using the planet's gravity to speed them along to other destinations. Only Galileo, which arrived in 1995, stuck around; it spent nearly eight years circling Jupiter's equator, repeatedly buzzing the four largest moons. — *Christopher Crockett*

C. CROCKETT, E. OTWELL

See the orbits in motion at **bit.ly/SN_Juno**

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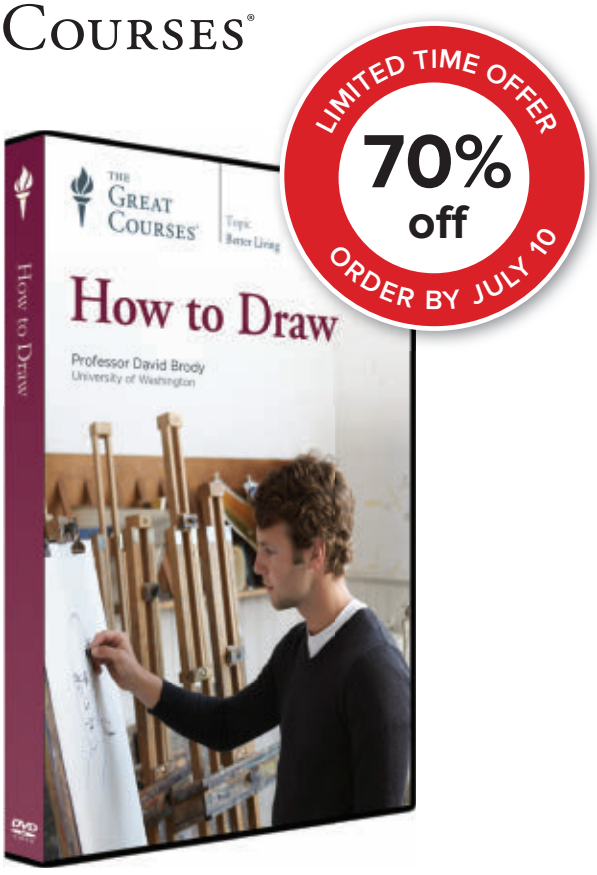

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