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SOCIETY FOR SCIENCE & THE PUBLIC
NOVEMBER 1, 2014

Muscle the Blues Away

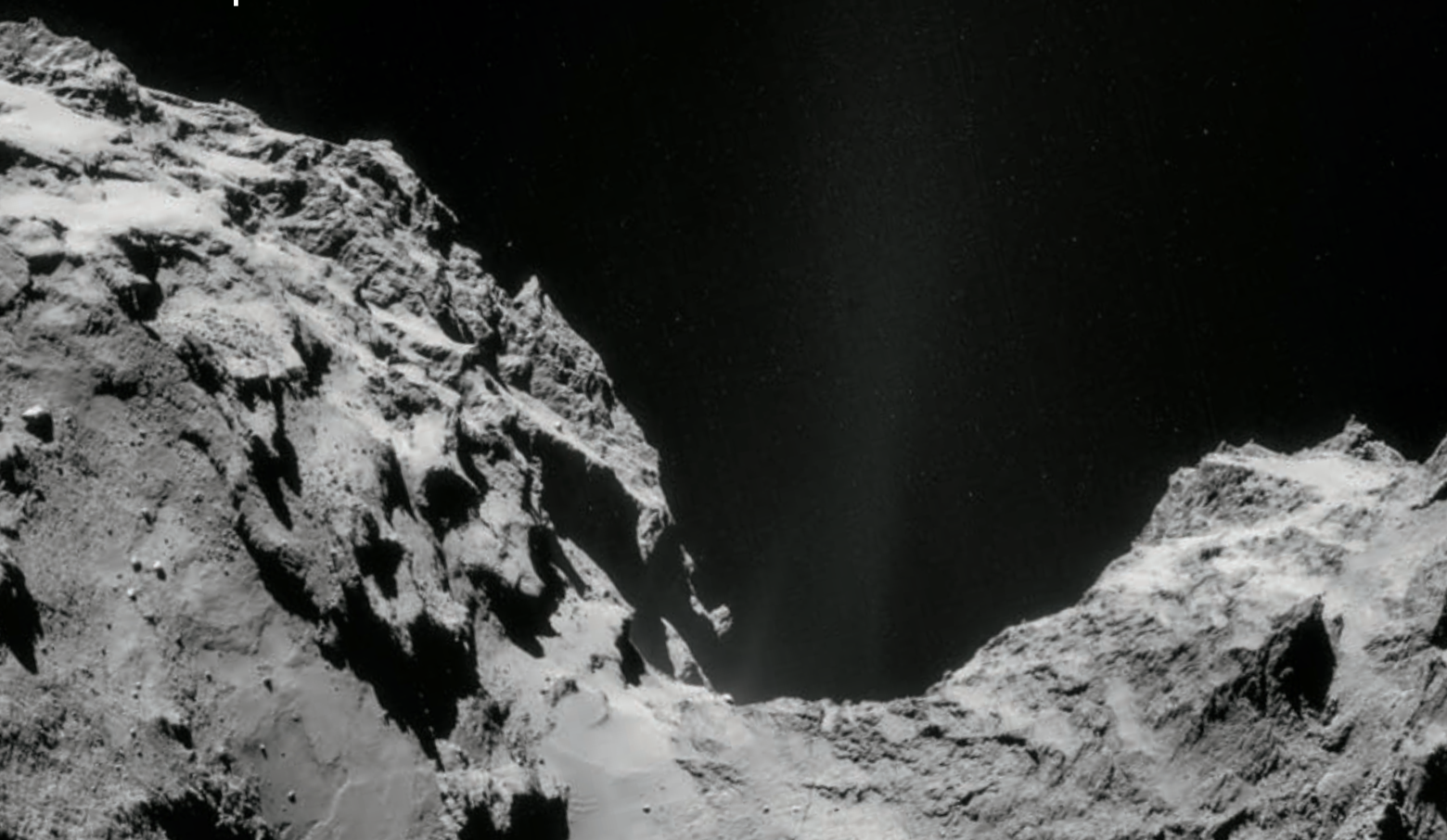
The Sahara's New Origin Story

Cancer-Fighting Microbes

Squishy Bots, Explosive Hops

Rosetta's Wild Ride

Spacecraft readies for first-ever attempt to set a lander on a comet



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News


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CLOCKWISE FROM TOP LEFT: NICOLLE RAGER FULLER; J. JUST ET AL/PLOS ONE 2014; SONIA ALTIZER


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Departments

COVER When the Philae lander reaches the surface of 67P, the comet will begin to give up its secrets about the early moments of the solar system.
Photo: NAVCAM/Rosetta/ESA; Illustration: ESA, ATG Medialab

Comet-crazed, and for good reason

The byline of web producer Ashley Yeager, whose look at the Rosetta mission graces this issue's cover, doesn't appear that often in *Science News* (or at least not since she was a writing intern here many moons ago). Yeager is among our most active bloggers, posting nearly daily updates on new research on the *Science Ticker* blog. She is also our in-house video editor, piecing together visuals from scientists with her own voice-overs to tell stories through image and sound (visit our YouTube channel to see some of her handiwork). Those duties and others leave her little time to write longer articles.

But Yeager found Rosetta hard to resist. So she made time, including nights and weekends, to report on the mission and the upcoming dramatic attempt to land a robotic explorer on a comet for the first time. "It's like landing on the moon," she says, "but it's a comet, a relic of the early solar system." The Rosetta spacecraft will also be the first to follow alongside a comet as it nears the sun. "This could completely change our conception of what comets are, of what they look like," she says. Her excitement about the mission comes through in her article, on Page 22, as she details the many unknowns of comets and of the mission itself, including the edge-of-your-seat landing attempt.

On November 12, Yeager plans to be alongside European Space Agency scientists and engineers in Darmstadt, Germany, as they wait for the lander to descend from the spacecraft. During those long hours, she will provide updates on the proceedings on Twitter and our website. The challenges are many for the lander, from the small, uneven target to the comet's very low gravity. If the lander comes down too hard, that lack of pull could lead the probe to bounce, some scientists think. Tantalizingly, the surface may be fluffy. No one knows because no one has ever been on a comet before.

That is at the heart of why Yeager wanted to write this story. Coming to the edge of knowledge, especially about what's out in space, fires her imagination. That's why she got into this business. That sensation is why most of us got into this business — and it's what I hope our readers will find in every issue. — *Eva Emerson, Editor in Chief*

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SANDY SCHAFFER

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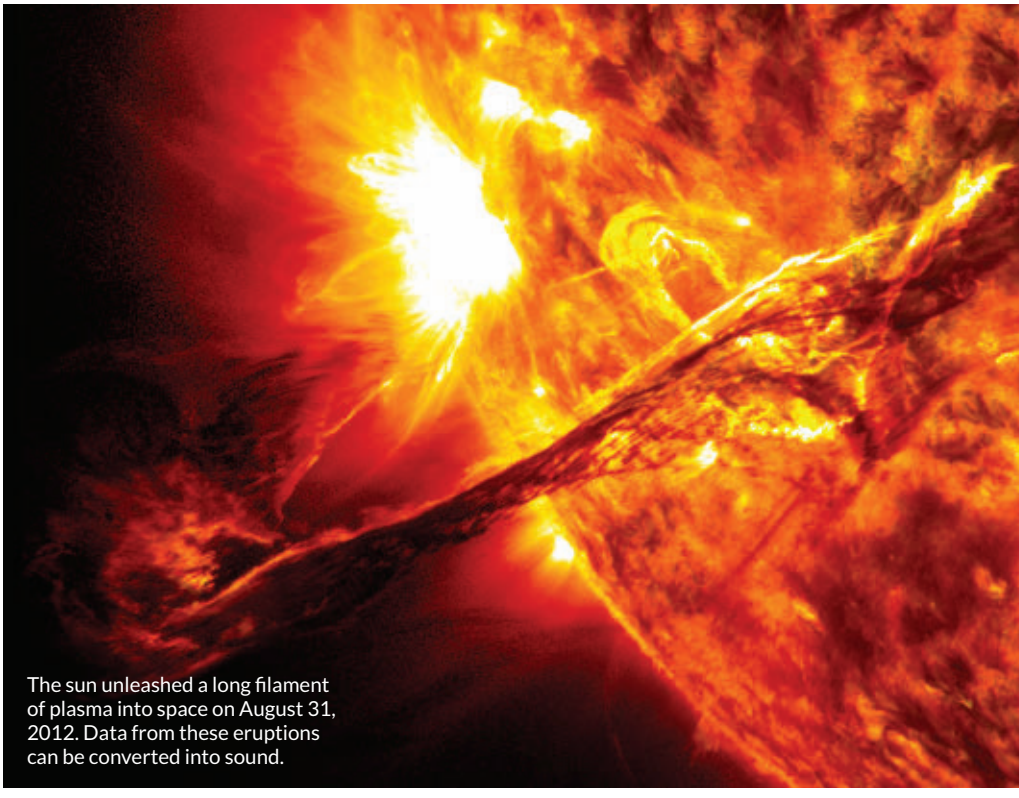
Excerpt from the November 7, 1964, issue of *Science News Letter*

50 YEARS AGO

Nobel Prize Winners: Prize for Chemistry

Few fields of science have changed more in the first half of the 20th century than crystallography, the field in which Dr. Dorothy Crowfoot Hodgkin won the Nobel Prize in Chemistry for 1964.... Dr. Hodgkin's X-ray crystallography unit at Oxford did the painstaking work, announced in 1955, to detect the structure of vitamin B-12. Her unit also worked on the chemical structure of the drug cephalosporin C, closely related to the penicillin family.

UPDATE: Dubbed the international year of crystallography, 2014 marks the centennial of X-ray diffraction — a technique that over the last few decades has led to discoveries such as the structures of key cellular proteins and the composition of soil on Mars. Yet despite the field's scientific progress, few women have joined Hodgkin on the roster of crystallographers. The prestigious Ewald Prize, awarded since 1987 by the International Union of Crystallography for outstanding contributions to the field, has gone to just one woman out of 14 winners.



The sun unleashed a long filament of plasma into space on August 31, 2012. Data from these eruptions can be converted into sound.

AIA/SDO/GSFC/NASA

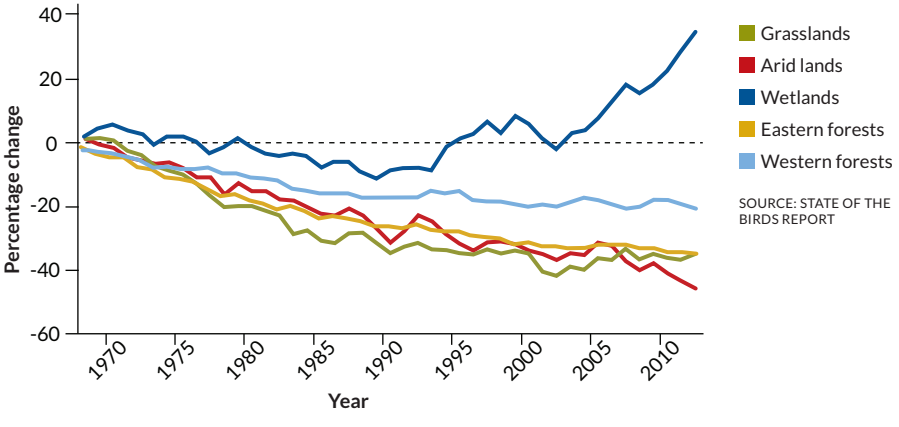
SCIENCE STATS

North American bird update has a little good news

A few signs of progress brightened the 2014 "State of the Birds" report for the United States and Canada, released September 9 by a collaboration of 23 federal and nongovernmental agencies. Overall, the tracked bird populations have mostly declined since 1968. But the populations of wetlands specialists, 87 species including mallards, on average have grown by more than 40 percent. And species breeding in freshwater wetlands and in grasslands grew in numbers or held steady since the last report in 2009.

But birds breeding in deserts or other arid lands, such as sage grouse, have dwindled to 54 percent of their 1968 numbers, according to the report. And 233 out of more than 800 species qualify for a "watch list" of birds in serious trouble. — *Susan Milius*

Bird population indicators in five inland habitats



SOURCE: STATE OF THE BIRDS REPORT

THE SCIENCE LIFE

A musician composes a solar soundtrack

Before tuning in to the rhythms of the sun, Robert Alexander watched dancers' movements and translated them into music. "When they got bigger," he says, "the sound would get bigger."

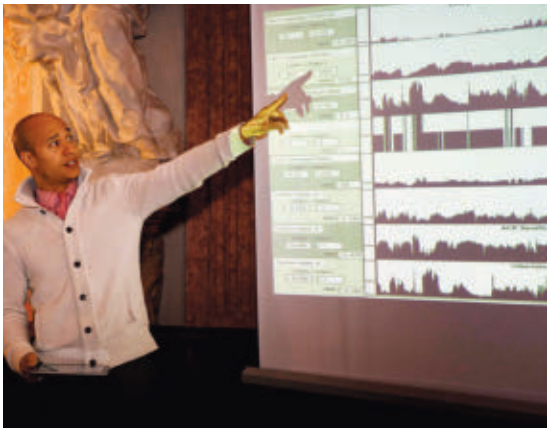
Alexander is a graduate student at the University of Michigan in Ann Arbor, splitting his time between music and solar physics. He's experimenting with data sonification — the art of converting data into sound.

His dancer-inspired creations caught the ear of physicists working with NASA's ACE satellite, which measures the constant shower of energetic particles from the sun known as the solar wind. Turning ACE data into audio "was just a matter of unplugging the dancers and plugging in the sun," he says.

Dancers, stars and sounds have something in common: They change. A surge of particles resembles a musical crescendo; a strengthening magnetic field is like a rise in pitch. Alexander turns intensity into volume, frequency into tone. A few hours of data collapse to a few seconds of audio.

Sonification lets researchers quickly explore data and listen for an unexpected signal. Typically, researchers rely on computer algorithms to sift through data. But computers work best when scientists already know what they're looking for.

While listening to the solar chatter of his transformed data in a coffee shop, Alexander heard a hum with a frequency that matched the sun's rotation period. He tracked the noise to fluctuating concentrations of carbon ions, which astronomers can use to probe the temperature of the sun's turbulent atmosphere. He used the same data to compose an ethereal piece in which the increase and decrease of carbon ions modulates the alto voice of his sister.



Robert Alexander converts data from NASA satellites that monitor the sun into sound, allowing researchers to quickly pick out interesting phenomena for further investigation.

While Alexander has always been fascinated by the universe, music is his first love. Sound "has been my way of exploring the human condition," he says. "And now I'm using that creative process to explore the universe at large." — *Christopher Crockett*

INTRODUCING

Mystery mushroomlike sea creatures

Little mushroom-shaped things collected in 1986 now have scientific names but no clear place on the tree of life.

Designated *Dendrogramma enigmatica* and *D. discoides*, they have what looks like a mouth at the base of a stubby stalk, which widens into a disc smaller than a dime. Researchers hauled them up from Australia's continental slope but preserved them in fluids that shrank tissues and damaged DNA, making genetic analysis impossible. The mystery organisms resemble, but lack important features of, both comb jellies and the phylum that includes stinging jellies.

Dendrogramma might even deserve its own new phylum, but scientists need more samples to confirm the idea, say Jean Just of the University of Copenhagen and colleagues September 3 in *PLOS ONE*. — *Susan Milius*

SAY WHAT?

Sleep drunkenness \SLEEP DRUHN-kuhn-ness\ *n.*

A foggy, disoriented state, also called confusional arousal, that occurs when the body beats the brain out of bed. If you've ever woken up not knowing where you are, had trouble talking or tried to answer the phone when the alarm clock rings, then you might have experienced sleep drunkenness. And you're not alone. Plenty of people regularly inhabit this hazy world, a study published August 26 in *Neurology* suggests.

A survey of more than 19,000 adults in the United States found that about 15 percent of individuals had experienced confusional arousal in the previous year, many of them suffering more than one episode a week. Such episodes were linked with other sleep problems, antidepressant use and mental illnesses such as bipolar disorder or panic disorder. — *Laura Sanders*

FROM TOP: R. ALEXANDER; J. JUST *ET AL*/*PLOS ONE* 2014

Listen to Robert Alexander's solar sounds at **bit.ly/SN_solarsound**

News

EARTH & ENVIRONMENT

Missing winds may foil 2014's El Niño

Rainstorms needed on West Coast will probably be unimpressive

BY THOMAS SUMNER

California won't see hoped-for relief from drought this winter, scientists say, because El Niño is likely to be weak or nonexistent.

Earlier this year, many scientists anticipated a blockbuster 2014 El Niño that would rival the record-setting 1997 event. That year's El Niño — a climate disruption generated by unusually warm seawater in the eastern Pacific Ocean — triggered severe weather worldwide, including storms and floods on the West Coast and droughts in Southeast Asia.

But now the Climate Prediction Center of the National Oceanic and Atmospheric Administration projects that a strong El Niño is unlikely and the chances of even a mild one forming have dwindled to about 60 percent.

A lack of wind gusts over the Pacific Ocean left this year's El Niño dead in the water, researchers propose September 26 in *Geophysical Research Letters*. Scientists think these winds push warm seawater eastward. The warm seawater in turn rises to the ocean surface along South America's coast and heats the atmosphere, causing dramatic shifts in weather.

"If we had the same series of wind events in 2014 as we had in 1997, we would have gone strongly toward an El Niño state," says study coauthor Jérôme Vialard, a climate scientist at the Institut Pierre Simon Laplace in Paris.

An oblong pool of warm seawater more than 14,000 kilometers wide always blankets the West Pacific. During the first few months of both 1997 and 2014, this warm pool shifted east as the westward trade winds slackened.

The similarities between the two periods "set off an alarm within the community," says study coauthor Christophe Menkes, a climate scientist at the Institute of Research for Development in New Caledonia, a self-governing French territory in the southwestern Pacific. However, in July 2014, unlike in 1997, the warm pool in the Pacific swung back to its normal position before it could rise to the ocean surface, decreasing the chance of a full-blown El Niño.

Menkes believes El Niño conditions fell flat this year because wind gusts called antitrade winds stopped blowing in April. These eastward gusts, Menkes says, would have helped lock the warm pool in place after it shifted into the East Pacific.

To determine whether the missing gusts were the key difference between the 1997 and 2014 seasons, Menkes, Vialard and colleagues did a virtual wind swap. Using computer simulations of the Pacific, the team calculated how 2014 El Niño conditions would have progressed under the wind patterns observed in 1997.

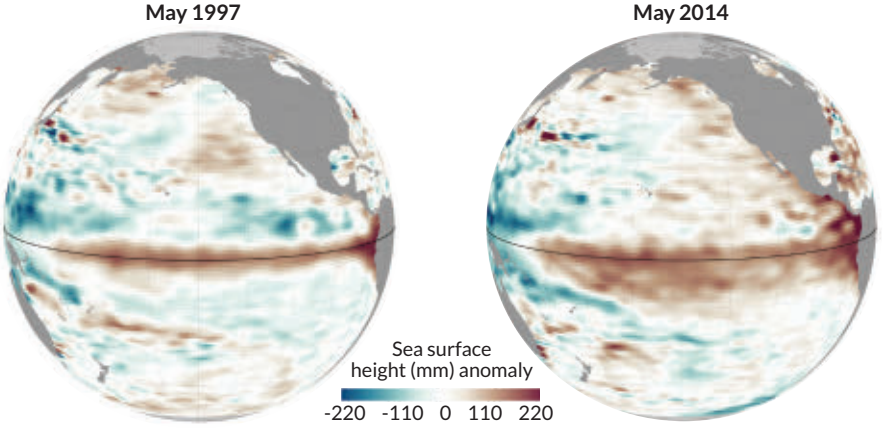
The warm pool would probably have stayed in the east and not have retreated westward, the team found, significantly boosting the possibility of a strong 2014 El Niño event. The results indicate that if the antitrade winds don't return, Vialard says, "this year's El Niño is more or less dead."

That's bad news for the West Coast. California is in the midst of one of the most severe multiyear droughts on record and multiple large wildfires raged across the state this summer. Many had hoped El Niño would bring much-needed water to the region, which has received only 55 percent of normal precipitation so far this year.

The root cause of this year's El Niño dud remains unknown, says Michelle L'Heureux, a NOAA climate scientist in College Park, Md. "The big question is why the winds weren't as strong and rigorous as they were in 1997," she says. Winds are difficult to forecast, L'Heureux explains, making El Niño events difficult to predict.

The uncertainty in part stems from the winds being influenced by atmospheric and oceanic conditions elsewhere on Earth, says climate scientist Kevin Trenberth of the National Center for Atmospheric Research in Boulder, Colo. The presence or absence of antitrade winds, he says, may be a by-product of the overall atmospheric changes that prompt El Niño as much as they are a cause. ■

Lukewarm Warm water in the Pacific Ocean sloshed eastward this spring, prompting many scientists to expect a strong 2014 El Niño like the record-setting one in 1997. Sea surface height is an indicator of how much heat is stored in the ocean; above-average heights (red) correspond with warmer-than-normal sea temperatures.



MARIT JENTOFT-NILSEN AND ROBERT SIMMON/OCEAN SURFACE TOPOGRAPHY TEAM/JPL-CALTECH/NASA

LIFE & EVOLUTION

Monarchs originated in North America

The butterflies' ancestors migrated, genetics study indicates

BY KATE BAGGALEY

The earliest monarch butterflies arose in North America and were migratory. Over time, the butterflies evolved populations in other locations, some of which stay put year-round, a genetics study shows October 1 in *Nature*.

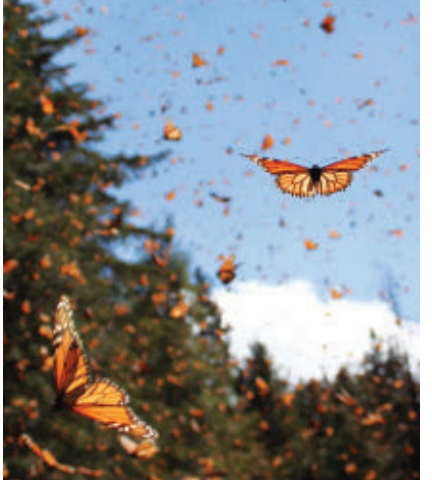
Because many of the monarch's closest butterfly relatives live in the tropics and do not migrate, "the thought was that the butterflies [came] from South and Central America and became migratory from resident populations," says Tyler Flockhart, a conservation biologist at the University of Guelph in Canada. "But that doesn't seem to be the case."

Monarchs, *Danaus plexippus*, are famous for their annual migration from the United States and Canada to Mexico and back. But nonmigratory populations live in the tropics of Central and South America and in sites across the Atlantic and Pacific.

To determine how these populations relate to each other, Marcus Kronforst, an evolutionary biologist at the University of Chicago, and his colleagues compared the genomes of 80 monarchs from various locations and of four closely related species. Surprisingly, the North American population ended up closest to the base of the monarchs' evolutionary tree, indicating that they are most closely related to the common ancestors of all monarchs.

Kronforst and his colleagues identified about 500 genes that are distinct in the monarchs that do not migrate. One of the genes stood out. "Every time the butterflies lose migration, this one gene changes entirely, and it changes exactly the same way," he says.

That gene, which turns on in muscle cells, was less active in tissue samples from migratory monarchs than in samples from nonmigratory insects. The researchers also found that migratory monarchs have slower metabolisms. Such differences may help the migratory insects fly more efficiently, the researchers conclude.



Some monarch butterflies live year-round in the tropics, but their ancestors were migratory North Americans, like these in Mexico.

Migratory monarch numbers are declining due to deforestation, extreme weather and herbicides killing the milkweed plants that the butterflies lay eggs on. Researchers want to decipher the mechanics and evolution of migration before it vanishes."If it disappears," Kronforst says, "there's nothing else like it." ■

ATOM & COSMOS

Space chemical mimics amino acids

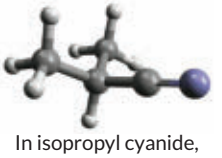
Gas cloud molecule is branched, as are protein building blocks

BY BETH MOLE

A cold cloud of gas and dust near the center of the galaxy may be able to create the molecular ingredients for life.

By searching the cloud Sagittarius B2, researchers found the first branched organic chemical in interstellar space: isopropyl cyanide. Its branched structure resembles that of many amino acids, fundamental components of life. The discovery, reported in the Sept. 26 *Science*, hints that compounds essential to life may arise between stars before making their way to Earth and other planets.

The long-sought discovery corroborates evidence collected from meteorites, where scientists have found more than 80 types of amino acids. Though the molecular cargo may have assembled on those space rocks, some of the molecules may also have been mere passengers, having been formed in dusty gas clouds.



In isopropyl cyanide, one carbon atom connects to three other carbons (large, dark gray balls).

Using radio telescopes, researchers can record frequencies that can identify individual chemicals. Scientists have detected around 180 molecules in the diffuse matter between stars. Many were spotted in Sagittarius B2, which is about 26,000 light-years from Earth and contains dense star-forming regions. But most of the chemicals have been either simple, straight chains of atoms or ringed structures. In 2003 researchers reported detecting glycine, the simplest amino acid, in Sagittarius B2, but that finding is under dispute.

In the new study, researchers parsed the signals from space with a powerful telescope network named the Atacama Large Millimeter/submillimeter Array. ALMA consists of 66 radio dishes located high in the Chilean Andes. Although ALMA had only 20 dishes up and running when Arnaud Belloche and colleagues scanned Sagittarius B2 in 2012, the observatory had high enough resolution to detect the signals of isopropyl cyanide.

The new finding is still not direct proof of molecules essential to life, says Belloche, an astronomer at the Max Planck Institute for Radio Astronomy in Bonn, Germany. But it's proof that the necessary branched structures can form in interstellar space, he says. Astrochemist Eric Herbst of the University of Virginia, who was not involved in the study, agrees. "This bodes well for the presence of amino acids," he says. ■

FROM TOP: SONIA ALTIZER; A. BELLOCHE *ET AL*/*SCIENCE* 2014

HUMANS & SOCIETY

Eurasians showed toolmaking skills

Hominids' stone flakes may not owe origin to Africans

BY MEGHAN ROSEN

More than 300,000 years ago, Stone Age people in Eurasia may have invented new toolmaking technology on their own instead of borrowing it from African migrants, as some researchers suspected.

A mix of stone artifacts sandwiched between lava flows in Armenia suggest that an early toolmaking method arose independently in multiple spots around the world, researchers report in the Sept. 26 *Science*.

"This tells us that archaic humans were a lot more innovative than we give them credit for," says archaeologist Mark White of Durham University in England.

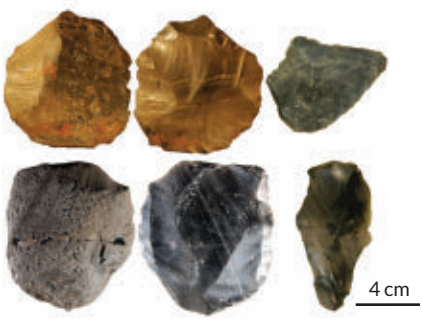
For almost 20 years, he says, scientists have argued about whether a way to make stone flakes, called Levallois technology, was invented in Africa and then spread to Eurasia. "It's one of those hypotheses that gets stuck like glue to the scientific consciousness," White says.

The new find may loosen up the glue. The Armenian site holds evidence of both old tools — stone hand axes — and newer stone flakes, as well as signs of a transition from one toolmaking technology to the other. What's more, the stone flakes from the Armenian site don't really look like those found in Africa, says Harvard archaeologist Christian Tryon.

So the Eurasian hominids may have developed their own Levallois flake making, rather than having African immigrants bring the technology in, says study coauthor Daniel Adler, an archaeologist at the University of Connecticut in Storrs.

Adler's team didn't uncover any bones at the site, so the researchers can't say who these hominids were.

But scientists do know that about 1.75 million years ago, African hominids invented a way to make stone tools with two faces, such as hand axes, by hammering chips off big lumps of rock. Archaeologists think hominids brought this toolmaking method to Eurasia some 600,000 to 900,000 years ago.



Hominids in Eurasia 330,000 years ago crafted stone tools using flake-making technology they may have invented themselves.

Hundreds of thousands of years later, Levallois flake-making technology emerged in Africa, some scientists believe. By whittling stones into dome-shaped chunks, toolmakers could strike off sharp flakes, possibly useful for cutting and slicing. That innovation may have let hunter-gatherers carry stone flakes instead of heavy hand axes.

Some researchers see such innovation

BODY & BRAIN

Muscles make natural antidepressant

Exercise blocks brain toxin linked to stress, mouse study shows

BY LAURA SANDERS

A powerful body can protect the brain, a new study suggests. Toned muscles filter a toxin to keep depression at bay, researchers report in the Sept. 25 *Cell*.

By discovering a previously unknown link between muscles and the brain in mice, the results provide compelling evidence for the healing power of exercise, says psychiatrist Andrew Miller of Emory University in Atlanta. "This paper really emphasizes 'strong body, strong mind.'" The finding also hints at new ways to treat brain disorders, he says.

Researchers have known that in response to a good workout, muscles produce a compound called PGC-1 alpha 1, which is a general do-gooder around the body. The compound prompts the body to make more blood vessels and mitochondria, for instance. The new study shows that PGC-1 alpha 1's protective effects extend to the brain.

In the study, mice were exposed to five weeks of unpredictable stressors, such as food deprivation, strobe lights and loud noises. At the end of their ordeal, mice showed signs of stress-induced depression, such as not drinking as much sweet water and giving up in a tank of water instead of struggling to swim. The brains of these mice also showed signs of depression: Key genes changed their behavior in response to the stress.

But mice genetically tweaked to produce more PGC-1 alpha 1 in their skeletal muscles seemed immune to chronic stress and showed fewer depressive signs, says study coauthor Maria Lindskog of the Karolinska Institutet in Stockholm. "Nothing happened," she says. "The brain was completely protected."

When produced in response to exercise, PGC-1 alpha 1 kicks off a chain of chemical events in muscles that culminates in neutralizing a stress-induced toxin called kynurenine. An injection of kynurenine, which travels easily between the body and brain, caused mice to show signs of depression, even when the animals weren't exposed to stressors. That result "suggests kynurenine may be a much more malignant molecule than we had previously appreciated," Miller says.

But PGC-1 alpha 1 in the muscle leads to conversion of kynurenine into a form that can't pass into the brain. The results show how muscle can have a profound effect on other organs, Lindskog says. "It's like a detoxifying organ, almost."

Mice that ran on an exercise wheel, covering more than four kilometers a night for eight weeks, also experienced benefits, the team found. And there are hints that people could achieve the same

D.S. ADLER

moments as rare, says archaeologist John Shea of Stony Brook University in New York. "One lone genius comes up with a new way of making stone tools and it spreads from one individual to the next."

But the Armenian site suggests that multiple groups figured out how to create the flake tools.

Adler discovered the site in 2008. While walking along a river gorge, he spotted flood plain sediments under a lava flow and thought, "Wow, there's got to be something there."

Adler's team eventually found thousands of artifacts fashioned from obsidian, a glassy volcanic rock that can be whittled into tools with razor-sharp edges.

Close inspection of the artifacts and dating of volcanic ash suggested that the ancient Eurasians were making both hand axes and stone flakes around 330,000 years ago, roughly the same time period of the earliest Levallois tools in Africa, Tryon says. ■

protection via working out. After three weeks of exercise, human volunteers' muscles produced more kynurenine-neutralizing molecules, biopsies from thigh muscles showed.

To get the benefits, people need to routinely challenge their muscles, which means regularly upping their exercise regimens, Lindskog says. An easy daily walk probably isn't rigorous enough to boost PGC-1 alpha 1 production.

A subset of people with depression might benefit strongly from exercise therapy, or from drugs developed to target kynurenine or the molecules that interact with it, Miller says. And the benefits probably wouldn't stop at depression. People with cancer, autoimmune disorders or other diseases that involve inflammation might benefit from stronger muscles, he says. "All of those are going to be associated with high levels of kynurenine," he says. "And we now know that we can begin to possibly clear out the system by encouraging patients to exercise." ■

ATOM & COSMOS

Tiny galaxy is home to huge black hole

Massive neighbor may be responsible for ultracompact dwarf

BY CHRISTOPHER CROCKETT

A supermassive black hole lives at the center of a supertiny galaxy, astronomers report in the Sept. 18 *Nature*. About 15 percent of the galaxy's mass is locked up in this one black hole.

"That's an outrageous number," says John Kormendy, an astrophysicist at the University of Texas at Austin who was not involved with the study. "It cries out for an understanding that we don't have."

Supermassive black holes reside at the center of nearly every large galaxy, including the Milky Way. But these black holes typically make up only a few tenths of a percent of their host galaxy's weight.

Study leader Anil Seth, an astrophysicist at the University of Utah in Salt Lake City, argues that this black hole's host galaxy, named M60-UCD1, used to be much larger. It is most likely a remnant of a galaxy that has been slowly shredded by numerous brushes with its neighbor, a giant galaxy named M60.

M60-UCD1 is about 54 million light-years away in the constellation Virgo. It's a type of galaxy known as an ultracompact dwarf, a dense ball of over 100 million stars, stretching about 150 light-years across. Ultracompact dwarfs, or UCDs, are so tiny that they can easily be mistaken for stars near Earth.

"Of all the kinds of galaxies we know about," Kormendy says, "UCDs are the least settled puzzle." Understanding where they come from could help astronomers better understand how all galaxies evolve.

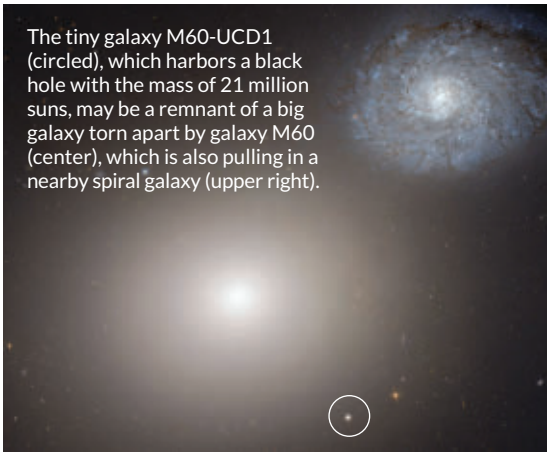
UCDs have also been overlooked as homes for supermassive black holes because determining the speeds of stars within such puny galaxies is difficult. But ignoring UCDs in a count of supermassive black holes, Seth says, is like taking a census of the United States and not counting anyone west of the Mississippi.

Seth and colleagues determined that M60-UCD1 had a central, supermassive black hole by measuring the speeds of stars in different parts of the galaxy with the Gemini North telescope in Hawaii. The telescope has deformable mirrors that cancel the turbulence of Earth's atmosphere, providing extra sharp images. The team noticed that stars closer to the galaxy's center whipped around much faster than could be explained by the gravity of the stars themselves. The high speeds revealed a black hole at the galaxy's core weighing roughly 21 million times as much as the sun.

If M60-UCD1 is typical of other dwarfs, there might be twice as many supermassive black holes in the local universe than previously thought. Having an accurate picture of where supermassive black holes live can help astronomers figure out how they formed.

Kormendy says he is puzzled by how M60-UCD1 could have survived 10 close encounters with the neighboring galaxy M60, as Seth's team's simulation describes. Galaxies usually coalesce after just a few passes, he says.

Another possibility is that M60 ejected the black hole as it gobbled down other galaxies. If M60 flung a black hole into space, that black hole could have dragged a cluster of stars along with it. Alternatively, M60-UCD1 might be a remnant from the early universe, when supermassive black holes grew much faster than the galaxies in which they lived. ■



The tiny galaxy M60-UCD1 (circled), which harbors a black hole with the mass of 21 million suns, may be a remnant of a big galaxy torn apart by galaxy M60 (center), which is also pulling in a nearby spiral galaxy (upper right).

NASA, ESA

See how M60-UCD1 became so tiny at **bit.ly/SN_galaxy**

ATOM & COSMOS

Photons can take roundabout route

Twist on two-slit experiment could detect light's loopy path

BY ANDREW GRANT

Light sometimes prefers to take the scenic route. Now, a new twist on a classic experiment could trace photons' wandering ways. In the Sept. 19 *Physical Review Letters*, researchers propose an experiment that encourages light to take weaving paths before striking a screen behind a barrier with two slits.

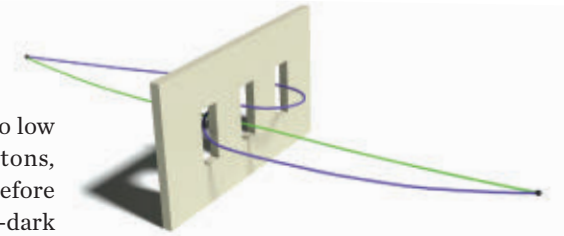
The classic double-slit experiment is simple to execute, requiring only a coherent light source such as a laser pointer, a screen and a plate with two thin parallel slits. Illuminate the slits and a pattern of bright and dark bands shows up on the screen. The striped pattern suggests that light travels in waves that interfere with each other behind the slits.

Yet when the light intensity is so low that individual particles, or photons, pass through the slits one by one before striking the screen, the same light-dark pattern still gradually builds up — even though the particles seemingly would not influence each other. This result demonstrates one of the basic mysteries of quantum physics.

The double-slit experiment has some misconceptions attached to it, says Urbasi Sinha, a physicist at the Raman Research Institute in Bangalore, India. Physicists generally assume that the striped pattern depends only on the light traveling through slit A or slit B. But quantum mechanics allows photons to take other routes, particularly in an apparatus with three slits. The light could perhaps pass through one slit, wind out the second slit and then loop back in through the third before finally hitting the screen.

Sinha and colleagues found that in a three-slit experiment using visible light, photons taking roundabout paths account for about one-millionth the intensity of the interference pattern — a contribution too small to measure directly. But the researchers could raise that fraction by tweaking the experiment to use microwave photons, which have a longer wavelength than visible light. Along with relatively wide, spread-out slits, that would make the looping photons detectable, at about one-thousandth of the total intensity, the calculations show.

"It's a cool calculation," says Howard Barnum, a physicist at the University of New Mexico in Albuquerque. ■



Meandering A new study quantifies the amount of light that takes a circuitous route (such as the purple photon) through three slits. Traditionally physicists have accounted for paths involving only one slit per photon (green).

BODY & BRAIN

Statins may improve stroke survival

Cholesterol drugs prolong life in cases caused by brain bleeding

BY NATHAN SEPPA

People in the throes of a stroke caused by bleeding in the brain appear to fare better if they are taking cholesterol-lowering drugs called statins. In a review of medical records, researchers found that those getting statins while being treated for a hemorrhagic stroke were twice as likely to be alive 30 days later as were those not getting the drugs during treatment. Researchers report the results September 22 in *JAMA Neurology*.

There are two main types of stroke. Most are caused by blood clots in the brain, but up to 20 percent result from bleeding. While research has shown that statins help prevent and possibly treat clot-based strokes, some studies have found no protection against bleeding strokes. One even suggested that statins increased the bleeding-stroke risk.

"The idea that statins should be avoided wherever brain hemorrhage is involved has permeated stroke practice," write physicians Marco Gonzalez-Castellon, now at Hospital Santo Tomás in Panama City, and Randolph Marshall of Columbia University in a commentary in *JAMA Neurology*.

This caution made sense, says stroke neurologist Alexander Flint of Kaiser Permanente in Redwood City, Calif. Just to be safe, physicians confronted with evidence of harm often accept such data with less skepticism than they would apply to evidence showing a benefit, he says. The priority is to do no harm. The data suggesting statins are harmful came from a trial in which people were getting very high doses of the drugs, he notes.

To check for a link between statins and bleeding strokes, Flint and his colleagues pored over the records of 3,481 patients admitted to Kaiser hospitals for hemorrhagic strokes over a 10-year period. In all, 18.4 percent of those receiving statins while in the hospital died within 30 days of the stroke, whereas 38.7 percent of those not getting the drugs did. When the team adjusted for differences between the statin users and nonusers, such as their medical problems and the size of their brain hemorrhage, 30-day survival was four times greater in those receiving statins. About 90 percent of the people in this analysis who were taking statins were getting low doses of the drugs.

But hemorrhagic stroke patients who were taking statins before entering the hospital — then taken off the drugs during stroke treatment — had 30-day death rates of nearly 58 percent, compared with about 19 percent for those who were kept on the drugs during treatment.

Doctors treating a brain hemorrhage have a lot to worry about — especially controlling high blood pressure, which is often the cause of such bleeds. Those concerns should no longer include statin treatment, says Jan Scheitz, a physician at Charité University Medicine in Berlin. ■

MATH & TECHNOLOGY

Hopping robot powered by explosion

Soft-bodied bot could aid search-and-rescue operations

BY MEGHAN ROSEN

Tiny explosions may be the next big leap for jumping robots.

Igniting a mix of oxygen and liquid butane releases a burst of energy that can propel a new soft-bodied robot skyward. Inflating the bot's rubbery legs before the explosion can control which way it hops, researchers from Harvard and Cornell reported September 15.

The robot has potential for use in disaster zones, said MIT engineer Sampriti Bhattacharyya, where rubble littering the ground can make walking difficult for rescue robots. "You want something very fast that can climb over broken stuff."

Unlike traditional search-and-rescue robots, with rigid metal or plastic parts, robots with soft bodies can be resilient to damage and may pose less physical threat to humans. But making squishy bots hustle is a challenge, said study coauthor Michael Tolley, a Harvard mechanical engineer.

He and colleagues recently built an untethered soft robot that could survive fire, snow and even being run over by a car. But the silicone-based machine crawled along the ground about as fast as a garden snail.

Large leaps would make for faster travel, but "jumping is quite difficult," said Mathieu Babel, an engineer at Parrot, a Paris-based electronics company. "You need to release a lot of energy in a very short amount of time. That's why combustion is a good way to do it."

In a project partially funded by DARPA, Tolley and his team built a pie-sized bot with a tripod of silicone legs that each look something like a Slinky dipped in melted erasers. The three legs extend from a central chamber that holds the robot's brains and guts. A fourth, springlike limb protrudes down from the chamber's middle.

To position the robot, a program cues a built-in air compressor to pump up the legs, which inflate like balloons and tilt the body in the direction of the jump. Then, the bot releases oxygen and a bit of butane into the springlike limb from a canister stashed inside the body.

An electrical spark triggers an explosion in the gas and fuel mix, forcing the springlike limb to shove off the ground, rocketing the bot into the air. In about a second, the blast can fling the bot as high as two 2-liter soda bottles stacked on top of one another, about 0.6 meters.

Tolley's team got the bot to jump onto a chair-high box and slide to the ground on the other side. But before the robot is ready to bound over rubble, researchers need to figure out how to stick the landing. The bot often ends up on its head and can't get up again.

"We're working on that," Tolley said. To make successive jumps, "you can either land on your feet every time, or you can flip yourself when you land." ■

D. TSAKIRIS/INSTITUTE OF COMPUTER SCIENCE/FORTH

MEETING NOTES

Octobot uses webbed arms to swim faster

Webbed underarms turn a sluggish robotic octopus into a speed demon.

A squishy membrane connecting the machine's eight arms helps the bot scoot through water nearly twice as fast as octobots without webs, researchers reported September 15.

Inspired by *Octopus vulgaris*, the well-known sea creature with arms connected by a fleshy, skirtlike mantle, computer scientist Dimitris Tsakiris and colleagues transformed the robotic octopus they had previously developed. The earlier, webless version could propel itself at up to 100 millimeters per second by slowly opening stiff plastic arms and then snapping them together.

But with arms and a web made of soft silicone, the shoe box–sized octobot swam at up to 180 millimeters per second. The web helps the bot generate more force to push through water faster than using arms alone.

Skittish sea animals seem unfrightened by the lifelike bot, said Tsakiris, of the Foundation for Research and Technology-Hellas in Heraklion, Greece. When researchers took the faux octopus for a swim in the Mediterranean, tiny fish tagged along.

Tsakiris thinks the robot could be used to observe marine ecosystems. "We want to put a camera on it and see what we can do." — *Meghan Rosen*

Hybrid robot merges flier with two snakelike machines

"Snakes on a plane" is a good strategy for building rescue robots. Pairing two snakelike robots with a flying one combines the exploring skills of small, ground-based bots with the swift moves of an aerial machine, researchers reported September 16.

Engineers have created search-and-rescue robots before, but most of these bots muscle over rough terrain with brute force. They can disturb damaged areas and have trouble reaching nooks and crannies within the wreckage.

Agile snakebots can burrow through rubble but can get stuck, said Stella Latscha, a mechanical engineer now at SpaceX in Hawthorne, Calif. So she and colleagues designed a four-propeller helicopter that can airlift wheeled snakebots out of tight spots.

The robot trio speeds over flat terrain as a team, or splits up to patrol air and ground separately. Using an Xbox controller, Latscha and colleagues drove snakebots through a 4-inch pipe and even up stairs. — *Meghan Rosen*

Watch videos at **bit.ly/SN_jumpingbot**, **bit.ly/SN_octobot**, and **bit.ly/SN_snakebot**

EARTH & ENVIRONMENT

Sahara may be twice as old as thought

Shrinking ancient sea may have dried out North Africa

BY THOMAS SUMNER

The Sahara may be millions of years older than scientists thought, researchers report in the Sept. 18 *Nature*. The team's climate reconstruction suggests that the desert formed 7 million years ago as the ancient forerunner of the Mediterranean Sea shriveled.

"We didn't expect such a big impact from the sea's retreat, so this was a surprise," says lead author and geologist Zhongshi Zhang of the Bjerknes Centre for Climate Research in Bergen, Norway. "This overturns the popular view on what formed the Sahara."

Most scientists have thought that arid conditions in the region took hold no more than 2 million to 3 million years ago. At that time, the onset of ice ages in the Northern Hemisphere changed wind patterns and parched North Africa. Although not all experts are convinced, Zhang and colleagues now demonstrate that millions of years earlier, the contracting sea could have drastically reduced rainfall in North Africa during summer monsoons.

This older age pegs the desert's formation close to the time and place where the chimpanzee and human lineages probably split, says study coauthor Gilles Ramstein, an earth scientist at the Laboratoire des Sciences du Climat et de l'Environnement in Gif-sur-Yvette, France.

About 200 million years ago, as the supercontinent Pangaea broke apart, a giant sea called the Tethys formed in the gap between the African and Eurasian continents. As the two continents started drifting toward each other about 100 million years later, the Tethys contracted. Sometime around 5.5 million years ago, it split into the modern Mediterranean, Caspian and Black seas.

Running atmospheric climate simulations, Zhang and colleagues traced climate changes incited by the withering Tethys. When the Tethys was large, the temperature difference between its warmer surface and the cooler surrounding continent probably powered an atmospheric conveyor belt that carried moisture from the tropical Atlantic across North Africa during summer monsoons.

As the Tethys gradually shrank and exposed more land, this moisture transport slowed to a crawl and less rain fell on the Sahara, the researchers propose. Over time, they say, the rainless region transformed into a desert.

This finding supports tentative evidence for an older Sahara announced in 2006 by scientists who uncovered petrified sand dunes in Chad. The age of nearby fossils suggested that the dunes dated to about 7 million years ago. The results were hotly challenged and lacked an explanation, Zhang says. "At long last we have a mechanism that explains the desert's older age."

However, a critic of the 2006 paper remains unconvinced by the new simulations. "This is just numerical speculation based on very little geological evidence," says geologist Stefan Kröpelin of the University of Cologne in Germany. "One dune doesn't make a desert, especially not the largest hot desert on Earth."

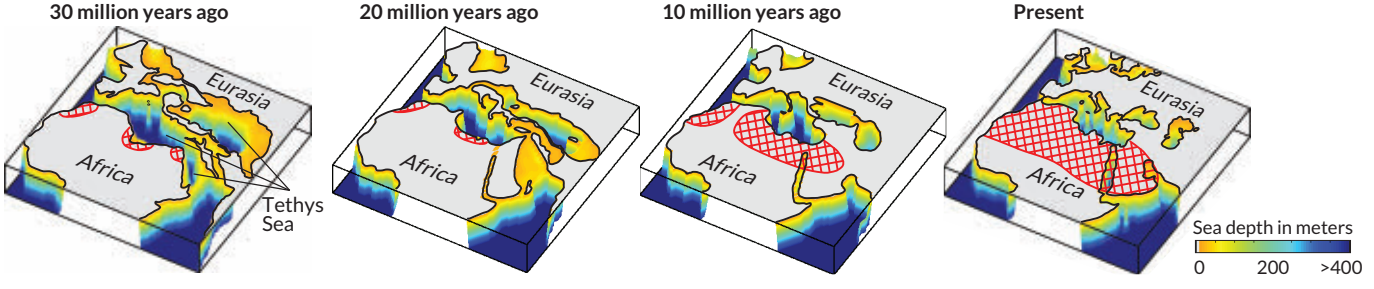
Regardless of when the desert formed, the dwindling Tethys probably destabilized North African climate. Ramstein says that this instability helps explain why small, gradual changes in the amount of incoming sunlight reaching Earth — triggered by periodic shifts in the planet's tilt and orbit — have caused the Sahara to fluctuate between wetter and drier periods every few thousand years (*SN: 8/5/06, p. 93*).

These cyclical changes in North African climate and the formation of the Sahara could have influenced early hominid evolution and later migrations across the region, Ramstein says.

But David McGee, a paleoclimatologist at MIT, says that it's hard to pin down what effect any large-scale climate changes would have had. Early hominids probably lived in microclimates such as lakeshores and grasslands mixed with forests that were quite different from the region's predominant climate.

"These really small-scale environments are really pushing the limits of a climate model like this," he says. The work "gives us a theoretical underpinning for what could have changed 7 million years ago in the African climate but not at the level that would be directly relevant to our early ancestors." ■

Run dry The Tethys Sea initially connected the Indian and Atlantic oceans but shrank as the African and Eurasian continents drifted together, as seen in this simulation. The shrinking may have led to the formation of the Sahara. Red hashed areas represent the extent of arid climate.



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A caterpillar called a lettuce shark sports bright coloring that warns predators of toxins or a bad taste. The colors can be a liability when young birds are learning what to eat.

LIFE & EVOLUTION

Bright caterpillars lose, regain edge

During flush of fledglings, flashy marks become risky

BY SUSAN MILIUS

For a few weeks every summer in central Finland, orange may become the new black. Black bodies temporarily provide caterpillars with better protection against the risk of getting eaten by birds than do bright colors, a new study says.

Dazzling markings on caterpillars can warn of toxins within, but predators have to learn the warnings. Every year, a new generation of fledgling birds pecks brightly colored caterpillars and gets an education in what not to eat.

That surge of young birds can cause a short, seasonal reversal in evolutionary pressures, so less colorful caterpillars are temporarily favored, says Johanna Mappes of the University of Jyväskylä in Finland. In an outdoor experiment with 1,243 handmade Plasticine caterpillars wired to wild plants, she and her colleagues concluded that early in birds' breeding season, when adult birds do the hunting, bright warnings work better than camouflage. Fake caterpillars sporting an orange patch suffered fewer bird pecks than all-black fakes.

Then in June and July, the orange-spotted fake caterpillars got gouged and pecked more often than the all-black ones. Records from bird banding and netting surveys suggested that these were the weeks when many young birds started venturing away from the nest, Mappes and colleagues report September 23 in *Nature Communications*. "It's costly to be conspicuous in the middle of the season when the naïve birds don't know what they're doing," Mappes says.

The caterpillars' life cycles may reflect the seasonal danger, she and her colleagues suggest. Combing a trove of photographs of larvae of 688 caterpillar species in the region, researchers took note of the ones most likely to be conspicuous to birds because of their color. The more eye-catching species represented a low proportion of the caterpillar population during the fledgling-bird period, Mappes and her colleagues report.

The results make a convincing case that warning colors wax and wane in effectiveness, says sensory and evolutionary ecologist Martin Stevens of the University of Exeter in Penryn, England. ■

EARTH & ENVIRONMENT

Mystery volcano pinned to the tropics

Records narrow down time and place of 19th century eruption

BY BETH MOLE

Reports of colorful skies may offer the first historical evidence of a volcanic eruption that occurred more than 200 years ago. The newly uncovered records help researchers figure out the time and place of the explosion that kicked off the coldest decade of the last 500 years, the 1810s.

Writings from Colombia and Peru describe a silvery sun, brilliant twilights and dimmed stars in December 1808. These are meteorological aftermaths of a mighty eruption.

Because of sulfur deposits in polar ice cores, which act as a physical record of volcanic activity, scientists had suspected that such an eruption occurred in 1808 or 1809. But they knew little else. "Until now there were no reports of any kind," says environmental chemist Jihong Cole-Dai of South Dakota State University in Brookings.

The newfound reports peg the geological fireworks to somewhere in the tropics in late November or early December of 1808. The study, by researchers at the University of Bristol in England, appears September 16 in *Climate of the Past*.

Volcanoes belch sulfurous particles high into the atmosphere, which can scatter sunlight and cool the Earth, says climatologist Alan Robock of Rutgers University in New Brunswick, N.J. Particles also cause hazes across the planet, subduing starlight and distorting colors.

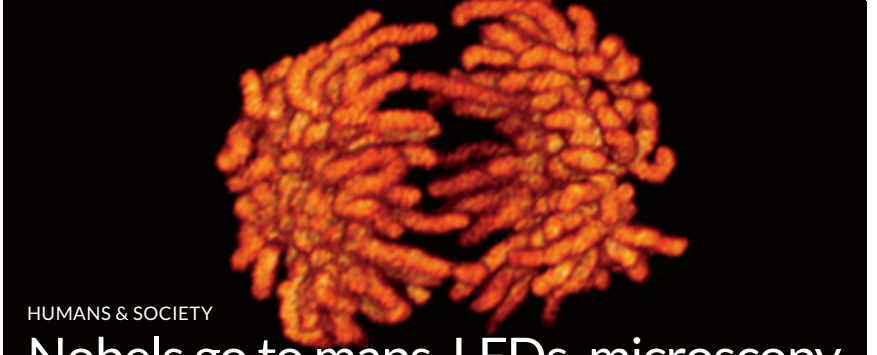
The 1815 eruption of Mount Tambora in Indonesia, one of the largest of the last millennium, helped trigger a "year without a summer." But the decade's cooling had begun well before the blast.

Bristol historian Caroline Williams searched an archive of Spanish colonial documents in Seville, Spain, for reference to any eruption. After about a year and a half, she came across an observation by Francisco José de Caldas, director of an astronomical observatory in Bogotá, Colombia. The record, in a scientific periodical from February 1809, described sunsets with red, green and blue hues during the previous December.

Then Williams found a second, similar observation in a footnote of an 1815 book on the climate of Lima, Peru. Written by physician José Hipólito Unanue, the note described prolonged twilights in mid-December 1808.

The volcano's exact location remains a mystery. But the new data should help tweak simulations of past climate to understand how the eruption spurred the cold decade that followed. ■

KIMMO SILVONEN



HUMANS & SOCIETY

Nobels go to maps, LEDs, microscopy

Research at boundaries of disciplines garners prizes

A cancer cell's chromosomes pull apart in an image made with a method pioneered by a Nobel-winning researcher.

As if to recognize that walls separating scientific fields are falling, the 2014 Nobel Prizes in chemistry, physics and physiology or medicine went to discoveries that defy single-discipline labels.

"Biology has turned into chemistry. Chemistry has turned into biology," says Sven Lidin, chairman of the chemistry Nobel committee. This year's chemistry laureates developed microscopy techniques that allow researchers to peer into the depths of cells, watch neurons shift shapes in learning brains and glimpse clumped-together proteins in diseases such as Alzheimer's, Huntington's and Parkinson's (*SN: 6/15/13, p. 20*).

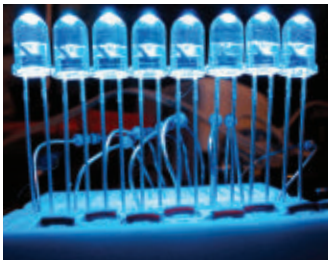
In 2000, chemistry winner Stefan Hell of Germany's Max Planck Institute for Biophysical Chemistry and colleagues shot lasers at fluorescent molecules. The first laser lit up a wide group of molecules while a second laser with a doughnut-shaped beam knocked out the glow of any molecules in its path. This left a tiny circle in which scientists could observe molecules in action.

To peer inside cells, chemistry winners Eric Betzig of the Howard Hughes Medical Institute and W.E. Moerner of Stanford University engineered light switches for molecules.

In 1997, Moerner and colleagues reported that zapping fluorescent molecules with different wavelengths could cause individual molecules to light up or black out. In 2006, Betzig and colleagues used similar molecules to view a lone membrane protein from a mammalian cell. The method, he says, could "tell us how inanimate molecules come together to create animate life."

Researchers in neuroscience won the Nobel Prize in physiology or medicine for figuring out how a rat's brain keeps track of the animal's location. In 1971, John O'Keefe of University College London found that certain cells in the rat hippocampus, a brain region involved in memory, became active only when an animal was in particular spots. These "place cells" allowed an animal to form an internal map of its surroundings.

More than three decades later, May-Britt Moser and Edvard Moser, married researchers at the Norwegian University of Science and Technology, discovered what they dubbed "grid cells" in a nearby brain area, the entorhinal cortex. These cells fired off signals when a rat passed through certain locations spaced at regular intervals, becoming active in multiple locales that correspond to a hexagonal grid.



Blue light-emitting diodes, which won the physics Nobel, feature in smartphones and white LED bulbs.

Along with other neurons, grid cells send messages to place cells, the Mosers found. This network of neurons allows an animal to know where it is.

The three laureates in physics are not physicists but engineers. They invented blue light-emitting diodes, which are central to the energy-efficient lights that illuminate homes and electronic displays.

After the discovery of red and green LEDs in the 1960s, materials emitting high-energy blue light proved difficult to create. In the late 1980s, Isamu Akasaki and Hiroshi Amano, both of Nagoya University in Japan, were studying a promising semiconductor material of gallium nitride doped with other chemicals. After dozens of engineers failed to grow high-quality gallium nitride crystals, Akasaki and Amano managed the feat in 1986 and soon made blue LEDs from them.

Shuji Nakamura, working at the same time at Nichia Chemicals, developed his own method for creating high-quality gallium nitride. That work led, by the early 1990s, to a simple and cheap way to produce blue LEDs.

The physics Nobel committee often presents awards for theories or for observing new fundamental physics phenomena. This time, the judges went for big-picture impact. Alfred Nobel "wanted his prize to be given to inventors for the benefit of mankind," said committee member Olle Inganäs. "What we emphasize today is the usefulness of this thing." —*Andrew Grant, Beth Mole, Meghan Rosen and Laura Sanders*

2014 Nobel Laureates

PHYSIOLOGY OR MEDICINE

John O'Keefe
University College London

May-Britt Moser
Norwegian University of Science and Technology

Edvard Moser
Norwegian University of Science and Technology

PHYSICS

Isamu Akasaki
Meijo University and Nagoya University

Hiroshi Amano
Nagoya University

Shuji Nakamura
University of California, Santa Barbara

CHEMISTRY

Eric Betzig
Howard Hughes Medical Institute

Stefan Hell
Max Planck Institute for Biophysical Chemistry

W.E. Moerner
Stanford University

FROM TOP: BETZIG LAB/JANELIA RESEARCH CAMPUS/HHMI; BILL BRADFORD/FLICKR (CC BY 2.0)

LIFE & EVOLUTION

Even on remote islands, busy ports mean more invasives

Regardless of how remote it is, an island that welcomes many ships may end up with more invasive species than one with fewer trading ties, scientists say in the Sept. 25 *Nature*. Secluded islands are rarely colonized by new species, but "islands aren't isolated the way that they used to be," says Matthew Helmus of VU University Amsterdam. Helmus and colleagues studied Caribbean lizards called anoles that island hop by hiding in ornamental plants bound for gardens. Helmus cataloged the distribution of native and exotic anoles. He then calculated islands' economic isolation using a U.N. shipping log. Islands with many ships docking have gained multiple anole species since the 1950s. Trinidad, for instance, has four new species; Cuba, which trades less, has none. Anoles aren't responsible for any mayhem so far. But the lizards indicate the potential for venomous snakes, crop pests and disease-carrying insects to reach remote shores. — *Kate Baggaley*

New view of big cats' energy drains

For some big cats, searching for dinner takes more effort than snagging it, researchers report in the Oct. 3 *Science*. Cheetahs and pumas' dramatic hunting styles have been thought to sap gobs of energy. But no one had looked carefully at the relative effort each cat puts into hunting. David Scantlebury of Queen's University Belfast in Northern Ireland and his team tracked 19 African cheetahs and analyzed their urine to gauge the animals' energy use. Though cheetahs were mobile for just 12 percent of the day, prowling around the hot, dry landscape sapped 42 percent of their daily energy budget. Speedy pursuits of prey lasted just a few seconds and used only a tiny portion of their energy budget. Another team, including Terrie Williams of UC Santa Cruz, outfitted four wild pumas, or mountain lions, with tracking collars. The team also measured the energy expenditure of three captive pumas trained to walk on treadmills. By comparing the wild and captive cats, the researchers discovered that pumas use more than twice as much energy locating prey as predicted. Ambushing prey in quick sprints and pounces may actually ease the energetic cost of hunting. — *Meghan Rosen*

BODY & BRAIN

Test foretells surgery recovery time

Blood taken from patients after surgery might reveal who is destined for a quick rebound, Martin Angst of Stanford University and colleagues report in the Sept. 24 *Science Translational Medicine*. A comparison of 32 people recovering from a hip replacement found that an immune-cell "signature" might predict a patient's recovery. The immune system responds to surgery as it would to any trauma. First-responder cells called monocytes rush to the scene, triggering inflammation. But too much inflammation slows recovery. While studying blood samples taken after surgery, the researchers noticed that certain monocytes seemed to contribute to a better recovery. In patients who recovered quickly, these cells limited the activity of three molecules broadly associated with inflammation within the first 24 hours after surgery. Tests looking for this cell-activity pattern predicted which patients were bound for good recoveries — with less fatigue, pain or functional impairment — 40 to 60 percent of the time. — *Nathan Seppa*

GENES & CELLS

Molecule boosts number of stem cells in umbilical cord blood

A new molecule multiplies stem cells in umbilical cord blood, researchers report in the Sept. 19 *Science*. The finding may lead to greater use of cord blood in blood-cancer treatments. Only 5 percent of stored cord blood samples have enough stem cells for transplants. The new molecule has the potential to make up to 50 percent of cord blood units available for transplants, says Guy Sauvageau of the Institute for Research in Immunology and Cancer in Montreal. Stem cells from umbilical cord blood can be used to replenish blood cells in patients whose blood-producing marrow has been obliterated by radiation or chemotherapy. With low numbers of stem cells in cord blood, however, patients regenerate blood slowly, putting them at higher risk for infections. Sauvageau and colleagues combed more than 5,000 lab-made molecules to see if any increased stem cell counts. The researchers chemically modified one promising molecule and treated cells from human cord blood. The molecule, called UM171, boosted stem cell counts to 13 times the original amount. Mice that received transplants of these treated cells produced more human blood cells six months later than did mice that received untreated cells. — *Kate Baggaley*

ATOM & COSMOS

Mystery resolved: how stellar explosions expel high-energy light

New observations might explain why explosions on three white dwarfs, the cores of dead stars, recently belched out gamma rays (*SN: 9/20/14, p. 15*). No one had expected this type of eruption, called a nova, to produce such high-energy light. Novas are thermonuclear blasts on the surfaces of white dwarfs that have gorged themselves on gas from a companion star. To spit out gamma rays, the blast needs to run into more gas, which is absent around typical novas. Laura Chomiuk of Michigan State University and colleagues monitored radio waves from one of the novas last year. As the white dwarf and its companion danced around each other, gas blown out between the stars slowed down while gas leaving their poles sped away, Chomiuk's team reports October 8 in *Nature*. Shock waves formed where the high-speed gas ran into the sluggish debris, accelerating charged particles that in turn produced gamma rays. Understanding novas could help explain whether these eruptions are precursors to type 1a supernovas. — *Christopher Crockett*

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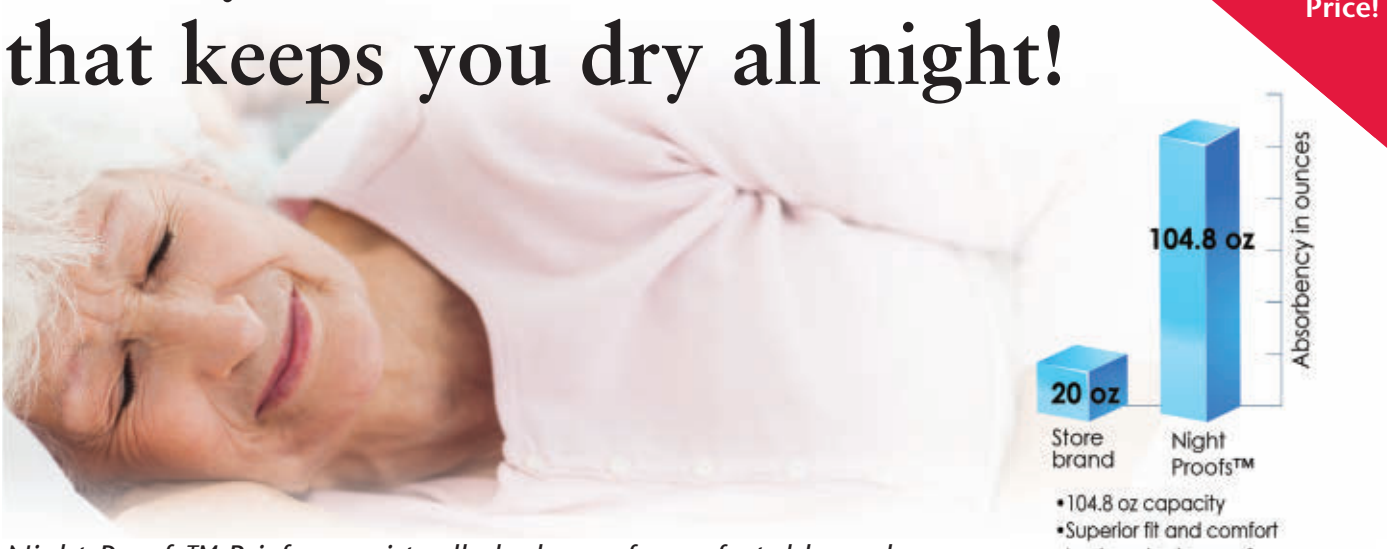

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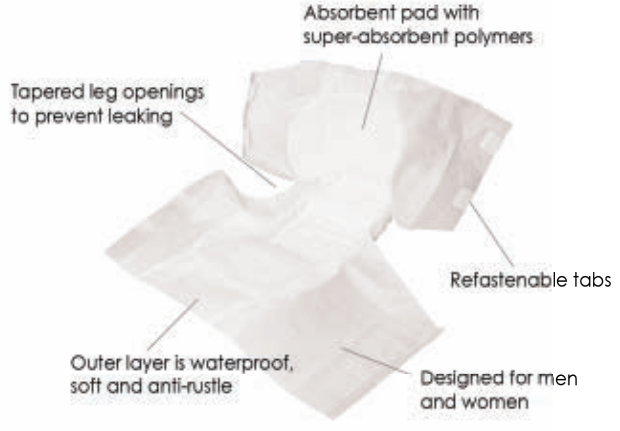

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Bacterial Healers

Microbes can redeem themselves to fight disease

By Susan Gaidos

Normally, you wouldn't want to have anything to do with *Clostridium novyi*.

The rod-shaped bacterium is commonly found in soil, manure or under rotting leaves. When it invades a human body, it releases flesh-eating toxins. The last place you would hope to find it is in a hospital.

But researchers used a modified version of this bacterium to destroy an advanced cancer that had spread to a patient's shoulder. When injected directly into the shoulder tumor, the altered bacterium killed the cancer cells, sparing nearby healthy ones.

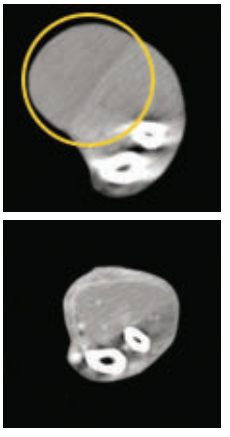
Another bad bacterium, *Listeria monocytogenes*, is a frequent culprit in serious foodborne illnesses. But the microbe is being tested in patients with several types of cancer. Engineered with special tumor-recognition molecules, *Listeria* prods the immune system into action, marshaling an attack against tumors that the body might otherwise be unable to combat.

True, these bacteria first had to be genetically reengineered to change their wicked ways. But this unlikely approach, fighting disease with agents known for causing illness, is gaining ground.

It's just a matter of time before bacterial-based treatments become a routine part of a doctor's toolkit, says microbiologist Robert Britton of the Baylor College of Medicine in Houston, who is studying the relationship between microbes and human health. Dangerous pathogens, once properly tweaked for the task, will become treatments for tumors and maybe infectious diseases such as malaria and HIV. Scientists are also modifying viruses to attack cancer cells.

Along with the bad bacteria persuaded to do good, some helpful bacteria are being enhanced to treat disorders such as osteoporosis (see sidebar, Page 20).

"I think the potential is enormous," says Martin Blaser, a microbiologist and physician at the New York University School of Medicine. "But there's a lot of homework that has to be done in order to bring this to the clinical realm."



Before treatment, a soft tissue sarcoma in a dog's leg fills the yellow circle (top image). Two months after injection with modified *C. novyi* spores, the tumor disappeared.

Dangers disabled

Efforts to develop bacterial-based treatments date back more than a century. In the 1890s, New York surgeon William B. Coley began using a brew made from infectious microbes to treat cancer patients. Intrigued by reports of patients whose tumors had shrunk after a brief bout with a bacterial infection, Coley mixed two strains of harmful bacteria, heating the solution to kill the bacteria. Over the next few decades, Coley and others treated cancer patients with mixed success: Tumors shrank or quit growing in some patients but not in others. By the 1950s, doctors had abandoned the treatment and began using chemotherapy.

Coley hypothesized that infection with his bacterial brew could somehow shift patients' immune response into overdrive, so that immune cells that rose up to vanquish the bacteria would also attack the cancer cells. Today, scientists are taking a fresh look at bacterial-based treatments to do just that. Live or disabled versions of harmful bacteria are being used to develop therapeutic vaccines for cancer. Unlike typical vaccines, which prevent certain infections before they can take hold, the bacterial-based vaccines train the body to recognize and destroy cancer cells that have already infiltrated.

Case in point: *L. monocytogenes*, a microbe that contaminates vegetables, dairy products and meat. Infection with *Listeria* can trigger days of intestinal distress. Some sufferers — especially children, the elderly and people with weakened immune systems — require hospitalization due to dehydration. An infection that spreads to the bloodstream can be deadly.

Microbiologist Daniel Portnoy of the University of California, Berkeley, an expert on *Listeria*, says the bacterium's ability to work its way into cells and trigger an intense immune response makes it an ideal carrier for these types of vaccines. While many disease-causing microbes do their dirty work from the outside — injecting toxins into cells — stealthy *Listeria* enters the cell and then goes to work. When consumed, say, in contaminated cantaloupe or cheese, *Listeria* makes itself at home after being gobbled up by an immune system cell called a macrophage.

The macrophage traps the microbe in a small, jail-like compartment within the cell called a vacuole, where it can supposedly do no harm. But once inside the vacuole, *Listeria* makes a protein called listeriolysin O, which forms a large pore, rupturing the vacuole. Now free within the cell, *Listeria* replicates rapidly and produces a protein called ActA, which uses the cell's internal framework to move to the cell's rim and then exit to spread infection to other cells.

This activity doesn't go unnoticed by the immune system — which is the point. Some tumors can tamp down the immune system, or even trick immune cells into aiding tumor growth. Fortunately, these are the very cells that *Listeria* infects. Once infected with the microbe, macrophages signal to other parts of the immune system to respond. The immune system creates an army of T cells designed to attack *Listeria*. In addition, the immune system creates a "memory" that makes future responses against that strain more efficient.

By knocking out the gene for the ActA protein, Portnoy and his group created a version of the bacterium that can generate a strong immune response without causing illness. Over

OPPOSITE PAGE: NICOLLE RAGER FULLER; THIS PAGE: N. ROBERTS *ET AL*/*SCIENCE TRANSLATIONAL MEDICINE* 2014

the last decade, Portnoy has worked with scientists at two biotech companies, including Berkeley-based Aduro BioTech, to turn the genetically engineered microbes into disease-fighting machines.

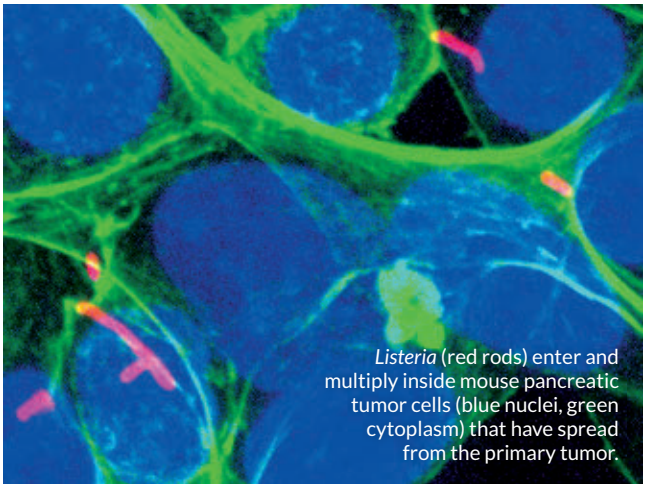
Recently, scientists at Aduro successfully inserted proteins that recognize pancreatic cancer cells into disabled *Listeria*. When given to patients, the microbes work their way into cells and spur the immune system into action, as usual. In addition, *Listeria* expels the proteins, known as tumor-specific antigens, which flag the cancer cells as a danger to the immune system.

In an early trial in patients with pancreatic cancer, the *Listeria* vaccine in combination with a cancer vaccine called GVAX (composed of tumor cells genetically altered to stimulate an immune response) improved overall survival, shrinking tumors and halting tumor growth. Patients who received the disabled *Listeria* plus GVAX survived longer than patients who received GVAX alone (6.1 months vs. 3.9 months).

Tom Dubensky, chief scientific officer for Aduro, says about 10 percent of the patients have been on *Listeria* therapy for more than a year. In July, the U.S. Food and Drug Administration granted the *Listeria* treatment "breakthrough therapy" status, allowing it to be fast-tracked for development and review by the agency.

In addition, Aduro is sponsoring early phase clinical trials using the same *Listeria* strain to treat mesothelioma and brain cancer, and plans are under way to develop a treatment for prostate cancer. For each treatment, a tumor-specific antigen is embedded in the *Listeria* to target select types of tumors.

Listeria can carry a payload of radiation to tumors as well.



Listeria (red rods) enter and multiply inside mouse pancreatic tumor cells (blue nuclei, green cytoplasm) that have spread from the primary tumor.

Scientists at the Albert Einstein College of Medicine in New York City are developing a radioactive form of *Listeria* to target tumors that have metastasized, or spread away from the main tumor. A team led by microbiologist Claudia Gravekamp and radiologist Ekaterina Dadachova attaches a radioactive isotope of rhenium — commonly used in conventional radiotherapy — to the bacteria. When injected into the abdomen of mice with pancreatic cancer, the radioactive microbes wiped out 90 percent of the metastasized tumors, the researchers reported last year in the *Proceedings of the National Academy of Sciences*.

"The *Listeria* does not necessarily need to be inside the tumor cells to kill them since the radioactivity has a

Bone-builders

Disease-causing bacteria give microbes a bad name, but in fact, many microbes in the human body do good.

Robert Britton of the Baylor College of Medicine in Houston has found that one strain of the bacterium *Lactobacillus reuteri* may dial down inflammation, helping to stop the bone loss that occurs after menopause.

L. reuteri is frequently found in the intestines of animals and humans. Different strains of *L. reuteri* have been shown to promote health by fighting off bad bacteria and producing certain B vitamins. In August 2013, Britton and his group published findings in the *Journal of Cellular Physiology* showing a probiotic supplement of *L. reuteri* helps male mice build stronger bones.

Femur density healthy mouse

Bone loss ovary-free mouse

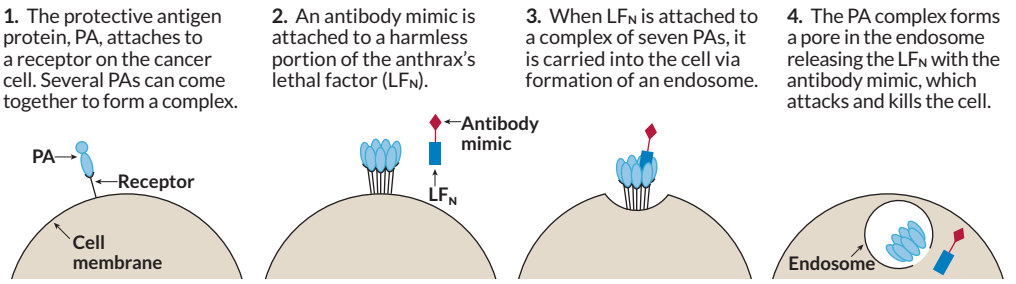
Density boost ovary-free mouse plus *L. reuteri*

L. reuteri also prevents bone loss in certain female mice, the group reported in the November *Journal of Cellular Physiology*. *L. reuteri* suppresses the rapid loss of bone that occurs when mice have their ovaries surgically removed to simulate menopause. The bone loss is caused by inflammation within the bone marrow. It occurs at low levels in men and women, but accelerates in women as they age, especially after menopause.

Britton and his colleagues hope to determine how *L. reuteri* prevents or slows bone turnover. One theory under investigation is that *L. reuteri* somehow works on an estrogen-receptor pathway. Like menopausal women, the mice with their ovaries removed make less estrogen. Other theories under study: The microbe makes a protein or enzyme that travels to the bone through the bloodstream or perhaps it alters the makeup of the microbiota to tighten what is known as a "leaky gut."

"As we get older, our guts become more permeable and allow things into our bloodstream that cause inflammation," Britton says. By calming the gut and suppressing that process, *L. reuteri* could help stop inflammation and bone loss, he adds. — *Susan Gaidos*

FROM TOP: DINESH CHANDRA; R.A. BRITTON *ET AL/JOURNAL OF CELLULAR PHYSIOLOGY* 2014



A way in Anthrax toxin from the *Bacillus anthracis* bacterium is composed of three proteins, called protective antigen, edema factor and lethal factor. They can be manipulated to enter certain cancer cells and help kill them.

SOURCE: AMY RABIDEAU AND B. PENTELUTE/MIT

cross-fire effect," Gravekamp says. "That means they can kill tumor cells at a short distance." Because radioactive *Listeria* infects only certain immune cells that are attracted by the tumor to help it grow, healthy cells are not harmed by the treatment.

Delivering the goods

Anthrax toxin, from the bacterium *Bacillus anthracis,* brings to mind envelopes of scary white powder. The thought is frightening for good reason. "Some of the most toxic materials on Earth are produced by bacteria," says microbiologist Bradley Pentelute at MIT.

But anthrax may get a chance to improve its reputation as scientists use its destructiveness for good. The toxin works its way into cells, carrying its deadly payload. Pentelute is putting this cargo-carrying feature to work to address a major challenge in biotechnology, delivering therapeutic proteins into cells by getting past the cell's protective plasma membrane.

Anthrax toxin is composed of three proteins: edema factor, lethal factor and protective antigen, or PA. The PA is nontoxic and carries the dangerous edema factor and lethal factor into a host cell. First, it binds to a receptor on the surface of a cell, latching on "like Velcro," Pentelute says. Once bound, the PA becomes activated on the cell surface and forms an indentation called an endosome that gets swallowed by the cell. Inside the endosome, the PA rearranges itself, forming a syringelike complex that injects anthrax's two deadly enzymes into the cell.

Pentelute and his team have revised the anthrax toxin to replace one of the toxic proteins with an antibody mimic that targets chronic myeloid leukemia cells. In laboratory studies, the PA protein delivers its cargo of the antibody mimic into the cancer cells, which causes cell death. The researchers published their results online September 22 in *ChemBioChem*.

Although not yet tested in animals or humans, the system is versatile and can be adjusted to deliver almost any antibody mimic to target any protein, Pentelute says. In his quest to deliver a broader range of therapeutics into cells, Pentelute plans to develop similar systems using the bacteria that cause diphtheria, cholera and botulism, which he hopes will deliver cargo that anthrax can't.

The bacterium called *C. novyi,* thrives in places where there is little or no oxygen. Once it finds its way into the body, it can chew through muscle tissue. Molecular biologist Shibin Zhou of Johns Hopkins University and colleagues are exploiting the microbe's love affair with low-oxygen environs to reach inside clusters of tumor cells, where oxygen is often scarce.

Proving there's a time and place for everything, the research team, including scientists at BioMed Valley Discoveries in Kansas City, Mo., are genetically altering the microbe, removing the lethal-toxin gene. The new, nonlethal strain, called *C. novyi-NT* for "nontoxic," still produces enzymes that eat proteins and lipids in cell membranes. The researchers have injected spores of *C. novyi-NT* directly into tumors of rodents, dogs and a woman whose advanced cancer had resisted all other treatments.

When injected, two things happened, as the team reported in the Aug. 13 *Science Translational Medicine*: The bacteria digested the tumor and the infection induced a powerful immune response, bringing the immune cells into the fight.

"This strong immune response, we believe, not only targets the bacteria, but it targets the cancer as well," Zhou says. After the bacteria was injected into her shoulder, the patient regained use of her arm, which had become immobile. She also developed a fever, severe pain in the injection area and an abscess in the tumor that doctors had to drain. She died six months after treatment due to cancer that had not been treated with the experimental bacteria.

C. novyi-NT is being tested in patients with various solid tumors in a clinical trial conducted in seven U.S. cities. But it will probably work only in tumors with low-oxygen cores, Zhou says.

The early findings are exciting, but some researchers suggest caution. Stanford University biologist David Relman notes that many of the bacterial-based treatments in development need further testing for safety and government approval, especially in cases of genetically engineered strains. And even "good bugs" can have unexpected effects when given in large quantities, he says.

In some cases, Relman adds, scientists don't fully understand how the microbes work. But he says he's in favor of pursuing strategies to use them for medicine. After all, certain bacteria have been making people sick since the origin of humans. With the ability to engineer nontoxic strains, these microbes might just change their ways and help conquer disease. ■

Explore more

- Daniel A. Portnoy. "Yogi Berra, Forrest Gump, and the discovery of *Listeria* actin comet tails." *Molecular Biology of the Cell*. April 1, 2012.

E. OTWELL

Touchdown on a Comet

Rosetta and its lander explore an ancient relic of the solar system **By Ashley Yeager**

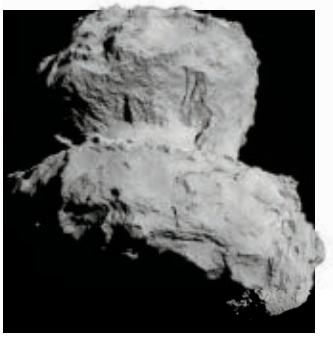
On November 12, scientists will attempt to land a robot on a comet, as shown in this illustration. If successful, the team will have a front-row seat to the spectacular show of a comet approaching the sun.

Very soon, on November 12, a spacecraft called Rosetta will sidle up to a comet, steady itself and drop a 100-kilogram robotic lander toward the hunk of rock, dust and ice. The lander, named Philae, will drift through space, tugged only slightly by the gravity of the comet, commonly called 67P. Mission scientists will be holding their breath for what could be several anxiety-filled hours to see if Philae lands where and how it's supposed to.

The exercise — the first attempt to set a lander on a comet — is as nerve-racking as landing on Mars or the moon, with some added challenges. Comets and other small space rocks have much less gravity than planets or moons, which is why it will take Philae close to seven hours to float to comet 67P's surface. Then there's the comet's speed: Rosetta will drop the lander toward 67P as the comet shoots through the solar system at 55,000 kilometers per hour.

Add to that a comets' unpredictable nature: At any moment and without warning, 67P might spew out jets of gas and dust. Such eruptions could blow the spacecraft off course or skew the lander's trajectory so it hits a boulder or misses its mark.

Early in the mission, scientists estimated that Philae had a 70 to 75 percent chance of successfully touching down on the comet, officially known as 67P/Churyumov-Gerasimenko. They made that prediction when they thought the comet was shaped like a potato. In July, Rosetta began sending pictures of 67P, indicating it looks more like a rubber duck — two masses connected by a thin neck. The new shape adds a bit more uncertainty to Philae sticking its landing.



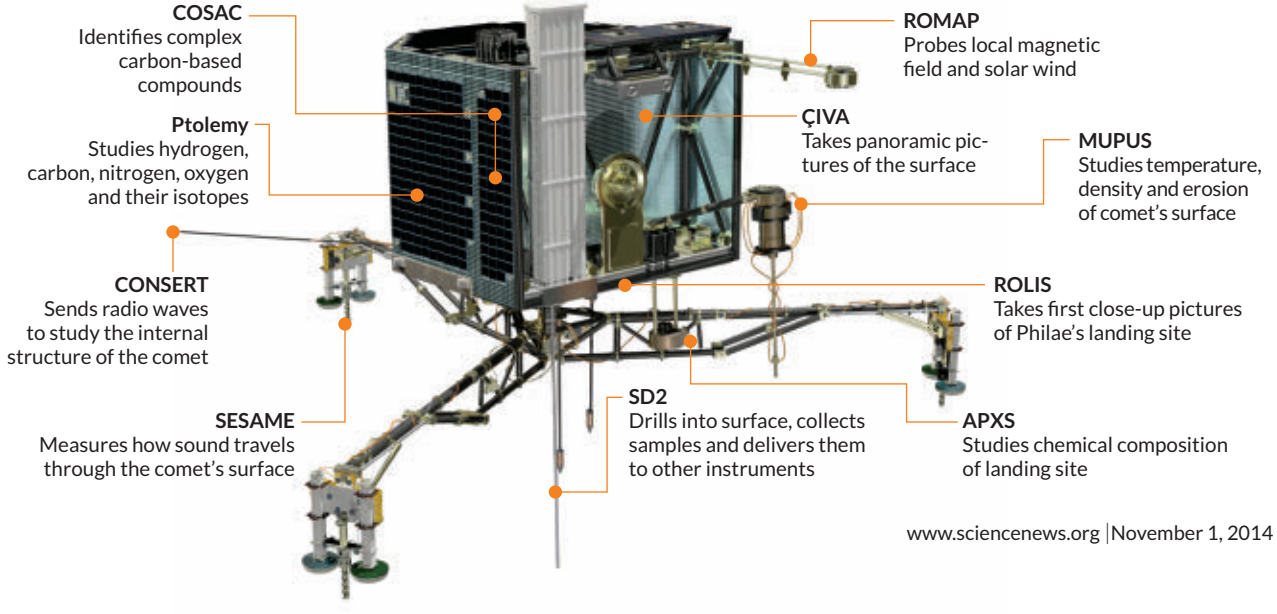
Rosetta photos revealed that comet 67P resembles a roughly 4-kilometer-wide rubber duck covered in crevices and cliffs.

The potential payoff of this mission is worth the hazards and the nail-biting, says Matt Taylor, Rosetta's project scientist at the European Space Agency's Science and Technology Center in Noordwijk, the Netherlands. Comets, along with asteroids, are thought to be the oldest, most pristine relics of the early solar system. We can't go back billions of years to the birth of the sun, Taylor says, so exploring comets and asteroids may be the best option for learning how the solar system evolved. Studying their geology and chemistry could give clues to how the planets became what they are today and whether comets brought water and other ingredients for life to Earth.

Cometary close-up

Rosetta's rendezvous with the comet, which is currently traveling between the orbits of Mars and Jupiter, has been a long time coming. The mission was first conceived in the late 1970s. By late 2002, when ESA was preparing to finally launch Rosetta, disaster struck. As part of a separate mission, the same type of rocket that was set to carry Rosetta exploded three minutes after liftoff. That rocket failure delayed Rosetta's launch, closing the

A busy machine The comet lander Philae is named after an island in the Nile where two ancient obelisks helped archaeologists decipher hieroglyphics. The lander is equipped with 10 instruments designed to take panoramic pictures of comet 67P's surface and investigate its chemical composition. SOURCE: ESA



OPPOSITE: ESA, ATG MEDIALAB; FROM TOP: NAVCAM/ROSETTA/ESA; ESA; ATG MEDIALAB

Rosetta's history

March 2, 2004
Rosetta and Philae launch

Late 1970s/early 1980s
Rosetta mission proposals developed

December 11, 2002
Rocket failure postpones Rosetta launch

A long road More than 30 years since its conception, the Rosetta mission hit a major milestone — catching up with comet 67P — in August. The next big steps are getting the lander Philae to 67P's surface and staying with the comet through 2015.

window to the original target of the mission, 46P/Wirtanen. Over the next few months, scientists scrambled to find another comet that would be at the right place in the solar system at the right time. 67P fit the bill.

Rosetta finally launched in 2004. Ten years later, on August 6, the spacecraft began orbiting 67P, and its 11 instruments started scrutinizing myriad characteristics of the comet (*SN: 9/6/14, p. 8*). Those instruments, plus the cameras and sensors on the Philae lander, are designed to map 67P, determine what it's made of and observe how its chemistry might change as it swings around the sun.

As 67P approaches the sun, its ice transforms directly to water vapor and other gases, which, along with dust, shoot outward. These jets collide with other particles from the sun to form two tails. Unlike Halley's comet and its showy run in 1986, 67P's tails won't be visible to the naked eye. But Rosetta will have a front-row seat on the action. As the comet's tails grow, Rosetta will give scientists their most detailed look at a comet and the changes it goes through.

Already, Rosetta's high-resolution photos have shown scientists that 67P looks different than other comets explored with spacecraft. It may even be two comets merged together with a surface that's a mountain climber's dream.

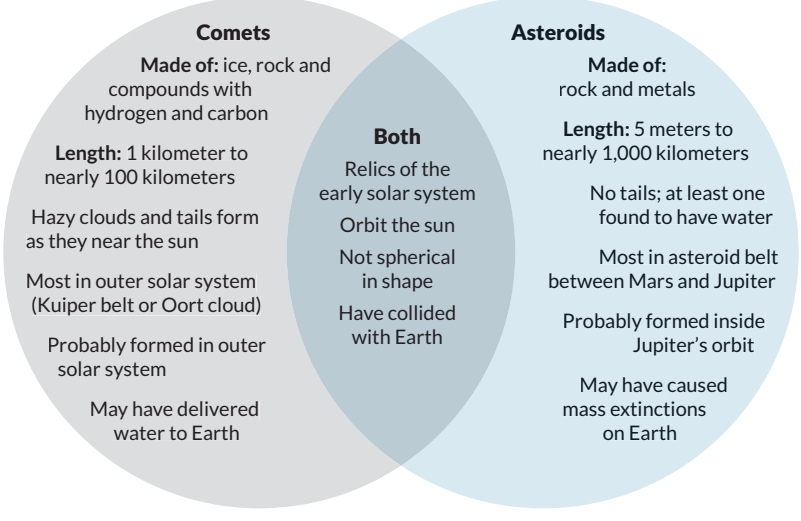
"The team really hit the jackpot with this comet," says Donald Brownlee, a planetary scientist at the University of Washington in Seattle. Seeing a duck-shaped comet with house-sized boulders, craggy craters and 150-meter-high cliffs "really knocks your socks off," he says. The bath-toy shape and rugged surface indicate that the comet has had an interesting life history, one scientists are eager to learn about. But first, they've got to get their instruments down to the comet's surface.

"This very particular shape of the comet doesn't make it easy to land," Philae project manager Stephan Ulamec of the German Aerospace Center in Cologne said at a September 15 news conference. But the team has confirmed that it will attempt to set the lander down in November on a sliver of flat land on 67P's small lobe, or head. The spot is flanked by cliffs, crevices and a few boulders.

It is also covered in carbon-rich dust, according to Rosetta's measurements, which makes mission scientists extremely happy with the site, says lead lander scientist Jean-Pierre Bibring of the Université Paris-Sud in Orsay, France. The lander, he explains, can immediately start testing the comet's surface and drill deeper to look for traces of ice and complex carbon-based compounds, which are among the major requirements for life.

Ice and certain complex carbon compounds are also some of the characteristics thought to distinguish comets from asteroids, the other early inhabitants of the solar system.

Distinctions blur Comets and asteroids seem to be different at first glance. But more detailed descriptions from space missions such as Rosetta suggest that the two types of space rocks may have more in common than scientists initially thought.



Rethinking space rocks

"At first glance, comets are fundamentally different from asteroids, the way ice cream is different from a cookie," says NASA scientist Claudia Alexander, based at the Jet Propulsion Laboratory in Pasadena, Calif. Most asteroids appear to be made of rocky materials and no water. Comets, however, seem to be icier. These distinctions are thought to explain where comets and asteroids originated as the solar system formed.

Scientists think that around 4.6 billion years ago, the solar system started to form as a giant cloud of gas and dust collapsed inward and

ESA, ATG MEDIALAB

See animation of Philae's landing at **bit.ly/SN_Rosetta**

September 5, 2008
Flyby and imaging of asteroid Steins

July 10, 2010
Flyby and imaging of asteroid Lutetia

August 6, 2014
Rosetta arrives at comet 67P

November 12, 2014
Philae deploys to surface

August 13, 2015
67P and Rosetta make closest approach to sun

December 31, 2015
Proposed mission end date

coalesced. Most of the material got pulled into the center of the cloud to form the sun. The rest condensed into a handful of huge rocks that became planets plus smaller bodies that became comets and asteroids.

In that scenario, asteroids probably formed between Mars and Jupiter, where it was too hot for water and other ices to survive. Comets, on the other hand, probably condensed farther out in this embryonic cloud where it was considerably cooler and ice could persist and start to attach to clumps of gas and dust.

If comets formed far out in the Kuiper belt or Oort cloud, where there was a lot more ice, they could have ferried a lot more water to Earth than did asteroids from the inner solar system.

"That's the conventional wisdom," says Alexander, a leader of the U.S. arm of Rosetta. NASA contributed electronics and three instruments to the mission; at least one of these instruments will look at 67P's water.

Rosetta and Philae will give scientists a chance to virtually "get their hands on" the comet's ice, says Alexander. That could help them figure out pretty quickly whether comets like 67P brought water to Earth billions of years ago.

The first question: What type of water is on 67P? If it is the same H_2O that makes up Earth's oceans, then perhaps 67P and similar comets brought that water to Earth. But if 67P, like most comets studied so far, contains a larger amount of the heavy hydrogen isotope called deuterium than does water found on Earth, then the idea that comets brought most of the water here is less likely.

That opens the door for the paradoxical idea that asteroids were the main source of our planet's water. Scientists have recently found at least one asteroid with water. For example, the asteroid Ceres (actually large enough to be considered a dwarf planet) orbits the sun on a path between Mars and Jupiter, but it spouts off water vapor, sort of like a comet.

To confuse matters further, Rosetta's observations indicate that 67P has characteristics of an asteroid. The comet, for example, isn't covered in surface ice. Instead, its water appears to be stored deeper within its core.

Comets visited by spacecraft

Giacobini–Zinner
Spacecraft: International Cometary Explorer (ICE), 1985
Shape: probably round, diameter 2 kilometers
Surface and Composition: unknown (ICE studied only the tail)
Length of orbit: 6.6 years

Halley
Spacecrafts: Giotto, Vega 1, Vega 2, ICE, Suisei, Sakigake, 1986
Shape: peanut, diameter 15 kilometers
Surface: dark and possibly dusty
Composition: water, carbon dioxide, carbon monoxide, methane and other hydrocarbons, ammonia, traces of iron, sodium and polyoxymethylene
Length of orbit: 75.3 years

Borrelly
Spacecraft: Deep Space 1, 2001
Shape: chicken leg, diameter 4.8 kilometers
Surface: tar black
Composition: water, carbon monoxide, methanol and formaldehyde
Length of orbit: 6.84 years

Wild 2
Spacecraft: Stardust, 2004
Shape: egg, diameter 4 kilometers
Surface: dark with craters, spires and pits
Composition: water, iron, copper sulfide and glycine
Length of orbit: 6.41 years

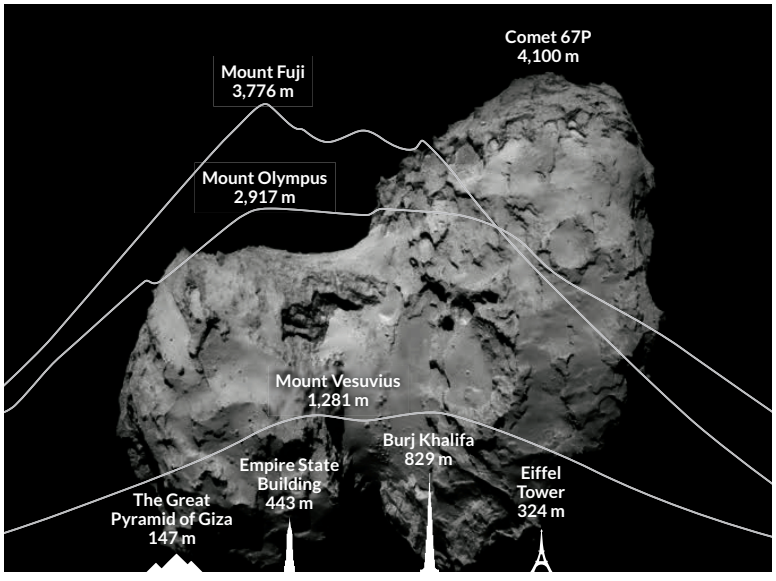
Tempel 1
Spacecraft: Deep Impact, 2005; Stardust-NExT, 2011
Shape: boulder, diameter 6 kilometers
Surface: dark and dusty with craters and large cliffs
Composition: water, carbon dioxide, silicates and clays
Length of orbit: 5.56 years

Hartley 2
Spacecraft: Deep Impact, 2010
Shape: duckling, diameter 1.6 kilometers
Surface: black with smoothed middle and building-sized boulders on the ends
Composition: water, carbon dioxide and methanol
Length of orbit: 6.46 years


Halley

MPAE LINDAU, ESA

A mountain of a comet 67P is average in size when it comes to icy space rocks. Compared with human-made structures, however, it's a behemoth, miniaturizing several iconic world wonders and rivaling the height of many of Earth's famous mountains. SOURCE: ESA



These observations hint that comets and asteroids aren't as radically different as scientists had thought. Instead, they may fall on a continuum with rocky, dry asteroids on one end, really icy comets on the other and everything else in between, Alexander says.

Getting warmer

When a comet gets close to the sun, a lot of its ice turns to vapor, and dust comes shooting out of its core. The comets with shorter orbits around the sun — 67P takes a brief 6.5 years — could eventually lose all of their ice and vapor leaving only rock and dust. Of course, scientists can't really understand the long-term fate of 67P and other comets until they figure out the chemistry of what happens as a comet swings close to the sun on its elliptical orbit.

"We have theories about what happens to a comet as it gets closer and then moves away from the sun, but we do not understand how a comet really works," says retired ESA scientist Gerhard Schwehm, one of the original leaders of the Rosetta mission.

That's because scientists have never been able to stay with one for very long. All the previous comet missions have been flybys, lasting a few hours. If Philae sticks its November landing, it could work on the surface of 67P until March 2015, when the sun's heat will become too hot for the lander to function. Rosetta will stay with 67P through August, when the comet reaches its closest point to the sun at a distance of 185 million kilometers. But Rosetta won't give up there. It will continue orbiting the comet until at least December 2015.

Spending a year or more with 67P will give scientists a chance to track how the sun's heat changes the comet's composition over time. To do this, Philae will first identify the elements and compounds that make up the comet's surface. These materials may have survived unchanged for billions of years and could give scientists clues to what materials were available when the solar system started to form.

Scientists are most interested in molecules containing carbon and hydrogen (see story, Page 7), which could have existed even before the birth of the solar system. Investigators are also looking for amino acids and other building blocks of life that may have been brought to Earth by comets. Past missions have found both kinds of materials on comets before (see sidebar, Page 25). If they exist on 67P, they could add more evidence for scientists' ideas that comets delivered the ingredients for life to Earth.

However, because scientists have never studied a comet while it faces the sun's intense heat, they cannot be sure if these molecules are primordial or if they formed later, after being cooked by the sun. There are hints to support both origin stories. Rosetta's observations could tell scientists if some of the molecules they see on the comet predate the solar system, or if they are created in reactions from the sun's heat.

This August 11 image from a ground-based telescope shows 67P's tails beginning to emerge.

The comet's chemistry could also have implications for places far beyond Earth, says Edward Young, a geochemist at the University of California, Los Angeles. "Establishing the link between these primitive building blocks of planets and our own planet will go a long way toward helping us understand whether rocky planets with at least as much water as Earth are the norm, or not," he says.

That's a lofty goal, one that hinges on a spectacular landing and the final 14 months of Rosetta's 10-year voyage. ■

Explore more

- European Space Agency's Rosetta mission page: rosetta.esa.int/
- Where is Rosetta?: bit.ly/whereisrosetta

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The challenging but rewarding relationship between Stephen (Eddie Redmayne) and Jane (Felicity Jones) Hawking plays a central role in *The Theory of Everything*.

FILM

'The Theory of Everything' reveals Stephen Hawking's personal side

When Stephen Hawking (played by Eddie Redmayne) first tries out his now-iconic computerized voice, his wife Jane (Felicity Jones) is aghast: "It's American!" she says. That line draws a laugh, but it also highlights a pivotal draw of *The Theory of Everything*: That American-accented robotic voice is one of the few things most people know about this brilliant, complicated — and British — man.

"Very little is understood about [Hawking] in America or Canada," says Anthony McCarten, the film's screenwriter. "Nine of 10 people think he's American. Most people think he was born disabled. They don't know he was married and has three kids. There's a lot of news to break with this film."

The movie, based on the 2007 memoir by Jane Hawking, starts in 1963, when Hawking is an able-bodied, intelligent and exceedingly lazy physics graduate student at the University of Cambridge. Just as he appears to be hitting his stride — he falls in love and begins developing insights into black holes and the origin of the universe — he is diagnosed with motor neuron disease (the British term for amyotrophic lateral sclerosis, or ALS) and told he has two years to live. (Nearly 50 years after his predicted expiration date, Hawking is still going strong.)

The rest of the movie shows that as Hawking rose to fame, thanks largely to his book *A Brief History of Time*, he and Jane were battling through a tumultuous 25-year marriage. The film impressively avoids sensationalizing the deterioration of the Hawkings' relationship, which ends with Stephen marrying the nurse Jane hired for him and Jane marrying a choir director who helped take care of Stephen.

The Theory of Everything
OPENS NOVEMBER 7
FOCUS FEATURES

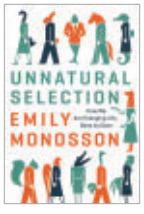
McCarten and director James Marsh get creative trying to incorporate Hawking's contributions to science: Cream swirling around a coffee cup illustrates the region around a black hole, while Jane Hawking uses a pea and a potato to explain the difference between quantum theory and general relativity. But for the most part, science takes a backseat to a story about love and, as Marsh puts it, "a battle against impossible odds to have a meaningful life."

McCarten says Hawking was hesitant about the movie at first — "What man really wants his story told by his ex-wife?" McCarten asks — but warmed up to it after reading the script. He visited the set a few times and offered his robotic voice for use in the film.

A tear ran down Hawking's face after he saw the completed film for the first time, McCarten says. Then, twitching his cheek to scroll through letters on his computer, Hawking composed two words: "Broadly true."

"That's a ringing endorsement," McCarten says. "I'll take that any day." — *Andrew Grant*

BOOKSHELF

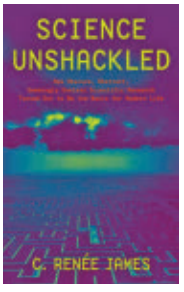


Unnatural Selection
Emily Monosson
The drugs, pesticides and other industrial chemicals that people dump in the environment are altering the evolution of everything from disease-causing microbes to fish, a toxicologist explains. *Island Press, $30*

Do Zombies Dream of Undead Sheep?
Timothy Verstynen and Bradley Voytek
Capitalizing on the popularity of zombies, two neuroscientists draw on the odd behavior of the walking dead to serve up some real science about how the brain works. *Princeton Univ., $19.95*

Dodging Extinction
Anthony Barnosky
A paleobiologist highlights evidence from the geologic record to make the case that Earth is on the cusp of a sixth mass extinction and offers advice on how to avoid it. *Univ. of California, $29.95*

LIAM DANIEL/FOCUS FEATURES



BOOKSHELF

How We Got to Now

Steven Johnson

Science Unshackled

C. Renée James

The route from scientific discovery to useful invention is often long and tortuous, extending over a horizon concealing a destination that can't be seen — or sometimes even imagined. Two new books on the history of technology do a good job chronicling engrossing tales of serendipitous innovation.

In *How We Got to Now*, best-selling author Johnson traces the development of six technologies vital to modern life from their modest beginnings to their oft-unintended consequences. Take artificial refrigeration. Who could have imagined that an entrepreneur's plan to harvest ice from frozen lakes in New England and ship it to the Caribbean in the early 1800s — despite ridicule that islanders wouldn't want anything cold to drink — would eventually lead to everything from home air-conditioning to in vitro fertilization?

In similarly circuitous and fascinating tales, Johnson recounts how the development of clocks, lenses, water purification, recorded sound and artificial light sculpted the world we inhabit today.

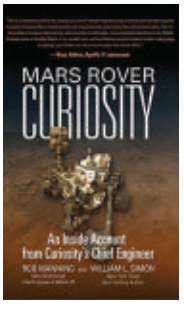
In *Science Unshackled*, James, an astronomer at Sam Houston State University in Huntsville, Texas, ambitiously takes readers on the same sort of quests but focuses on more recent developments. For instance, she describes how mathematical techniques used by astronomers in the search for moderate-sized black holes helped engineers develop Wi-Fi. The study of heat-loving microbes found in the hot springs of Yellowstone National Park, she explains, led to techniques of genetic analysis vital to forensic investigations, paternity testing and the Human Genome Project.

While *How We Got to Now* describes technologies largely in terms of their broad cultural impact, *Science Unshackled* often provides a detailed look at the basic science behind the innovations themselves.

And by focusing on the scientific foundations for these well-known technologies, *Science Unshackled* makes a compelling case for continued support for research. While many people fail to see the need for government investment in basic science, James cites figures from the National Science Foundation that overall U.S. expenditures in fundamental research see a return on investment of between 20 and 60 percent.

Both books are celebrations of ingenuity and the scientific process. They are filled with troves of examples of how scientific research can transform our lives in important yet often unpredictable ways. — *Sid Perkins*

How We Got to Now*: Riverhead, $30;* Science Unshackled*: Johns Hopkins Univ., $24.95*



BOOKSHELF

Mars Rover Curiosity

Rob Manning and William L. Simon

During its first two years on Mars, NASA's Curiosity rover discovered that the Red Planet was once hospitable to life. For Manning, the rover's chief engineer, landing on Mars was the capstone of an adventure that started 10 years and $2 billion earlier.

In *Mars Rover Curiosity*, Manning and coauthor Simon offer a firsthand account of designing the most complex piece of machinery ever to land on another planet. Starting with a harebrained scheme and ending with a drive across the red dust of Gale Crater, the book deftly guides readers through the many setbacks, victories and difficult decisions that came with planning an interplanetary mission.

The book is a fun way to learn about the journey to Mars. The authors steer readers through the technical challenges without getting tangled in jargon. They explain engineering solutions with clear analogies, such as comparing lowering an 899-kilogram rover dangling from a hovering spacecraft equipped with an arsenal of thrusters to controlling a weight on a string with your fingertips while your eyes are closed.

Curiosity's story is set within the context of previous Mars missions and the culture at NASA. The endless loop of budget pressures and redesigns haunts Manning's team, eventually leading to a two-year launch delay and a temporarily shrink-wrapped spacecraft. But in the end, the team celebrated numerous successes, from convincing NASA to support a daring landing maneuver to the celebrated touchdown to the discovery of clays that formed when water once flowed across the Martian surface (*SN Online: 3/12/13*).

More than just a story about a nuclear-powered, laser-wielding robot, the book is about the people who brought Curiosity to life. Hundreds of engineers and scientists worked 70-hour weeks for years to make the impossible happen. And the effort took its toll: Manning lost (and regained) over 15 pounds and struggled with hypertension.

The book is a celebration of the ingenuity, the fears and the dedication of the people who were called to pull off one of NASA's most daring missions to Mars. — *Christopher Crockett*

Smithsonian, $29.95

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SEPTEMBER 20, 2014

Ebola — airborne or not?

Two years ago (SN: 12/15/12, p. 12) *an Ebola study stoked notions of a terror transmissible by air when pigs passed the virus to monkeys.* ***Tina Hesman Saey*** *reported in "Airborne transmission of Ebola unlikely"* (SN: 9/6/14, p. 7)*, though, that the phenomenon may be more thriller than threat.* The story reminded a few readers of a high-profile U.S. outbreak, when a variant of the virus appeared in lab monkeys imported from the Philippines. "Didn't the Reston, Va., Ebola outbreak of 1989 show evidence of aerosol transmission?" asked **Ken Jordan**.

First, keep in mind that *Reston ebolavirus* and *Zaire ebolavirus* (the pathogen ravaging West Africa) are different beasts. The Reston species has never caused illness in humans, **Saey** notes. And in the Reston incident, researchers never found definitive evidence of air-based transmission.

Much confusion about the issue stems from a failure to define terms, **Saey** says. "*Airborne* viruses create clouds of tiny dried particles containing the virus. These particles may hang in the air for relatively long periods of time," she explains. "People can contract such a virus by breathing it in. Those aerosols are different from the much larger mucus droplets sprayed by coughs or sneezes, which don't travel far before falling out of the air onto surfaces. People can catch the virus by touching a contaminated surface and then touching their nose or mouth. If someone sneezed right in your face, it's possible — but not likely — that droplets might land on your mucus membranes and infect you, but that is not airborne transmission." Ebola is not an airborne infection, it spreads by direct contact with body fluids.

Genes that fit

Laura Beil's *"Ancient genes, modern meals"* (SN: 9/20/14, p. 18) *looked into the debate surrounding calorie-conserving genes — a component of a popular obesity narrative that pits our species's genetic past against its dietary present.* **William Grant** defended the idea of "thrifty genes" by citing research on a protein-making gene called *APOE*. A genetic variant of *APOE* promotes fat storage, he wrote. "Hunter-gatherer peoples such as Pygmies have a high prevalence of this allele" — an adaptation theoretically connected to lasting long stretches without food.

"Body weight certainly has a genetic component," **Beil** responds, "but it's a product of perhaps hundreds, if not thousands, of genes. No single gene is responsible for the whole physiological response to an environment. Also, the correlation with hunter-gatherer societies doesn't necessarily have anything to do with starvation. Despite the common assumption that hunter-gatherers were more prone to food shortages, the evidence is not clear this is the case."

Sepsis and suppression

In "Collagen-making cells curb sepsis" (SN: 9/20/14, p. 15)*,* ***Nathan Seppa*** *described injecting mice with tissue-building cells to help prevent an often fatal immune system overreaction that occurs when bacterial infections reach the blood stream.* In the article, **Seppa** wrote that "suppressing immunity amid an infection is ill-advised." **John Hereford** took issue with that statement, drawing on his own observations as a medical laboratory technician involving cases of spinal meningitis that triggered septic shock. "I saw young teens, with healthy immune systems, alert and walking into the ER, only to expire in the next three to four hours," he wrote. He concluded that immune suppression may be exactly what is needed in some cases, if inflammation and not the bacterial infection poses a greater risk.

Treatment is tricky, says study coauthor **Shannon Turley** of Harvard Medical School. "You don't want to completely dampen or eliminate patients' immune systems. They have bacterial infections. You want to modulate immunity but not by completely wiping out the immune system of the patients, or they'd really be in trouble."

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When a rainbow goes full circle

A full double rainbow, captured from a helicopter flying over Cottesloe Beach in Western Australia, frames a golf course near Perth. A downpour reflects light from the setting sun back toward photographer Colin Leonhardt, creating two concentric rings of color that appear to encircle the course.

You can't touch a rainbow; birds can't fly over them, and leprechauns can't loiter at their ends. A rainbow is an illusion crafted by mist. Each water droplet behaves like a prism suspended in the air. The colors embedded in sunlight separate as they race through the droplet at different speeds. When the bands of color reach the far end of the drop, they bounce back toward the sun. People looking toward the mist with their back to the sun can see the rainbow.

All rainbows are round, but seeing a full circle requires a viewing area with plenty of droplets in all directions; that's tough for people on the ground. When the observer flies through a water-laden sky, however, a complete rainbow emerges.

The second, dimmer rainbow appears when light bounces off the inside of raindrops twice before coming back. Because most of the light leaks out after just one reflection, secondary rainbows are usually much fainter than primary ones. — *Christopher Crockett*

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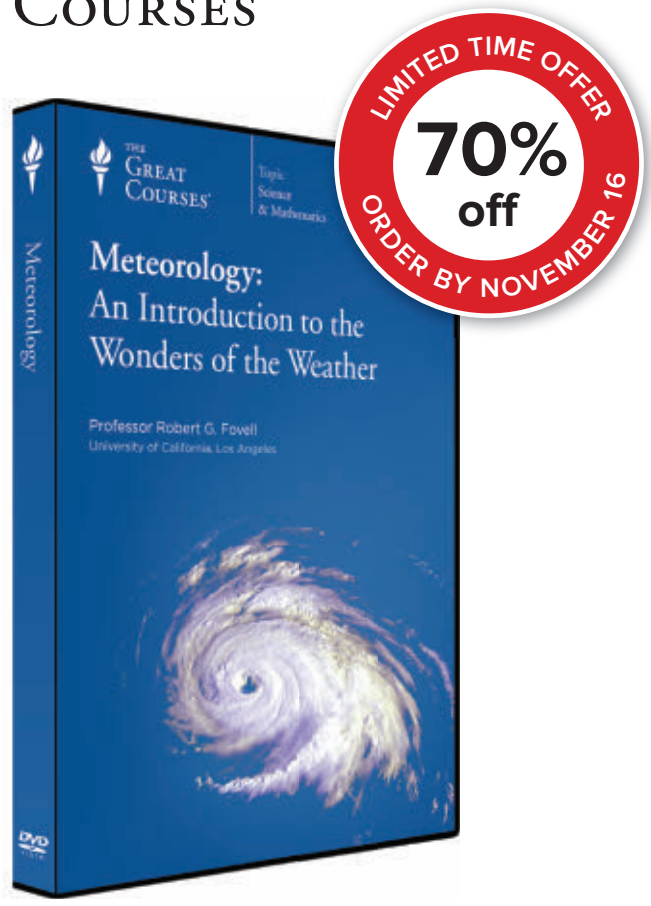

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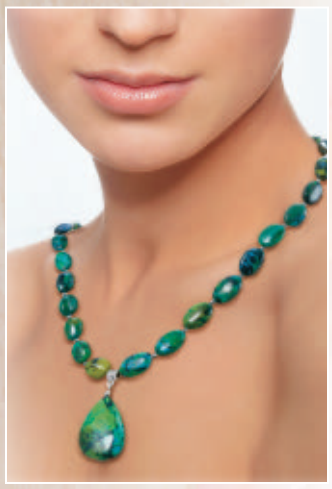

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