SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
JANUARY 25, 2014

Chaos Theory: Wall Street to Waterfront

The Primordial Galaxy Next Door

Rewiring Injured Brains

The Coldest Place on Earth

# The storied COLORADO

## Tracing the history of the river that carved the West

# Rare African Emerald Find Shocks Colombian Cartel

***U.S. jeweler seizes more than 10,000 carats and makes history by releasing the One-Carat Pride of Zambia Emerald Ring for UNDER $100!***

**LUSAKA, ZAMBIA** - A recent find of high quality emeralds in this African republic has thrown the luxury gem world into tumult. For hundreds of years, Colombians have controlled the high-end emerald market and sent prices soaring to over $15,000 per carat for top graded stones. But the history-making discovery of Zambian emeralds has revealed a green gemstone with mesmerizing clarity that simply changes everything.

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The rise of emeralds is more than just a passing trend. An article in the *Financial Times of London* from June of this year pointed to the reason. In "Emeralds: Shades of Green Start to Outshine Diamonds," the newspaper reported that emerald demand is soaring worldwide even as diamond demand softens. Rarity is key as fine emeralds are much rarer than diamonds.

"With wealthy Russian and Chinese demand for emeralds way up, we expect prices to continue to rise quickly," Bisceglia said. "That's why we're so happy to have found these beautiful stones at this price."

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# ScienceNews

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## Features



## News



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## Departments



**COVER** A controversy has arisen among geologists over the age of the Grand Canyon and of the river that carved it. *Michael Breitung/Flickr/Getty Images*

# Creativity offers insights into the past and future

Viewed through the window of an airplane, the Colorado River just seems so unlikely. On a cross-country flight this New Year's Day, I watched as the snow-covered Rockies gave way to pancaked expanses of red rock. At its headwaters in the mountain foothills, the Colorado makes sense. But as I watched it flow through the deep scars that its waters had carved into a desiccated landscape, the river felt strange.

As a native of drought-ridden Southern California, the Colorado River has always loomed large to me. It is the only game in town for much of the Southwest, irrigating farmland and flowing into city water supplies that allow tens of millions to call the desert home. Over the ages, the river has also played a central role in shaping the Southwest. Over millions of years it has cut through solid red rock to create the Grand Canyon and other spectacular landscapes. But how many millions? Just figuring out when the river began watering the Southwest has long puzzled geologists.

It turns out to be surprisingly hard to pinpoint the river's age. On Page 22, contributing correspondent Alexandra Witze reports on the latest efforts to understand the history of the mighty Colorado and its most dramatic work. Scientists are searching for ancient gravel and analyzing the chemistry of certain minerals in their efforts to paint a more complete picture of the Southwest through time.

That a mineral's chemistry can tell us something about how long ago its residential rock was eroded shows how creative scientists need to be when searching for clues about the natural world. Science writer intern Gabriel Popkin describes another creative approach to a hard problem in his article on Page 18. Popkin writes about a scientist who has sought to bring a new kind of mathematical model to fishery management, one that relies less on any biological understanding of fish and more on finding patterns in an enormous amount of historical data. These nonlinear analyses, already used to predict short-term changes in financial markets, offer a novel way of estimating how many fish can be caught without compromising a population's stability. That novelty has some managers hesitant to adopt the model, but at least the new approach reveals some of the shortcomings of current practice.

This type of creativity is one of science's most potent forces. With the long-term future of many fisheries in doubt and severe drought once again hitting the Southwest, coming up with new insights into the past and future on land and sea may be crucial to protecting some of our most precious resources.

*— Eva Emerson, Editor in Chief*



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SANDY SCHAEFFER

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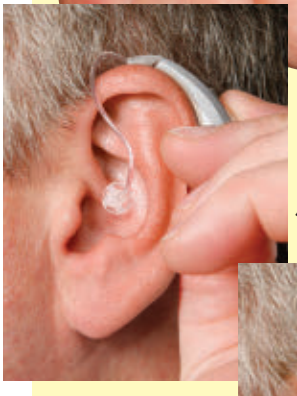

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Excerpt from the January 18, 1964, issue of *Science News Letter*

50 YEARS AGO

## "Black Holes" in Space

Space may be peppered with "black holes." This was suggested at the American Association for the Advancement of Science meeting in Cleveland by astronomers and physicists who are experts on what are called degenerate stars.... Degenerate stars are made of densely packed electrons and nuclei, or cores of atoms.... Because a degenerate star is so dense, its gravitational field is very strong. According to Einstein's general theory of relativity, as mass is added to a degenerate star a sudden collapse will take place and the intense gravitational field of the star will close in on itself. Such a star then forms a "black hole" in the universe.

**UPDATE:** *Science News Letter* was the first publication to use the term "black hole" in print, beating a story in *Life* magazine by a week with this news story by reporter Ann Ewing. Physicist John Wheeler has often been credited with coining the term in 1967, but actually no one knows who was first to use it, and Ewing's report did not specify who used the phrase at the 1964 meeting.

Springtails (*Orchesella cincta* shown) use a springlike appendage to fling their tiny bodies, just a few millimeters long, into the air.

IT'S ALIVE

## Sperm on a stick for springtails

For springtails, sex can be an Easter egg hunt. Many males of the tiny soil organisms sustain their species by leaving drops of sperm glistening here and there in the landscape in case a female chooses to pick one up.

"The male never meets the female," says Zaira Valentina Zizzari of VU University Amsterdam, who studies a species of these extreme loners called *Orchesella cincta*. Just about every degree of mating intimacy, from unseen sperm donors to elaborate courtship and internal insemination, shows up in springtails. That makes the ancient group — which may not belong to the insects but to another set of six-legged arthropods on its own evolutionary trajectory — a treasure trove for biologists studying sex.

In *O. cincta*, little brown-and-white males roam the leaf litter making no apparent effort to find a female. Instead, males pause here and there for a few seconds to leave behind white stalks topped by a shiny-coated globes, each holding more than 1,000 sperm.

Sperm on a stalk is still viable after sitting two days in the lab. Outdoors it may not last so long. "You have a lot of rivals searching for sperm just to destroy it," Zizzari says. Males eat rivals' sperm.

Sperm droplets on stalks left by *Orchesella* males have a shiny coating that preserves viability.

Given the rivalry, it wouldn't be surprising if males engaged in an arms race to produce more sperm stalks than their competitors. But Zizzari was surprised to discover that male *O. cincta* make fewer sperm packages when a competitor is sperm-dotting the neighborhood. Maybe he's enhancing the few he makes with extra sex appeal, Zizzari mused. To test the idea, she offered lab females a choice of globes from males with rivals or those made by an uncrowded guy.

Given the two options, "some females just sit and wait — and suddenly you see a female running to a sperm droplet and picking it up," Zizzari says. Others make the rounds of droplets on offer, gently touching them with their antennae. "Then she's not convinced, and she goes for another round."

As Zizzari peered through a microscope watching the deliberations, only 24 of 40 females made up their minds within 15 minutes. Those that reached a decision preferred, 3-to-1, to touch their reproductive tract openings to a droplet from a male vexed with a nearby rival, she and her colleagues reported December 4 in *Biology Letters*. Even in a species that evolved anonymous sperm-banking, it seems, competition inspires special effort. — *Susan Milius*

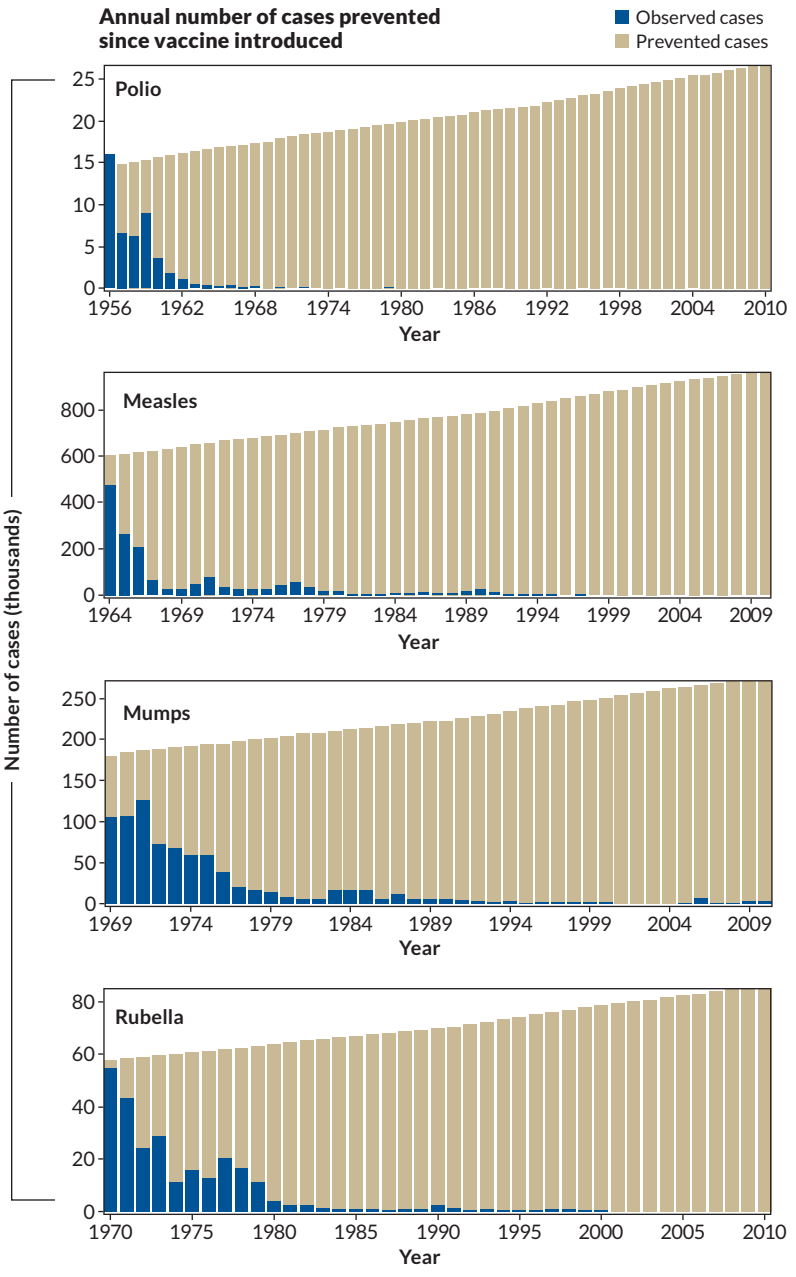
FROM TOP: © G. DRANGE/BIOPIX; COURTESY OF Z. ZIZZARI

SCIENCE STATS

# Vaccine vindication

1957: A teenage boy gets a polio vaccine shot while a group of children looks on.

At least 103 million cases of childhood disease have been prevented by vaccines since 1924, according to a new survey tracking reports of 56 diseases back to 1888. Within five years of introducing the measles vaccine, 95 percent of cases were prevented. Some diseases have seen recent resurgences as parents delay or skip immunizations for their children; the worst whooping cough outbreak since 1959 occurred in 2012. SOURCE: W.G. VAN PANHUIS *ET AL/NEJM* 2013

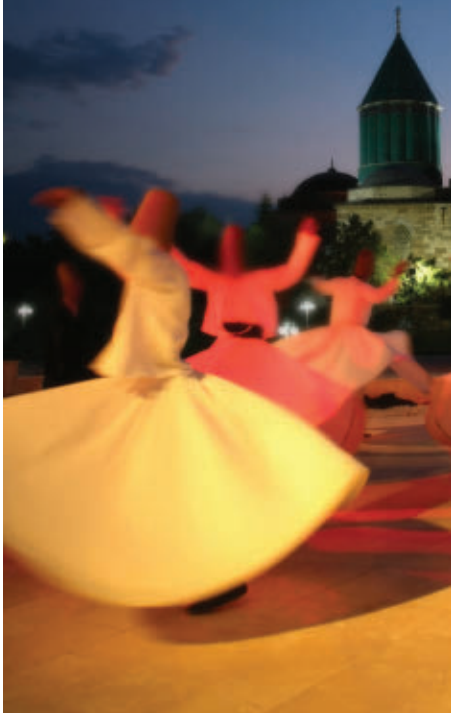



MYSTERY SOLVED

# Transfixing tetrahedrons

As a whirling dervish spins, his long skirt can form mesmerizing shapes such as a three-faced pyramid that rotates more slowly than its wearer. Dervishes are Sufi Muslims who represent the revolving heavens with their spinning dance, and it turns out the dance also mirrors the physics of a spinning Earth. The flowing shapes made by a dervish's skirt, physicists have discovered, depend on the same force that deflects objects to the right in the Northern Hemisphere: the Coriolis effect. As the spinning skirt's fabric flows into a pyramidal shape, it is deflected similarly to the Earth's atmosphere flowing over the spinning planet, scientists report November 26 in the *New Journal of Physics*. Only by including the Coriolis effect could the researchers' equations reproduce the rotating peaks and valleys of real dervishes' skirts.

*—Sarah Zielinski*

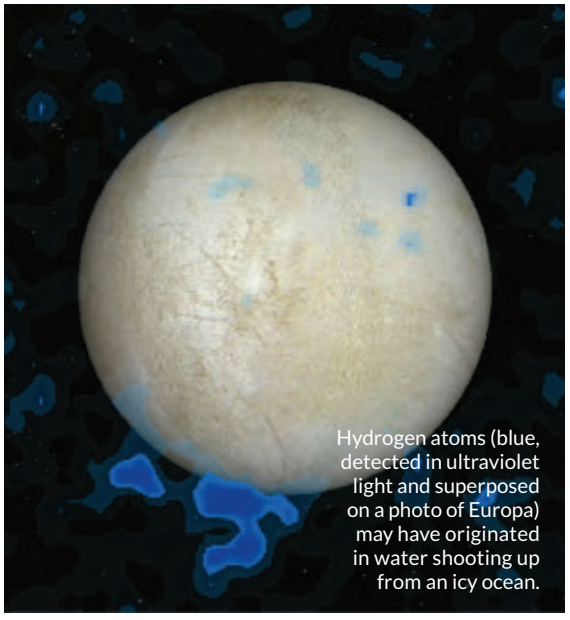


FROM LEFT: © JACK MOEBES/CORBIS; MEHMETCAN/SHUTTERSTOCK

ATOM & COSMOS

# Plumes of water detected on Europa

## Discovery raises likelihood that icy moon of Jupiter hosts life



Hydrogen atoms (blue, detected in ultraviolet light and superposed on a photo of Europa) may have originated in water shooting up from an icy ocean.

L. ROTH/SOUTHWEST RESEARCH INSTITUTE, USGS

**BY ANDREW GRANT**

Water vapor spews from jagged cracks near the south pole of Jupiter's icy moon Europa, according to a study published December 12 in *Science*. If confirmed, these geysers would allow astronomers to probe the moon's watery and possibly life-supporting interior.

"It's incredibly exciting," says planetary scientist Britney Schmidt of the Georgia Institute of Technology in Atlanta. "It blows your mind at what these worlds can do."

Europa, Jupiter's fourth-largest moon, has tantalized scientists since NASA's Galileo mission in the 1990s. The probe beamed back photos of a fractured, icy surface with few impact craters, suggesting the moon has active geology. Galileo also found strong evidence that the moon harbors a buried ocean heated by the alternating push and pull of Jupiter's gravity.

However, the failure of Galileo's main communications antenna prevented astronomers from getting detailed photos and measurements. Since then, scientists have debated whether Europa supports a habitable ocean. For life to exist on Europa, water and heat beneath a kilometers-thick layer of ice would have to mix with organic chemicals on the surface.

Knowing that Saturn's icy moon Enceladus shoots water into space (*SN Online: 7/31/13*), a team led by space scientist Lorenz Roth of the Southwest Research Institute in San Antonio decided to see if Europa emits similar plumes. The researchers analyzed hours-long observations of Europa taken by the Hubble Space Telescope in October 1999, November 2012 and December 2012. Hubble can detect ultraviolet radiation emitted by hydrogen and other atoms. The December 2012 data revealed unusually high concentrations of both hydrogen and oxygen hovering over Europa's southern hemisphere, suggesting the presence of water molecules. No analogous signal showed up in the other two months.

The researchers conclude that in December 2012, liquid water encased under Europa's ice shell escaped through cracks to form plumes of vapor reaching heights of about 200 kilometers, the approximate distance between Seattle and Vancouver. The water output rate was about 10 times as high as that on Enceladus, says study coauthor and University of California, Santa Cruz planetary scientist Francis Nimmo: about 1,000 liters, or a hot tub's worth, every second.

The plumes suggest that at least some of Europa's buried water supply reaches the surface. Meanwhile, research by Schmidt and others has hinted that chemicals can work their way down through the ice (*SN: 12/17/11, p. 5*). Researchers at an American Geophysical Union meeting in San Francisco in December presented evidence that Europa has a form of plate tectonics, with sheets of ice that slide beneath one another and transport surface chemicals to the ocean.

However, says Carolyn Porco, a planetary scientist at the Space Science Institute in Boulder, Colo., "before people start jumping up and down over this, there needs to be some confirmation." Her imaging team for the Cassini probe, which orbits Saturn, has released brilliant photos of Enceladus' plumes of water vapor and ice crystals. Its geysers are most active when the moon is farthest from Saturn, and the Hubble detection similarly took place when Europa was farthest from Jupiter. Porco suggests taking follow-up measurements when Europa is again at this point in its 3.5-day-long orbit, as well as at other times when Jupiter's gravity would presumably weaken the plumes. Nimmo agrees that additional plume detections would solidify the study's conclusion.

Data in the Galileo archive may provide an additional line of evidence. During one of Galileo's close passes to Europa, the probe detected a strange magnetic signal that astronomers could not explain; the new findings imply that it could be the signature of water molecules floating above Europa. "If this work is correct, then it's an obvious answer to that puzzle," says UCLA geophysicist Krishan Khurana, who analyzed the perplexing result for the Galileo team in 1997.

Confirmation that Europa is shooting its insides into space would increase the clamor by planetary scientists to send a robotic explorer there. Instead of drilling through the ice to explore the moon's ocean, a probe could fly through the plumes and scan molecules that fall back to the surface. Porco suggests including instruments that can identify molecules such as protein fragments that could indicate the presence of microbes. ■

ATOM & COSMOS

# Relic of early universe spotted

## Nearby galaxy appears little changed in 10 billion years

**BY CHRISTOPHER CROCKETT**

A nearby galaxy looks as if it was snatched from the dawn of time and delivered to our galactic neighborhood, new observations reveal. Just over 230 million light-years away in the Perseus cluster, the galaxy NGC 1277 formed all of its stars in a quick burst roughly 10 billion years ago — less than 4 billion years after the Big Bang. Then it appears to have abruptly switched off.

Observations published in the Jan. 10 *Astrophysical Journal Letters* show that stars throughout NGC 1277 are uniformly old and formed in a 100-million-year-long flash that created new suns at a rate of up to 1,000 per year. For comparison, our Milky Way gives birth to only a few suns each year.

"There is nothing in the local universe that is similar," says coauthor Ignacio Trujillo, a research fellow at Spain's Instituto de Astrofísica de Canarias. "We see an extremely different star formation history in the early universe compared to today."

Most galaxies, including our own, grow by cannibalizing other galaxies. Every time one galaxy smashes into another, new gas pours in and sparks a wave of star formation. It's a slow process that takes billions of years. Usually, hints of this violent past show up as streams of gas and stars. NGC 1277 shows none of this.

What researchers see in NGC 1277 is a galaxy that assembled most of its mass very quickly, including a gargantuan black hole at its center. The black hole, weighing in at 17 billion suns, is one of the most massive known and much heavier than astronomers expected to find in a galaxy the size of NGC 1277. How it got there is a mystery (*SN: 4/6/13, p. 12*). Contrary to the standard picture of supermassive black holes slowly growing over many billions of years, the observations make clear that NGC 1277's black hole formed fast and has been around for a very long time.

"It's unusual to see an old stellar population formed in a burst in a disk galaxy," says astronomer John Kormendy of the University of Texas at Austin. "Disks usually form very slowly; to have a disk this old ... something prevented any kind of star formation since its beginning."

Typically, the only way researchers can learn about galaxy birth is to look at very distant systems. Such galaxies are so distant that their light has taken nearly the age of the universe to reach Earth, so telescopes see them as they were in the first billion or so years after the Big Bang. At distances of billions of light-years, it's hard to tease out much information; the galaxies are little more than smudges of light. However, computer simulations suggest that a very tiny fraction — just 0.1 percent — of nearby massive galaxies have gone their whole lives without running into a neighbor.

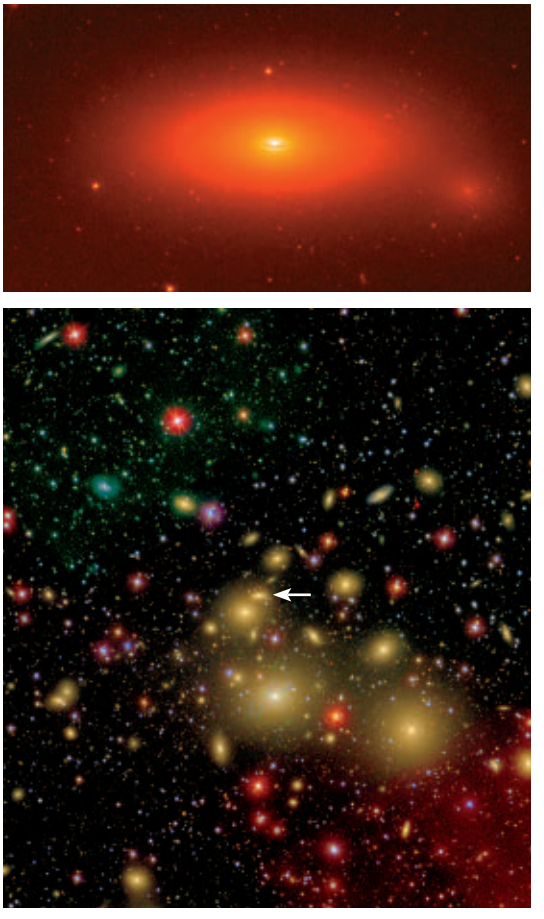
> "We see an extremely different star formation history in the early universe compared to today."
>
> **IGNACIO TRUJILLO**

Though Trujillo thinks the galaxy survived by escaping collisions, Kormendy believes the hot gas that surrounds NGC 1277 has kept it well preserved.

"It's not OK to make the assumption that it hasn't done any interacting with its environment," Kormendy says. Galaxies need cool gas to make stars. But the entire Perseus cluster is bathed in a gas at 10 million degrees Celsius, and Kormendy maintains that this gas is probably stifling growth in the galaxy.

What's more, while there are no signs of recent collisions, Kormendy thinks that NGC 1277 hasn't escaped the influence of other galaxies: "It's been whittled by interactions with neighbors and probably smaller than it was 5 billion years ago." He adds that the galaxy may have lost up to half its mass, which may be the reason the central black hole appears so massive.

Regardless, Kormendy agrees that this is an ancient galaxy that formed quickly and then shut down, which is itself fascinating and surprising. "It's not easy to understand anything about this galaxy," he says. "It's in an unusual volume of the universe where lots of mass collected very early into a collection of galaxies. [There is] something special about this environment." ■



All of the stars in galaxy NGC 1277 (top, as seen by the Hubble Space Telescope) formed in a rapid spurt 10 billion years ago. Astronomers suggest that the galaxy, some 230 million light-years away in the Perseus galaxy cluster (bottom, arrow points to NGC 1277), has remained the same since then by somehow avoiding bumping into other galaxies.

FROM TOP: ANDREW C. FABIAN, REMCO C. VAN DEN BOSCH/MPIA, NASA, ESA; DAVID W. HOGG, MICHAEL BLANTON AND THE SDSS COLLABORATION

LIFE & EVOLUTION

# Earliest farm cats found in China

## Evidence points to grain as a force in feline domestication

**BY SUSAN MILIUS**

House cat history has unexpectedly leapt from the Near East into ancient China.

Small cats hunted grain-thieving rodents around the farming village of Quanhucun in central China about 5,300 years ago, reports Yaowu Hu of the University of Chinese Academy of Sciences in Beijing. The Chinese cats may not be the oldest signs of the onset of domestication or the source for today's domesticated cats. But they do provide the earliest evidence of grain farming as a possible pathway to domestication, Hu and his colleagues report December 16 in the *Proceedings of the National Academy of Sciences*.

The discovery that farm cats lived in China more than 5,000 years ago suggests that grain agriculture played a role in domesticating wildcats (shown) and transforming them into today's popular pets.

The location "couldn't have been more surprising," says study coauthor Fiona Marshall of Washington University in St. Louis, who studies animal domestication.

Eight cat bones from the village are more than 3,000 years older than any other evidence in China of cat domestication, she says. Feline remains have been unearthed from older archaeological sites: a 9,500-year-old human burial in Cyprus and a 5,500-year-old grave in Egypt. Yet there's hardly any evidence of what process turned skittish, territorial loners into the tolerant human companions that appear in paintings from Egypt around 4,000 years ago.

At the Chinese village, a quirk of plant metabolism let researchers test the idea that grain farming drew cats and people together. The villagers there raised imported species of millet, which capture solar energy with what's called $C_4$ photosynthesis.

Eating $C_4$ plants raises concentrations of a certain form of carbon in bones. And that distinctive rise showed up in the remains of the village's people, pigs, dogs — and cats, the researchers report. In contrast, wild animals such as deer and hares that ate native, non-$C_4$ plants weren't souped-up with unusual carbon.

One cat seems to have scrounged, or perhaps been fed, substantial millet-based food. But otherwise the cats probably caught rodents that had filched people's grain stores. How much the villagers encouraged the cats isn't known. The bones, found in piles of rubbish, could indicate that people were eating the cats.

Just what kind of small cats these were isn't clear from the battered feline bones. If they were China's native subspecies of the wildcat, then their domestication didn't lead to modern house cats. Today's kitty DNA looks more closely related to the Near Eastern subspecies' DNA than to the Chinese one's, says Carlos Driscoll of the National Institutes of Health in Bethesda, Md.

But there might be a connection. If ancient Near Eastern cats had unexpectedly reached China, Driscoll says, Quanhucun would be a good spot for researchers to look for them. The village lies toward the eastern end of the ancient Eurasian route called the Silk Road, where trade mingled East and West.

DNA studies of the cat bones may resolve whether they're imports or the native subspecies. "Either way it's an exciting story," Driscoll says. ■

BODY & BRAIN

# Dog dust may benefit infant immune systems

## Microbes from pet-owning house protected mice against allergy, infection

**BY NATHAN SEPPA**

Dogs that bring outdoor dust into the house might be doing a favor for babies in the home. A study of mice suggests that exposure to doggy dust imparts immune protection to infants. The benefits may derive from microbes in the dust that enter the intestines and improve the microbial mix, steering the immune system toward fighting disease and away from initiating allergic reactions.

The findings represent a microbial twist in the hygiene hypothesis, which argues that a less-than-sanitary early life may prime a child's immune system against overreacting to grass, dust mites and other ordinary substances. Past studies suggested that babies exposed to multiple siblings, daycare, pets or farm living grow up to have less asthma or allergy.

In the new study, researchers find that dust from a house with a dog contains more diverse microbes than dust from a home with no pets. Since human infants ingest at least some dust, the scientists fed one kind of dust or the other to mice that were 6 to 8 weeks old. Although unappetizing, it had the desired effect: Exposure to the dog-house dust greatly toned down immune reactions in the mice that were exposed to a common trigger, cockroach allergen.

Mice getting the no-dog dust had

ANDYWORKS/ISTOCKPHOTO

Radiocarbon data support the argument that makers of huge stone sculptures on Easter Island weathered environmental challenges rather than succumbing to them.

HUMANS & SOCIETY

# Easter Island's farmers cultivated social resilience, not collapse

## Polynesian society thrived despite extensive deforestation

**BY BRUCE BOWER**

Easter Island's Polynesian society is known for having created huge, human-like statues and for supposedly folding in the late 1600s after overexploiting limited land. But that proposed societal collapse may never have happened, a new study suggests.

Despite largely clearing the island of its palm forest by roughly 1550, groups on Easter Island, also known as Rapa Nui, contained enough people to farm coastal and inland sites until well after Europeans first arrived in 1722, says anthropologist Mara Mulrooney of the Bernice Pauahi Bishop Museum in Honolulu.

"Deforestation did not equal societal failure on Rapa Nui," Mulrooney says. "We should celebrate the remarkable achievements of this island civilization."

Mulrooney's analysis of 313 radiocarbon dates from structures and settlements across Rapa Nui appears in the December *Journal of Archaeological Science*.

Starting at least 30 years ago, archaeologists proposed that slash-and-burn agriculture wiped out palm forests and robbed the soil of nutrients, and the depletion of natural resources triggered a social implosion on Rapa Nui before Europeans arrived. Geographer Jared Diamond of UCLA popularized that scenario in his 2005 book *Collapse*.

Mulrooney's investigation, which includes 15 new radiocarbon dates from 11 excavations in a northern section of Rapa Nui, suggests that farmers successfully adapted to the loss of the island's trees. It wasn't until around the time of Captain Cook's 1774 visit to Rapa Nui that signs of population decline — indicated by a decrease in the number of radiocarbon dates, especially at inland sites — appeared. The decline could have been due to infectious diseases introduced by the Europeans, she suggests.

Studies conducted by other researchers on Rapa Nui over the last two decades indicate that as the palm forest shrank, island farmers increasingly cultivated gardens of yams, sweet potatoes, taro and other crops in enclosures with stones and boulders strategically placed on the soil. These rocks protected plants from wind, prevented evaporation of rainwater, deterred weed growth and boosted soil nutrients. Mulrooney thinks that this tactic allowed the island society to thrive and sustain different social classes, including artisans who carved giant sculptures, after the palm forest had been destroyed.

Mulrooney doesn't firmly demonstrate that the radiocarbon dates she sampled track relative population changes over time, comments archaeologist Carl Lipo of California State University, Long Beach. But in his view the new paper joins emerging lines of evidence suggesting that islanders worked around environmental challenges to achieve cultural greatness.

"The idea of societal collapse on Rapa Nui has long been assumed," Lipo says, "but there is no scientific basis for it." ■

BISHOP MUSEUM

inflammation in their airways. They also had evidence of excess mucus and immune proteins that are common in allergic reactions. But these reactions were virtually absent in mice that had been primed with the dog dust, the scientists report December 16 in the *Proceedings of the National Academy of Sciences*.

The researchers also found that the doggy-dust microbes affected the bacteria inhabiting the young mouse intestines. "We saw a profound change in the microbiome," says study coauthor Nicholas Lukacs, an immunologist at the University of Michigan Medical School in Ann Arbor.

The dust-primed mice developed colonies of *Lactobacillus johnsonii*, a protective bacterium that lives in the mammalian gut.

*L. johnsonii* provided defense against respiratory syncytial virus. RSV is the most common cause of pneumonia in U.S. children under age 1, according to the Centers for Disease Control and Prevention.

The study suggests protection against RSV in newborns is possible, says Ian Mitchell, a pediatrician at the Faculty of Medicine at the University of Calgary in Canada. The work offers "a glimmer of hope that we might find a way to perhaps delay the time to infants acquiring RSV," he says. RSV infections that strike later in childhood tend to be less severe.

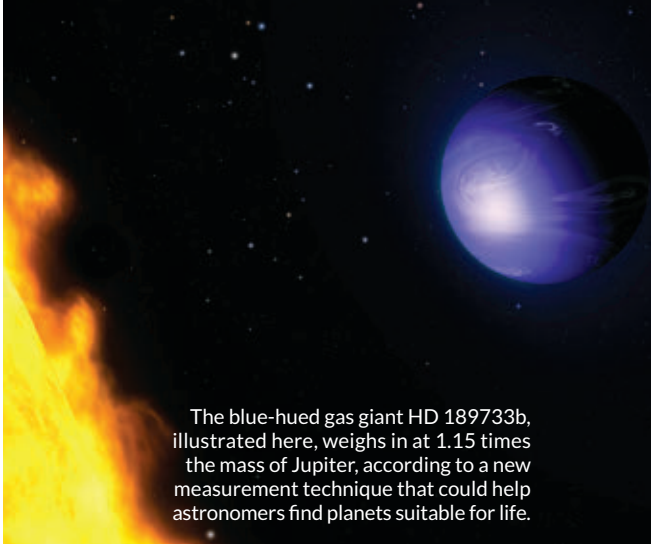
Newborns' gut microbiomes are still works in progress. The period when exposure to environmental factors such as dust microbes makes a difference in lifelong immunity may be short. Lukacs says researchers have yet to define this window of opportunity.

Introducing *L. johnsonii* on its own into the mice's digestive tract induced some protection against allergy and infection, but less than the dog-house dust induced. Lukacs says the dust must contain components other than *L. johnsonii* that have value in orienting the gut microbiome. ■

ATOM & COSMOS

# Exoplanet mass revealed in light

## Method may help pinpoint potentially habitable worlds



The blue-hued gas giant HD 189733b, illustrated here, weighs in at 1.15 times the mass of Jupiter, according to a new measurement technique that could help astronomers find planets suitable for life.

**BY ANDREW GRANT**

A distant planet has been weighed with light that passed through its atmosphere 63 years ago. This new mass-measuring technique should allow researchers to identify planets orbiting other stars that could support life.

To peg a truly Earthlike exoplanet with the potential for life, astronomers need to confirm three attributes: an atmosphere that contains life-supporting molecules such as oxygen and water, plus a size and a mass similar to Earth's. The only attribute that is easy to measure now is size: Telescopes provide good estimates by measuring planets' shadows when they cross in front of their stars.

Soon, detailed observations of exoplanet atmospheres will become possible. With NASA's James Webb Space Telescope, set for launch in 2018, astronomers will be able to analyze starlight that passed through a planet's atmosphere, known as a transmission spectrum. That spectrum can reveal what kinds of molecules the planet's atmosphere holds.

But an Earth-sized planet with water in its atmosphere could still be made of gas. That's why astronomers need to know a planet's mass to determine its composition. Astronomers can use the radial velocity method, which measures a planet's gravitational tug on its star, but it works mainly for large planets too close to their stars for life.

MIT astronomer Julien de Wit didn't set out to weigh exoplanets; he was interested in their atmospheres. But he and MIT colleague Sara Seager realized that measurements of a planet's atmosphere and mass are linked: For planets of the same size, more massive ones will have thinner atmospheres because of their stronger gravitational pull. At the same time, heavier molecules tend to sink toward the surface, also thinning a planet's atmosphere.

The researchers conclude in the Dec. 20 *Science* that by determining planet sizes and atmospheric composition, they can calculate planets' masses. The technique requires astronomers to dissect the same transmission spectrum they would use to characterize a planet's atmosphere. "It's almost like you can make this analysis for free," says Rory Barnes, an astronomer at the University of Washington in Seattle who was not

BODY & BRAIN

# Heartburn drugs linked to vitamin deficiency

## People who take Nexium, Prilosec and other brands more prone to low B12 levels

**BY NATHAN SEPPA**

Knocking down stomach acid may come with a cost. People with a deficiency in vitamin B12 are more likely to regularly use popular heartburn drugs than those who aren't deficient, researchers find. The connection suggests that the drugs interfere with the digestive process that extracts the vitamin from foods.

Researchers analyzing a large database of medical records report in the Dec. 11 *JAMA* that taking proton pump inhibitors, or PPIs, was associated with a two-thirds increase in the risk of vitamin B12 deficiency. A chronic B12 shortage can lead to anemia, nerve damage and dementia.

PPIs, sold as Nexium, Prilosec and other brands, curb the stomach's production of acid. This reduces reflux, in which stomach acid splashes up into the tender esophagus and causes heartburn.

But stomach acid is needed for digestion, part of which involves carving vitamin B12 out of proteins in foods. By changing the pH of the stomach, PPIs might inhibit how much vitamin B12 gets cleaved from proteins, says Robert Valuck, a pharmacist at the University of Colorado Denver's campus in Aurora who wasn't part of the new study.

Douglas Corley, a gastroenterologist at the Kaiser Permanente Division of Research in Oakland, Calif., and his colleagues identified nearly 26,000 people with vitamin B12 deficiency in the Kaiser records and matched them up with roughly 184,000 people who didn't have the shortage. The researchers found that 16.2 percent of the deficient group took a PPI or another heartburn drug for at least two years, compared with 10.4 percent of the people with normal levels of vitamin B12. The scientists linked PPIs with a risk of vitamin B12 deficiency 65 percent higher than that of not taking any heartburn drug. The apparent risk lingered for three years after stopping PPIs, decreasing gradually.

**14.9 million**

People in the United States who received proton pump inhibitor prescriptions in 2012

People taking less potent heartburn medications belonging to a family of drugs that includes Zantac had a risk of vitamin B12 deficiency that was 25 percent greater than did those not taking heartburn drugs.

G. BACON/STSCI/NASA, ESA

involved in the study.

To test the technique, dubbed MassSpec, de Wit and Seager calculated the mass of HD 189733b, a sizzling gas giant located 63 light-years away in the constellation Vulpecula. Since the planet is large, its mass had also been estimated using the radial velocity method. The results from the two methods matched almost perfectly.

Because the Webb Telescope will be able to measure transmission spectra of distant planets, de Wit says, researchers should also be able to derive the planets' masses. That would enable astronomers to evaluate the probability of life on a wide array of worlds, including the appealing ones that are too small and too distant to weigh with the radial velocity method. "This is likely the only way to get the mass of planets that are potentially habitable," de Wit says.

Barnes questions MassSpec's ability to weigh some planets, particularly those with atmospheres obscured by high, thick clouds. But the technique is still invaluable, he says. "It's a no-brainer that we'd want to do this every chance we get." ■

Still, about four-fifths of the people who had low levels of vitamin B12 weren't taking any of the acid-blockers. That suggests that other factors contribute to B12 deficiency, Valuck says, such as nutrition, age, genetics, exercise level and alcohol consumption. The good news, he says, is that this deficiency, whatever the cause, "is fairly easy to remedy. It's cheap and easy to take in a multivitamin."

The exact prevalence of vitamin B12 deficiency in the population is unknown, but studies suggest it ranges from 5 to 20 percent, with highest rates in the elderly. Corley says the new results raise questions about whether people taking PPIs should get their vitamin levels checked. He also wonders whether those on high PPI doses might manage with lower amounts, since higher doses were linked to greater risk of vitamin B12 deficiency. ■

COURTESY OF A.R. OGANOV AND WEIWEI ZHANG

MATTER & ENERGY

# Weird salt shakes up chemistry

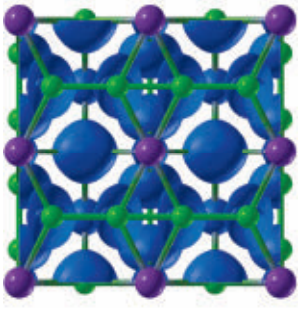
## Hot, compressed compounds challenge laws of matter

**BY BETH MOLE**

With a dash of table salt, scientists have created exotic compounds that bend the basic rules of chemical bonds and matter in the universe, researchers report in the Dec. 20 *Science*.

The team pulled off the spicy chemistry by squeezing grains of sodium chloride between two diamonds while frying the salt with a laser.

The high-temperature, high-pressure conditions mimic those inside stars and planets, says chemist Artem Oganov of Stony Brook University in New York. His team's discovery that these conditions create unexpected compounds suggests that alien chemical structures make up a vast fraction of the solar system's matter.



Experiments using extreme conditions reveal that common table salt, NaCl, can form exotic compounds such as $NaCl_3$. In this illustration, purple represents sodium, green represents chlorine and blue represents electron clouds.

"This is a new chapter of chemistry," Oganov says. It means that the rules in chemistry textbooks have much more limited applicability than previously thought, he says.

Scientists had predicted that extreme conditions could change how atoms interact and bind together. For instance, chemists expected that high pressure could convert ionic bonds such as those in salt, in which one atom donates an electron to another atom, to metallic bonds, in which electrons travel more freely among atoms.

But Oganov and his colleagues went beyond unconventional bonds to discover entirely new compounds, says physicist Jordi Ibáñez Insa of the Institute of Earth Sciences Jaume Almera in Barcelona. This is the first experimental evidence of exotic compounds not ordinarily found on Earth, Insa says.

At Earth's surface, sodium and chlorine atoms normally bind only in a 1-to-1 ratio to make NaCl, which has an internal structure with atoms arrayed in neat cubes. But in the hot, pressurized experiments, Oganov and his colleagues found that sodium and chlorine could also bind in novel ratios such as 1-to-3, 3-to-2 and 1-to-7.

By using X-ray diffraction measurements, the researchers discovered that the extreme conditions altered how the atoms bonded by allowing them to get closer to one another. In doing so, the compounds break the octet rule, which states that atoms in the first rows of the periodic table tend to form bonds that complete a set of eight electrons in the outskirts of their electron cloud. In the new compounds, the sodium and chlorine atoms did not always have eight electrons spinning in their outer orbits.

The new compounds of sodium and chlorine also formed rectangular and gemlike internal structures that had different properties. For instance, the compound $NaCl_3$ probably conducts electricity, the authors predict based on computer simulations.

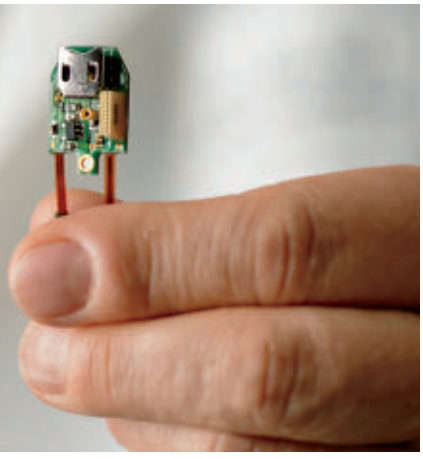
On a practical level, the study demonstrates how scientists might re-create extreme conditions to build novel and useful materials that violate conventional wisdom, says materials scientist Yanming Ma of Jilin University in Changchun, China.

Eugene Gregoryanz of the University of Edinburgh agrees. But so far, he notes, the newly created compounds don't survive when they're brought back to low-pressure, low-temperature conditions. "The jaw-dropping discovery," he says, would be bringing the exotic compounds back to ambient conditions — in other words, if chemists could make metallic table salt. ■

BODY & BRAIN

# Injured rats achieve movement with implant

## Chip skirts impaired brain region to connect neurons



**BY LAURA SANDERS**

With a futuristic patch, brain-injured rats have regained the ability to reach out and grab a bit of food. Similar electrical devices that bypass a damaged brain area may ultimately lead to ways to repair damage from stroke, blast injuries and diseases such as Parkinson's.

Results published in the Dec. 24 *Proceedings of the National Academy of Sciences* "open the door for new experiments and new ways of approaching brain repair after injury," says S. Thomas Carmichael of UCLA.

Scientists have made strides in brain-machine interface technology (*SN: 11/16/13, p. 22*), which directs brain signals to external machines such as prosthetic limbs or computer cursors. In contrast, the new neural patch does all of its work inside the skull, routing signals from one part of the brain to another.

Scientists led by Randolph Nudo of the University of Kansas Medical Center in Kansas City tested the device on rats that had injuries in the motor cortex, a brain region that helps control movement. Before their injuries, rats could easily thread their paws through a slot to grab a morsel of food. Postinjury, the task became much more difficult.

But after eight days with the neural prosthesis, injured rats showed signs of improvement. After two weeks, the animals' performance was as good as it had been before the brain injury, the team found.

Using electrodes, the neural patch collects messages from neurons in a rat's premotor cortex, a brain region involved in initiating movements. The device then converts these neural signals to small artificial electrical currents that ping neurons in another part of the brain, the somatosensory cortex. Usually the motor cortex acts as a middleman between these two areas, which work together to control movement. But when the motor cortex is injured, the neural patch bridges the damage and links activity in the premotor cortex to the somatosensory cortex.

Wounded rats can reach for food normally when a newly developed brain implant sidesteps the damaged motor cortex to send messages to other parts of the brain.

Nudo and colleagues don't yet know exactly how the device might be used. One possibility is that the prosthesis would be required permanently. Another is that the brain patch would be needed only temporarily if it stimulates the growth of new, long-lasting physical connections between neurons in the far-flung brain regions.

The rats' brain damage approximates the damage to the motor cortex that a human might experience after a traumatic brain injury. People who have trouble moving after a stroke might also benefit from a similar neural patch. Although the results are intriguing, much more work will be needed to advance the technology and to understand how it would work in the human brain, says Eberhard Fetz of the University of Washington in Seattle. ■

BODY & BRAIN

# Narcolepsy may be rooted in the immune system

## Assault on brain cells appears to induce sleep disorder

**BY NATHAN SEPPA**

Narcolepsy occurs when wayward immune forces launch an attack on the brain cells responsible for wakefulness, a new study suggests. In a case of mistaken identity, immune cells that target a protein fragment from a microbial invader also on rare occasions ravage neurons that produce a similar protein fragment, or peptide, researchers report.

The victims of this cross fire are neurons that make a peptide called orexin, a neurotransmitter that is crucial for staying awake. The researchers say this could explain the lack of orexin neurons in people with narcolepsy, as shown previously in patient autopsies. A lack of orexin, also called hypocretin, leaves a person with disordered sleep, daytime drowsiness and the risk of nodding off abruptly — the hallmarks of narcolepsy.

The new findings, along with previous work, indicate that narcolepsy needs three conditions to occur. A person must harbor an immune system gene variation that shows up in about one-fourth of people but in 98 percent of narcolepsy patients. Second, the individual needs to encounter a pathogen in the environment that provokes an immune reaction against a foreign peptide that resembles orexin. Finally, the immune system must then destroy the brain's orexin-making neurons.

It remains unclear precisely how the immune system kills the neurons. But immunologist Elizabeth Mellins of Stanford says the new results point to narcolepsy as an autoimmune disease.

Evidence of an immune connection arose in 2009 when Stanford researchers reported that narcolepsy patients are more likely than other people to carry certain genetic variants related to immunity

ELISSA MONROE/UNIV. OF KANSAS MEDICAL CENTER

in addition to the well-known, common variant. Now the team has discovered an environmental trigger to go with these genetic hints. Writing in the Dec. 18 *Science Translational Medicine*, the Stanford researchers show that a peptide on the H1N1 flu virus that caused a pandemic in 2009 can generate an immune reaction that hits orexin neurons.

Mellins and others had noticed a spate of narcolepsy in China in 2010 in the wake of the H1N1 flu pandemic. There were also reports of narcolepsy in Northern Europe tied to a vaccine called Pandemrix that contained protein fragments from the H1N1 flu virus. About 31 million Europeans got the vaccine, and about 1 in 15,000 developed narcolepsy. That's far higher than narcolepsy's usual rate of less than 1 per 100,000 per year in Finland, where the link was first noted, says study coauthor Emmanuel Mignot, a Stanford sleep researcher. The vaccine, never given in the United States, is no longer in use, Mignot says.

Mignot, Mellins and colleagues screened H1N1 flu virus proteins and found a peptide in them that mimics the shape of orexin. They also tested in a lab dish immune cells called T cells from narcolepsy patients, most of whom hadn't gotten the vaccine, and found the cells reacted potently to orexin, whereas T cells from healthy people didn't. In another test, the researchers examined blood samples from four pairs of identical twins, each with one twin who had narcolepsy. These narcolepsy patients' T cells also reacted to orexin; the healthy twins' T cells didn't.

Something in the environment must have influenced the reactivity of T cells in the narcolepsy patients, says Mellins. "Most likely that explains why one twin was unlucky."

A separate test of blood from 17 Irish children who had gotten the Pandemrix vaccine showed that those who later developed narcolepsy had T cells that reacted strongly to orexin, while T cells from their vaccinated siblings who didn't develop narcolepsy were nonreactive.

"The T cell findings really provide one of the most robust clues we have that there is an autoimmune mechanism here," says sleep researcher Thomas Scammell, a Harvard neurologist. "Orexin neurons' death is like a murder mystery. We didn't know who did it or why it happened." In the new report, he says, the immune reaction sheds light on why.

There could be a range of triggers in the environment tripping this reaction, Mellins says. She surmises that, in addition to the flu peptide, streptococcus or other pathogens might play a role.

The new findings also pose a parallel between narcolepsy and type 1 diabetes, an autoimmune disease in which a rogue immune attack kills pancreatic cells that make the hormone insulin. In type 1 diabetes, symptoms show up before all the cells are destroyed, a "honeymoon period" that scientists are targeting with experimental treatments, Mellins says. A similar approach might someday be applied in narcolepsy, she says, if the condition can be caught early. ■

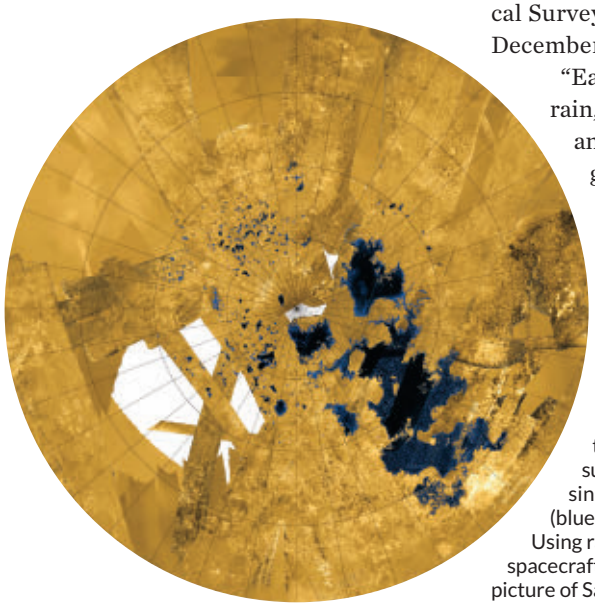
ATOM & COSMOS

# Tectonics, sinkholes may have shaped Titan's landscape

## Map reveals clues about the origin of seas and lakes on Saturn's largest moon

**BY MEGHAN ROSEN**

For a frigid hunk of rock and ice more than a billion kilometers away, Titan acts a lot like Earth. It has lakes and seas that may have formed in ways similar to those that created Earth's bodies of water, according to an analysis of the newest map of Titan's surface.



Titan remains mysterious, but this new mosaic false-color image suggests that tectonic activity and sinkholes created seas and lakes (blue-black) near the moon's north pole. Using radar data collected by the Cassini spacecraft, scientists pieced together this picture of Saturn's largest moon.

JPL-CALTECH/NASA, ASI, USGS

Vast, elongated seas and smaller, roundish lakes filled with oily liquid speckle the moon's north pole. They could be the handiwork of tectonics and sinkholes, geophysicist Randolph Kirk of the U.S. Geological Survey in Flagstaff, Ariz., reported December 12.

"Earth has seas, and rivers, and rain, and tectonics, and volcanism and glaciers," Kirk said. "Titan's got the full list from Earth, except for life."

Scientists received their first up-close look at the big moon in 2004, when Cassini, a spacecraft orbiting Saturn, snapped radar images of Titan's surface. The spacecraft spotted some of the moon's lakes and seas in 2006, but until now scientists didn't have a full picture of Titan's north pole.

The latest mosaic is a patchwork of coarse- and fine-resolution images from Cassini's flybys. Filling in the northern landscape's details helped Kirk figure out the forces that may have shaped the moon's geography.

This summer, when Kirk first looked at the new images, he noticed that the large seas seemed to cluster together. "Wow, that's really weird," Kirk remembers thinking. "It looks like a rectangular area."

The coastlines of the seas run parallel to the edges of the rectangle. "When geologists see straight lines, they immediately jump to the idea of tectonics," Kirk said.

Tectonics, or fracturing of a planetary body's crust, carves its signature into a landscape with the same lines and angles seen around Titan's seas, he said.

EARTH & ENVIRONMENT

# Tornado intensity climbing in the United States

## Since 1994, twisters have left bigger paths of destruction

**BY MEGHAN ROSEN**

Tornadoes are getting stronger. Over the last two decades, the intensity of twisters pummeling the United States has crept up, geographer James Elsner of Florida State University in Tallahassee reported December 10.

The National Weather Service ranks tornado intensity using the Enhanced Fujita Scale. The EF Scale lumps the storms into one of six categories based on damage to trees, light poles, buildings and other structures. Scientists assign a rating by looking at photographs of a tornado's aftermath.

But fitting tornadoes into narrow categories gives scientists only a rough gauge of a tornado's strength. "We need a continuous estimate of tornado intensity," Elsner argued.

He and colleagues created such an estimate using a computer analysis that factors in the length and width of a tornado's path. Then the team tapped into data from the U.S. Storm Prediction Center about tornadoes from 1994 to 2011.

According to the analysis, tornadoes have spent more time on the ground and left busted-up trails that get about 2 percent bigger each year, Elsner said.

He thinks the rise in intensity could be linked to climate change. A boost in temperature means more warm, moist air, which fuels whirling columns of wind.

How — and if — climate change affects tornadoes is still controversial, though, Elsner said. "When people see tornadoes and climate in the same sentence, their eyes roll."

Even Elsner's finding of an increase in tornado intensity is preliminary, cautioned hurricane risk researcher Emmi Yonekura of Princeton University. Data from hurricanes and tornadoes can be inconsistent, she said, so analyzing trends is tricky.

Still, Elsner's claim is "highly plausible," said Peter Kalmus, a climate scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. Five years from now, he said, "I'd be really surprised if everyone didn't agree there's a strong link to climate change." ■

The layout of the moon's seas resembles western North America's Basin and Range Province, a series of parallel ridges that formed when Earth's crust stretched around 17 million years ago. On Earth, these stretch marks indicate plate tectonic activity, although on Titan the tectonic process may be different.

Researchers studying Titan's surface had previously suggested that rivers might be formed via tectonics, said geophysicist Howard Zebker of Stanford University. Kirk's data bolster the case for tectonics on this moon.

Still, Zebker added, there's a lot left to learn. "The problem with tectonics on Titan is the same as the problem with tectonics on Earth," he said. "We don't know what drives it."

Another Earthlike mechanism may be responsible for forming Titan's lakes, Kirk thinks. On Earth, water can dissolve rock and create sinkholes that fill with liquid. The resulting lakes look similar to those on Titan, he said.

If sinkholes did fashion Titan's lakes, that may hint at another geological surprise, Kirk said. Groundwater on Earth can whittle soluble rock into caves. Similar underground caverns might exist on Titan, he said. ■

FROM TOP: RIDVAN EFE/SHUTTERSTOCK, ADAPTED BY E. OTWELL; TODD SHOEMAKE/SHUTTERSTOCK

By analyzing the length and width of tornadoes' paths, scientists have found that the intensity of twisters in the United States has gone up since 1994.

EARTH & ENVIRONMENT

# World's coldest spot moves from one Antarctic site to another

## New record low measured by satellite

**BY MEGHAN ROSEN**

A swath of icy slopes in Antarctica has staked an unofficial claim as the coldest place on Earth.

Frigid pockets of air downhill from the East Antarctic plateau can chill ice surfaces to as low as –93.2° Celsius, Ted Scambos of the National Snow and Ice Data Center in Boulder, Colo., reported December 9.

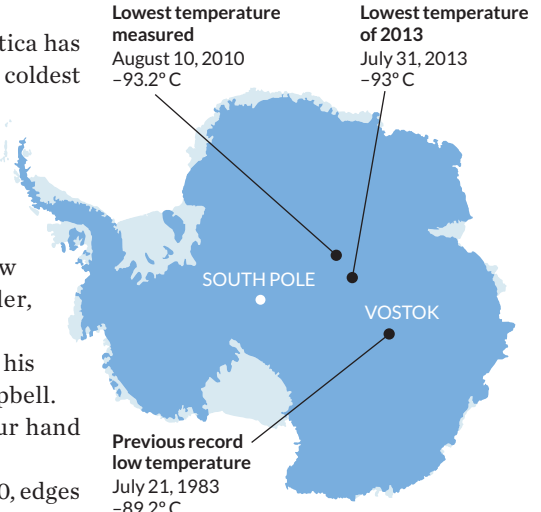
"It's colder than dry ice," said his NSIDC colleague Garrett Campbell. "If you took your glove off, your hand would freeze off very fast."

The new low, recorded in 2010, edges out the previous record of –89.2° C, which was set at Antarctica's Vostok Station in 1983, several hundred kilometers away.

Scambos, Campbell and colleagues used satellite data to measure surface ice temperatures from 1982 to 2013. Their work included data collected by thermal sensors aboard NASA's Landsat 8, a newly launched satellite with higher spatial resolution than other satellites.

The new findings have helped scientists pinpoint conditions needed to reach ultracold temperatures. The chilliest spots lay along the gentle slopes of a ridge at an elevation of 4,000 meters. On clear winter nights, air on the ridge loses heat to space, said Scambos. The dense, cold air sinks to the ground and slides down the ridge, where it can puddle in flat basins. While this pooled air rests on the ice, even more heat escapes and the ice surface cools down further.

But Vostok may keep its place in the record books a little longer, said polar meteorologist Michiel van den Broeke of Utrecht University in the Netherlands.




Using thermal-sensing satellites, scientists have pinpointed a region in East Antarctica with the coldest recorded temperatures on Earth.
SOURCE: T. SCAMBOS/NSIDC

The World Meteorological Organization, the U.N. agency that registers climate extremes, awards official records only to air temperatures measured 2 meters above the Earth's surface, he said.

In contrast, Scambos, Campbell and colleagues measured surface ice temperatures using Earth-orbiting satellites. The Vostok record came from measurements of air just outside a research station. "You can't break the record from space," van den Broeke said.

> "If you took your glove off, your hand would freeze off very fast."
> GARRETT CAMPBELL

One of the new frigid locations may yet beat out Vostok's record, he added. "I'm pretty sure that if you go to one of these cold spots, you will confirm that it is actually the coldest place on Earth."

The new temperature lows may be fleeting. Scientists expect Antarctica to warm by 3 or 4 degrees before the end of the century, said John Turner of the British Antarctic Survey, so "we may not get such cold temperatures again." ■

LIFE & EVOLUTION

# Comb jelly genes redraw tree of life

## DNA data show creature belongs to earliest animal lineage

The comb jelly *Mnemiopsis leidyi* rests at the base of the tree of animal life, according to analyses of its genome.

COURTESY OF STEFAN SIEBERT/BROWN UNIV.

**BY AMY MAXMEN**

Complex marine creatures called comb jellies should replace brainless, gutless, simple sponges at the base of the evolutionary tree of animal life, a new report asserts.

Scientists have long assumed that the ancestor of all living animals vaguely resembled sponges. Now, biologists must reformulate hypotheses on the evolution of the first animals more than 550 million years ago. "This finding makes people very uncomfortable," says Joseph Ryan, an evolutionary biologist at the National Human Genome Research Institute in Bethesda, Md., and lead author of the study in the Dec. 13 *Science*.

For over a century, biologists painted a picture of early animal evolution marked by the gradual addition of indispensible features. In that scenario, colonies of single-celled organisms called choanoflagellates gave way to multicellular predecessors of sponges; millions of years later, an offshoot of these organisms formed nerve cells. Later on, muscles developed. Scientists thought that comb jellies emerged after this point because they possess both a nervous system (complete with a rudimentary brain) and muscles.

Ryan and his colleagues questioned this scenario at a meeting in January when they announced that comb jellies may descend from an ancestor that evolved before sponges. The team had sequenced the genome of the comb jelly species *Mnemiopsis leidyi* and compared it with genomes of sponges and dozens of other organisms. However, a hint of uncertainty in their results caused many biologists to reject the rearrangement of the evolutionary tree's branches (*SN: 5/18/13, p. 20*).

> "This finding makes people very uncomfortable."
>
> JOSEPH RYAN

Since then, the team has solidified the conclusion with an additional analysis. It used algorithms to take stock of the presence or absence of specific genes across animals and single-celled organisms such as choanoflagellates, whose ancestors predate animals. Comb jellies and the single-celled organisms turn out to lack many genes that animals typically have. This analysis, plus the genome studies, are published for the first time in the report.

"The new analysis together with earlier ones is very strong," says biologist Claus Nielsen of the Natural History Museum of Denmark in Copenhagen, who doubted the rearrangement until he saw this report. If he writes a new edition of his textbook *Animal Evolution*, he says he will put comb jellies at the base of the animal tree.

Thomas Bosch, a biologist at the University of Kiel in Germany, agrees with the new placement of comb jellies. But, he adds, "I don't understand the result in terms of biology." The rearrangement suggests that the most recent common ancestor of animals may have had nerves and muscles, since comb jellies do. If that is true, sponges must have lost the parts without a trace.

An alternative explanation that Bosch and Nielsen prefer is that animals' common ancestor had most of the genes to develop nerves and muscles, but that the creature did not actually possess those complex parts.

Ryan's study supports the idea. The researchers found that comb jellies lack some of the genes that other animals use to grow muscles, which means that comb jellies probably evolved muscles independently over millions of years with a different set of genes. It's possible that the comb jelly also evolved its nervous system after diverging from the common ancestor. In these scenarios, the comb jellies use genes in ways that no other living animals do.

Still, some biologists remain unconvinced of the new tree's structure. Mansi Srivastava, an evolutionary biologist at MIT who helped sequence the sponge genome, says that both comb jellies and sponges might have lost many genes since they originated, scrambling the record of which group came first. "It's a really tough problem to solve," she says. ■

EARTH & ENVIRONMENT

## Protein fibers trap greenhouse gas

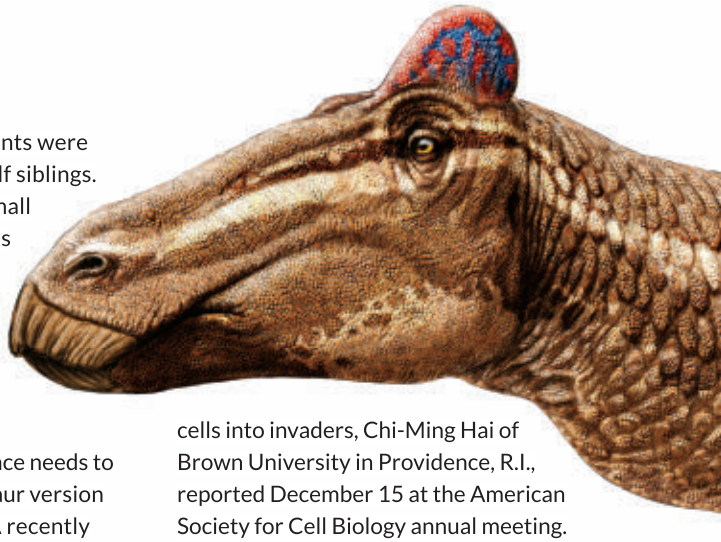
Fibrous protein fragments similar to those in the brains of people with Alzheimer's disease can pull carbon dioxide out of the air. Existing methods to capture $CO_2$ have drawbacks. Some require toxic materials and large amounts of energy; others falter when exposed to water vapor, which fossil fuel combustion releases alongside $CO_2$. Because building blocks of proteins bind $CO_2$ in blood, scientists including David Eisenberg of UCLA exposed protein fibers called amyloids to $CO_2$ in air, mimicking conditions in a power plant chimney. Each amyloid captured one $CO_2$ molecule, and the reaction worked even with water vapor present. The fibers released the gas when heated to 100° Celsius, allowing reuse of the amyloids. (To lower atmospheric greenhouse gas levels, $CO_2$ would need to be stored permanently.) The fibers do not capture enough $CO_2$ for industrial use, but they could be improved, the authors write December 23 in the *Proceedings of the National Academy of Sciences*. — *Gabriel Popkin*

HUMANS & SOCIETY

## Neandertal DNA reveals interbreeding, inbreeding

DNA from a Neandertal woman's roughly 50,000-year-old toe bone (below) has sharpened scientists' view of genetic ties among Stone Age hominids. The fossil comes from a Siberian cave that also yielded a DNA-bearing bone from the Denisovans, close genetic relatives of Neandertals. Neandertals contributed around 2 percent of the DNA carried by non-African people today, a team led by Kay Prüfer of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, reports December 18 in *Nature*. Comparisons of the Neandertal DNA with human and Denisovan DNA indicate that Denisovans inherited at least 0.5 percent of their DNA from Neandertals and a small percentage of genes from another, unknown hominid species. Signs of low genetic diversity in the Neandertal woman's DNA indicate that her parents were closely related, possibly half siblings. The researchers suggest small Neandertal population sizes encouraged inbreeding. — *Bruce Bower*

FROM TOP: P.R. BELL *ET AL*/*CURR. BIO.* 2013; BENCE VIOLA



LIFE & EVOLUTION

## Boneless head crest is a first for dinosaurs

A well-known duck-billed face needs to be reimagined with a dinosaur version of a chicken comb on top. A recently unearthed skull of the duck-billed dinosaur *Edmontosaurus regalis* has remains of a fleshy head dome, says Phil Bell of the University of New England in Armidale, Australia. It's the first boneless crest found on any dinosaur, Bell and his colleagues report December 12 in *Current Biology*. Paleontologists know of plenty of extravagant dinosaur headgear, including on other duck-billed species, but all are bony structures. Skin and soft tissue rot so fast that only extraordinary conditions preserve them. A fluke mummified part of the scaly skin and crest plus some bones of a nearly grown *E. regalis*. One of Bell's coauthors noticed the bones nudging out of a coffin-sized boulder that had broken off cliffs by the Redwillow River in Canada. Rivaling *T. rex* in size, *E. regalis* was a plant eater that lived about 70 million to 65 million years ago. Bell suspects the fleshy head ornament signaled social status or sex appeal or both. — *Susan Milius*

GENES & CELLS

## Nicotine may damage arteries

**NEW ORLEANS** — Even smokeless cigarettes may cause damage that can lead to hardening of the arteries, a study implies. Vascular smooth muscle cells wrap around blood vessels and help control blood flow and pressure. But inflammation and chemicals, such as those found in cigarette smoke, can turn the cells into miniature drills that burrow through connective tissue, allowing muscle cells to tunnel into blood vessels. Once inside, the cells and other debris clump into artery-clogging plaques. Nicotine is one chemical that helps turn normal muscle cells into invaders, Chi-Ming Hai of Brown University in Providence, R.I., reported December 15 at the American Society for Cell Biology annual meeting. When exposed to nicotine, smooth muscle cells already riled up by inflammation formed ringlike structures that started the invasion. Scientists had thought other chemicals in smoke were responsible for most of the bodily damage, while nicotine caused addiction. Electronic cigarettes were thought to be safer because they deliver nicotine without other potentially dangerous chemicals. But "the data suggest that nicotine is not harmless," Hai said. — *Tina Hesman Saey*

## Antioxidants can help repair persistent sores

**NEW ORLEANS** — Vitamins may help chronic wounds heal, studies of mice suggest. People who are bedridden, have circulation problems or have diabetes often develop sores that won't heal. If infection sets in, people may die or need to have limbs amputated. Most therapies, including antibiotics, don't work well, said Manuela Martins-Green of the University of California, Riverside. Martins-Green, Sandeep Dhall and colleagues discovered that wounds made on the backs of diabetic mice stay open for 90 days or longer if the action of natural antioxidants is inhibited at the time of wounding. Oxides, chemically reactive molecules that damage tissue, keep the sores open and foster the growth of bacteria, the researchers found. But antioxidants such as vitamin E or *N*-acetylcysteine neutralized oxidants and reduced bacteria, allowing the sores to close sooner, Dhall reported December 17 at the American Society for Cell Biology annual meeting. Combining the treatments closed the wounds within 20 days. — *Tina Hesman Saey*

# Tomorrow's CATCH

## Chaos theory's potential for fisheries management

By Gabriel Popkin

There's something fishy going on with Pacific sardines. The pint-size swimmers, whose abundance sustained California's famed Cannery Row for decades, all but disappeared from coastal waters in the 1950s. Numbers remained low until the late 1980s, when enough fish finally reappeared to make commercial harvesting worthwhile again. By then, sardines in the highly productive California Current were carefully managed: Nobody wanted another crash.

Scientists still debate what causes sardine numbers to rise and fall. Overfishing certainly played a part in the collapse; the first catch limits weren't set until the 1960s, after the population had already declined steeply. Research suggests that a cooling of the eastern Pacific Ocean also played a key role in the 1950s crash. Sardines like warm water, and the eastern Pacific flips between cooler and warmer conditions every few decades. The thinking goes that a cool period starting in the mid-1940s, combined with decades of overfishing, sank the sardine.

Based on this understanding, the Pacific Fishery Management Council developed a temperature-dependent method to predict population changes and set harvest limits for sardines in the California Current. In 2010, however, scientists analyzed data from the previous two decades and published a study questioning the correlation between sardine population growth and sea surface temperature. As a result, the council removed ocean temperature from the mathematical models they use to forecast sardine population growth.

The council's decision frustrates George Sugihara, a theoretical biologist at the Scripps Institution of Oceanography in La Jolla, Calif. In his view, the simulations that fishery scientists use to predict population changes and set quotas are fundamentally flawed. When constructing these models, scientists typically assume that a given population of fish will grow, reproduce and die at known rates for the rest of time. The simulations can include environmental variables like sea surface temperature, but mostly rely on what scientists know about the biology of individual fish species.

A management approach based on chaos theory could help prevent collapses of sardines (shown) and other valuable fishes.

As a result, the predictions these models make don't reflect the dynamic complexity of the environment in which fish actually live, Sugihara says. The simulations can't capture how a population's growth rate might change in response to the other fish species living in the ocean, for example, or to the amount of zooplankton, or to wind speeds or, for that matter, to fishing itself. He says "it's like trying to understand reality by just looking at one page" of a book.

Sugihara has developed a radically different approach that he says can reveal all the pages. His method doesn't require any assumptions about fish growth rates. Instead, it uses particularly rich troves of population and environmental data from the past to predict the near future. The technique allows researchers to make pictures of what they call the past "states" of a population, which are based on variables like the numbers of adult, juvenile and baby fish, as well as the environmental factors that conventional models leave out. Sugihara and his colleagues then look for times when a population was in a state similar to its present one — for example, when fish numbers and weather were comparable — and study how the population fluctuated then. The present population will change in similar ways, Sugihara says, at least for a few years.

Using such methods, Sugihara and colleagues weighed in on the sardine conundrum. They found that if they removed just one measurement from their model — sea surface temperature as recorded at the Scripps pier — it became less accurate at tracking observed Pacific sardine populations off the California coast over the previous 50 years. The researchers

concluded that ocean temperature changes do cause fluctuations in sardine numbers, even though the relationship between the two is not readily obvious.

On the strength of this result, Sugihara's team called on managers to reverse course and once again factor in ocean temperature when forecasting sardine population change. Other researchers have made similar recommendations for different reasons, and the council is now reviewing its rules.

Solving the sardine puzzle is an important coup. But Sugihara has his sights on a much larger prize: changing how the world's fisheries are managed. He thinks his techniques should complement, if not replace, the mathematical models scientists typically use to estimate how many fish can be taken without causing their populations to decline. Methods currently in use, Sugihara thinks, are based on simplistic assumptions about nature and could make fished populations vulnerable to collapse.

Nature is simply too complex, he argues, its connections too subtle, for human-made simulations to reproduce. As conservationist John Muir wrote in his 1911 book *My First Summer in the Sierra*, "When we try to pick out anything by itself, we find it hitched to everything else in the universe."

## Putting chaos to work

To put this wisdom into action, Sugihara first has to convince the scientists who advise fishery managers that his techniques can work in real-world practice. While these scientists are intrigued by Sugihara's work, they are also hesitant to adopt methods that can seem, in the words of Alec MacCall, a senior ecologist at the National Oceanic and Atmospheric Administration who has collaborated with Sugihara, "almost magical."

For the soft-spoken but intensely driven Sugihara, there is no magic. It's just a matter of abandoning a linear view of nature, he says. In a linear model, effects scale up or down with their causes. For instance, if next year's sardine population depends solely on this year's, one could expect a doubling of spawning adults to yield twice as many fish larvae, some fraction of which would eventually become adults. Many commonly used fishery models rely on such assumptions, and allow scientists to neatly arrive at a number of adults needed to sustain a given population into the future.

In a nonlinear approach, however, small changes can have large effects. For example, a small rise in ocean temperature could send fish stocks soaring or plummeting. Or harvesting too many of the largest individuals could send the entire population into convulsions. In a 2006 *Nature* paper, Sugihara and colleagues discovered nonlinear effects in fish populations. The team analyzed data on fish living off the coast from San Diego to San Francisco, and found that populations of exploited fish species varied more over time than those of unexploited species living in the same waters. The reason, the researchers determined, is that fishermen tend to harvest the largest individuals, which makes the entire population unstable.

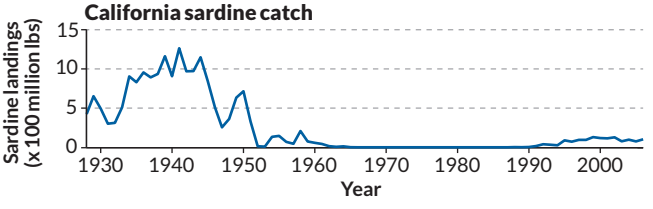
The upshot of nonlinearity is that seemingly disparate phenomena like ocean temperatures and fish populations can be connected even if they don't appear to be. As a result, you can't try to manage just one part of the environment as if it isn't being prodded and perturbed by everything around it, Sugihara says. "It's kind of wishful thinking that the world is a stable place," he says.

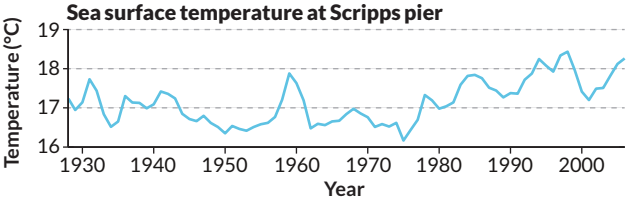
This wishful thinking has deep roots, going back at least to Isaac Newton and the mechanistic universe that emerged from his laws of motion. But in the late 1880s, French mathematician Henri Poincaré dealt a major blow to such dreams of predictability when he announced that the solar system, the classic test case for Newtonian motion, is actually nonlinear. In other words, it is impossible to calculate the precise trajectories of the sun, planets and other bodies whizzing through the void, because they are continually pushing and pulling on each other.

In the 1960s the American mathematician Edward Lorenz came to a similar conclusion about wind and rain. To communicate the challenge of making long-range weather predictions, Lorenz later coined the term "butterfly effect," which suggests that something as small as a butterfly flapping its wings can influence storms across the globe. Indeed, even with today's modern satellites and computer simulations, seemingly insignificant differences in starting conditions can lead to vast divergences in the results weather models give when they're run for more than a week or two out.

A decade later Robert May, an Australian physicist turned biologist at Princeton, applied nonlinearity to the study of life. At the time, May was studying a mathematical technique frequently used to predict how a population will change in time. Ecologists had long assumed that any population will grow toward a stable value known as its carrying capacity, at which the population's demand for resources matches the amount of resources available, and it levels off.

**Deep connection** Pacific sardine numbers (left) have fluctuated dramatically over the last century. Although scientists have long seen an association between ocean temperature (right) and sardine numbers, data since 1991 have called this relationship into question. A new technique based on chaos theory establishes that sea surface temperature causes some variation in sardine populations, even if the two variables appear unconnected. SOURCE: E. DEYLE

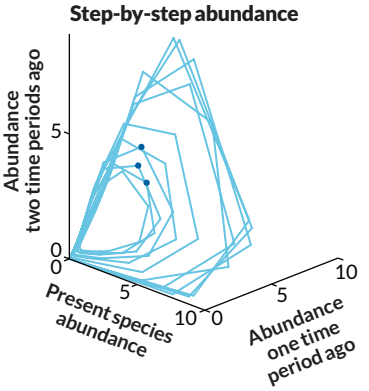


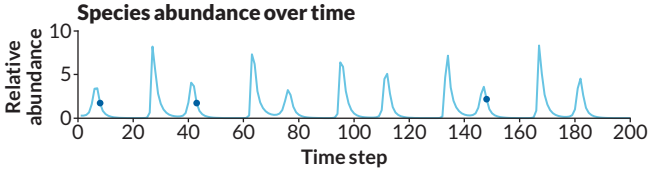



## Order from chaos

Hidden patterns can be found by tracing how multiple variables change with time. In this hypothetical example, the 3-D plot at right shows how a fish population changes relative to its value one time period and two time periods earlier. Because the three black dots at right are so near one another, they suggest that the system will behave similarly for the next few periods, as shown below.

SOURCE: E. DEYLE *ET AL*/*PNAS* 2013




But May found that if he made the growth rate — the number of offspring an individual has in a year — higher, the final population did not stabilize at a predictable number. Instead, the end point began alternating between two wildly different values as the growth rate rose. Increase the rate a bit more, and the final population bounced between four values, then eight, then 16.... Eventually, any discernible order disappeared. May showed his results to University of Maryland mathematician James Yorke, who gave the phenomenon a memorable name: chaos. "Jim Yorke is fond of saying we weren't the first people to discover chaos, but we were the last," May says.

May published his findings in a short 1976 paper in *Nature*. The work has since been cited thousands of times, as scientists from far-flung disciplines have absorbed the disturbing lesson that even simple natural systems can evade prediction. But while scientists had little trouble finding chaos once they knew to look for it, they have had less success making it useful.

Making chaos useful is what drives Sugihara. Attracted by May's intensely mathematical approach to ecology, Sugihara came to Princeton in the late 1970s and earned his Ph.D. in May's lab in 1983. He eventually headed to Scripps, but he and May kept in touch, and in 1990 they coauthored a paper in *Nature* that finally showed how chaos could be applied. The crucial insight, for which May gives Sugihara all the credit, was that chaos, though it precludes long-term prediction, is not the same thing as randomness. Randomness — the white noise on old television sets, for example — is just that, informationless noise. Chaos, by contrast, contains information, and that information can be used to predict the near future of a nonlinear system. May calls this short-term predictability the "flip side" of chaos.

Sugihara has built the rest of his career around applying the flip side of chaos to disparate fields — finance, fish, heart rhythms, atmospheric circulation and more recently gene activity and paleoclimate. Strangely, his ideas have probably found their warmest welcome far from the scientific world. Sugihara was recruited by Deutsche Bank, where he worked from 1997 to 2002 modeling short-term stock futures and, by all accounts, earning a salary unheard of among his scientist colleagues.

But after earning what May calls "more money than he'd ever need," Sugihara returned to Scripps in 2002, eager to apply the nonlinear methods with which he had achieved success in finance to thorny problems in conservation. He and colleagues used a technique called nonlinear time series analysis to study whether environmental factors affecting fish in the North Pacific Ocean were chaotic or just random. They found that while physical variables like temperature fluctuated randomly, actual fish populations behaved chaotically. Based on this finding, Sugihara and colleagues published a 2005 *Nature* paper that called on fishery managers to adopt a more "precautionary" approach, which would make fish populations resilient to abrupt shifts in environmental factors like temperature.

## Managing uncertainty

In the United States, fisheries are overseen by regional management councils that set catch limits for different species based on advice from scientists at NOAA's National Marine Fisheries Service. The Magnuson-Stevens Act, which Congress enacted in 1976 and last reauthorized in 2006, requires these scientists to set limits at no higher than a number called "maximum sustainable yield," defined as the largest number of a given type of fish that fishermen can take without causing the population to decline. This number is typically based on linear models that use current population and knowledge about how fast fish grow and reproduce to estimate future years' populations. These models have immense power: They determine how many fish will be caught, how much money fishermen can make and, to a significant extent, how marine life will fare on a planet full of fish-eating humans and domestic animals.

Thanks to the concept of maximum sustainable yield, many scientists and conservationists consider U.S. fisheries management a relative success. Under the Magnuson-Stevens Act, catch limits are in place for nearly every fished species in federal waters, defined as between three and 200 miles from shore. Managers must also create recovery plans for any stock found to be severely depleted. As a result, dramatic overfishing disasters like the collapse of Canada's North Atlantic cod fishery in the early 1990s rarely happen in the United States.

But Sugihara believes the maximum sustainable yields that managers use are little more than guesswork. The models that spit them out rely on fish populations varying around a stable equilibrium, and that, says Sugihara, is a "fiction." In the real world, a sudden change in temperature or a drop in food supply could send a population on an entirely new trajectory. Especially with climate change likely to stress marine life in unpredictable ways, Sugihara thinks fishing year after year to a theoretical (and scientifically questionable) maximum sustainable yield could

easily tip a vulnerable population toward collapse.

Sugihara advocates a different approach that would help make fish populations resilient to environmental and human-made disruptions. Rather than treat fish growth and reproduction rates as static quantities, Sugihara says, the ideal management scheme would nimbly adapt to the predictions that nonlinear time series analysis makes. For instance, if scientists detected an environmental shift likely to imperil a certain fish population, they could advise managers to quickly ratchet down catch limits. "I think it would be more dynamic, making constant adjustments to try to keep things from crashing," he says.

Providing the kind of predictive power Sugihara dreams of means overcoming several challenges. For one thing, fish, unlike stock prices, are notoriously hard to quantify. The creatures live mostly invisible lives underwater and cover vast areas. Catch numbers have traditionally been a means of estimating fish populations, but those data can reflect the number of fishermen on the water and the fishing technology used as much as actual fish numbers. Over the past few decades, scientists have made major advances in gathering data on marine life; Sugihara and his colleagues have built many of their results on a dataset produced by the California Cooperative Oceanic Fisheries Investigations, which has taken measurements on fish and environmental variables almost yearly since 1950. But nonlinear time series analysis requires data stretching back at least 30 or 40 years, which don't exist for many species in many places, especially in the developing world.

> "His methods aren't a replacement for what's being done in fisheries, but they're a really important check."
>
> ANDREW ROSENBERG

Data can always be collected, of course, but a more fundamental challenge is the long timescales on which fish populations change. While banks can capitalize on a prediction of a stock's value minutes or even seconds in advance, fishery managers need projections for a species' population years out. Nonlinear time series analysis does a decent job of forecasting next year's population, and perhaps the one after that, but beyond two years, says NOAA's MacCall, "it's worthless." This is an especially serious limitation for managing long-lived species like rockfish, whose populations change over decades, not years.

## A long road to implementation

Sugihara is used to his ideas encountering resistance. In the mid-2000s, he spent a lot of time promoting a derivatives market in fishing bycatch, which would have borrowed a quantitative tool from the financial industry to reduce the catch of nontarget species. The system would have capped the amount of bycatch fishermen were permitted; they could then sell credits in a regulated marketplace, much like in cap-and-trade systems commonly used to limit pollution. Managers implemented what Sugihara calls a "watered-down" version of his plan for salmon caught by Alaskan pollock fishermen, but such tradeable credits haven't caught on broadly. For one thing, the idea struck people as an inappropriate way to manage what are, after all, living beings, says MacCall. "A lot of people felt that was distasteful." When derivatives based on home mortgages contributed to the 2008 stock market crash, any appetite anyone might have had for such complex financial schemes vanished.

This time around, Sugihara is packaging his ideas more conventionally. He has led workshops where fisheries scientists can try using his methods with their own data, to see if environmental factors like temperature can help predict how populations of the fish species they manage vary. At one recent workshop, initially skeptical scientists studying Atlantic menhaden discovered that Sugihara's method could account for half the population's past variability over a certain period. The scientists had thought ups and downs in their data were just random. Because menhaden managers currently lack any workable model, says Ethan Deyle, a graduate researcher in Sugihara's lab, this species may provide nonlinear methods' first real-world test.

Sugihara and his students are also building software packages to help fishery professionals become more comfortable with nonlinear time series. Making these programs user-friendly so they provide just the right amount of information is crucial, says Michael Fogarty, a NOAA fishery scientist who has collaborated with Sugihara and is enthusiastic about his work.

Despite these efforts, getting nonlinear time series analysis incorporated into actual practice has proven a slow and, for Sugihara, often frustrating process. A collaboration Sugihara has launched with Fisheries and Oceans Canada is just getting off the ground. Meanwhile, fishery scientists in the United States say they will need more time to convince managers that the technique is solid enough to base catch limits on. Not even Sugihara thinks nonlinear time series analysis will replace conventional linear models any time soon. "It's not like saying this guy has a better pickax, so forget this shovel," he says. "That's not something that's realistic."

Andrew Rosenberg, a former regional administrator for the National Marine Fisheries Service, thinks Sugihara's techniques could help correct errors that routinely creep into population forecasts from linear models. "His methods aren't a replacement for what's being done in fisheries, but they're a really important check," says Rosenberg, who now heads the Center for Science and Democracy at the Union of Concerned Scientists.

Managers' conservative attitudes toward unproven methods is understandable, given the high stakes for people who fish for a living, says Fogarty. "People don't want their livelihoods used as an experiment." But like many fisheries scientists, he and MacCall wish managers were less reluctant to incorporate new ideas.

"I think what [Sugihara has] done has opened up a different way of looking at things," MacCall says. "A way the traditional viewpoint never, ever would have considered." ■

## Explore more


- G. Sugihara *et al*. "Detecting causality in complex ecosystems." *Science*. October 26, 2012.

# THE LONG AND WINDING COLO

PETE MCBRIDE/NATIONAL GEOGRAPHIC CREATIVE

Standing on a mesa high above the town of Rifle, Colo., Andres Aslan is having a hard time staying quiet. The lanky geologist from nearby Colorado Mesa University normally speaks in a low-key professorial drone. But here, looking down at a sprawling river valley blazing with autumnal cottonwoods, his enthusiasm cranks up his volume. "This could be it," says Aslan, gesticulating wildly. "This may end up being the most important site anywhere."

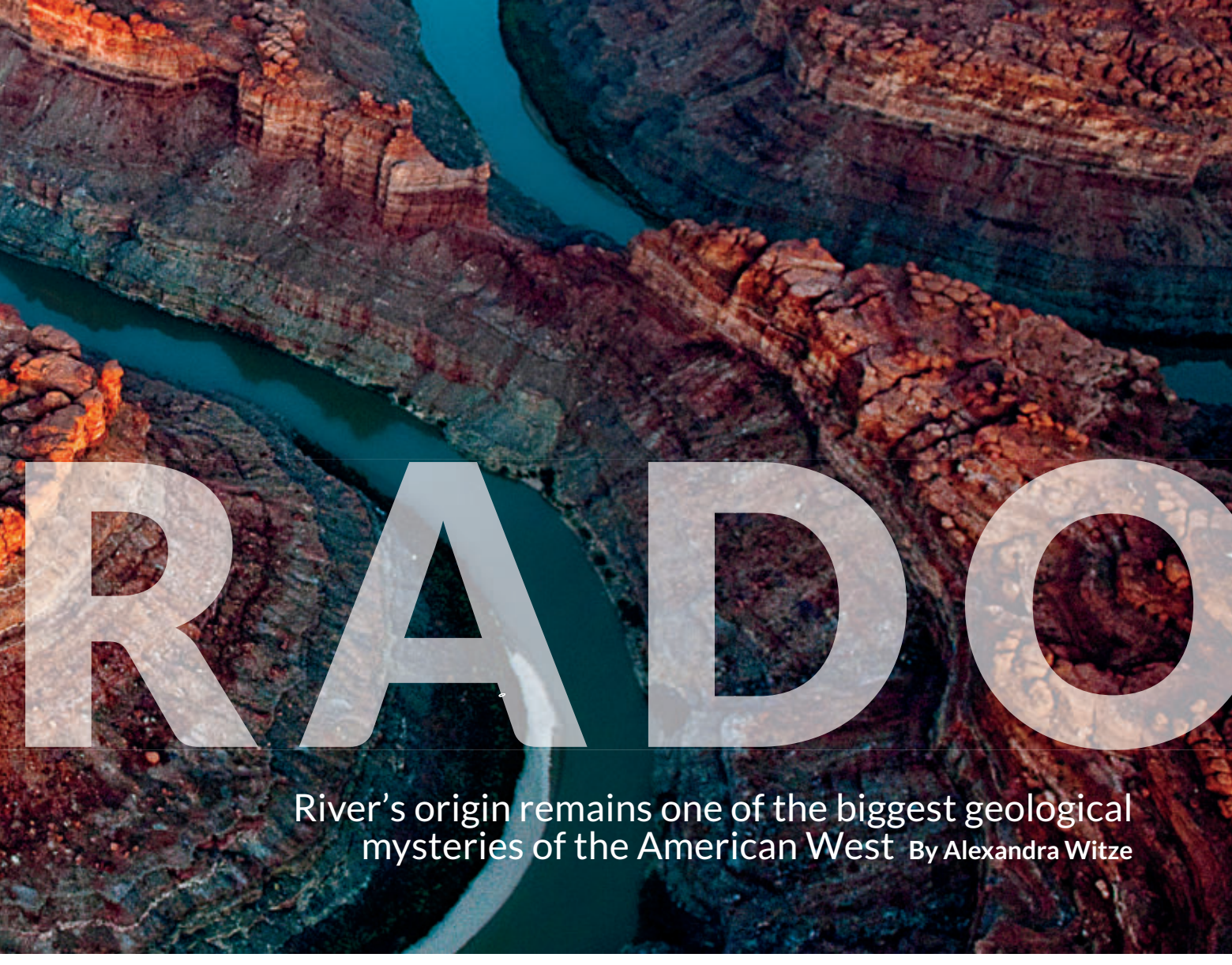
What's important about this mesa, called Taughenbaugh, is the gravel under Aslan's feet. It was laid down 1.75 million years ago by the Colorado River. The modern Colorado wends through the valley beneath. Over those millions of years, the river eroded away all the rock layers that once existed between the high mesa and the valley below.

> "It's among the world's most fascinating rivers."
>
> KARL KARLSTROM

Aslan has been striding up and down Taughenbaugh and neighboring mesas for years, gathering clues about how the famous river shaped the landscape. He hopes to help crack one of the biggest geological mysteries of the American West: how and when the mighty Colorado River came to be.

From its headwaters in western Colorado, the river makes its way west and south. It passes through the red rocks of Utah, carving dramatic landscapes such as Arches and Canyonlands National Parks, and surges onward through the Grand Canyon. Bottlenecked by dams, tapped along its course for drinking and irrigation, the Colorado eventually crosses into Mexico and trickles to the Gulf of California, 2,300 kilometers from where it began.

It is one of the world's most storied rivers. Its deep canyons provided passage for the first



# RADO

## River's origin remains one of the biggest geological mysteries of the American West

By Alexandra Witze

geological explorations of the American West. Its waters, fought over from Phoenix to Los Angeles to Mexicali, make desert life possible for millions. Yet scientists know surprisingly little about the ancient history of the Colorado River.

They do know that by about 11 million years ago, rainfall was running off the western Rockies in a sort of proto–Colorado River. By about 5 million years ago, those waters had breached the Gulf of California and completed the entire river system drainage. But many mysteries remain.

One huge puzzle is when and how the Grand Canyon — the river's most glorious stretch — came to be. In the last few years, a handful of geologists have put forward a startling alternative explanation of the canyon's history. Rather than being carved in the last 6 million years or so, they contend, the Grand Canyon may date back some 70 million years. If they are right, then water has been running through essentially the same deep gorge since the time of the dinosaurs. Other researchers are far from convinced, and the two camps continue to argue over what the canyon's rocks have to say about its history.

New research may illuminate the story of the Colorado River and the Grand Canyon. Crystals trapped in ancient sandstone are providing new time stamps for key stages in the river's evolutionary past. Chunks of the mineral apatite offer clues to how long particular rocks have been exposed at the surface, revealing when canyons were carved. And good old-fashioned geological mapping, like Aslan's, is tying lots of little river drainages together into a much fuller picture of how the Colorado arose over time.

"It's among the world's most fascinating rivers," says Karl Karlstrom, a geologist at the University of New Mexico in Albuquerque. "It carved one of the most iconic landscape features on Earth. It's a terrific laboratory."

The waters of the Colorado River (seen here looping through Canyonlands National Park in Utah) have eroded rock formations into some of the most spectacular landscapes on the planet.

## Drilling down to the early days

In the years after the Civil War, the explorer John Wesley Powell tried to make sense of the Colorado as he surveyed the length of the Grand Canyon. Powell knew that water was the key element that had shaped the otherworldly landscape. "The carving of the Grand Canyon is the work of rains and rivers," he wrote. "Though storms are far apart and the heavens above are cloudless for most of the days of the year ... an intermittent rill called to life by a shower can do much work in centuries of centuries."

After all, even the mightiest river begins as a tiny stream. Rainwater running off the land carves the underlying surface to create a gully. Over time, more and more stream-filled gullies connect in a branching pattern to form a large river.

Powell believed the Colorado was an ancient drainage, one that had followed essentially the same course from the Rockies to the Pacific for tens of millions of years. Later geologists discovered problems with this simplistic picture. Among other things, there's no evidence that the river made it off the western edge of the Colorado Plateau — the raised area encompassing the Four Corners region where Utah, Colorado, New Mexico and Arizona come together — before about 6 million years ago.

**A watershed river** From its headwaters in the western Rocky Mountains, the Colorado drains much of the western United States. Because millions of people use its water for agriculture and development, what finally reaches the Gulf of California, between mainland Mexico and the Baja peninsula, is a remnant of its once-mighty self.


A big river spilling off the plateau should have left massive deposits of river gravel. But no one can find any.

In fact, the more geologists have looked at Colorado River history, the more complicated the story has become. Part of the problem is the sheer difficulty of measuring a landscape torn apart by water. "There just isn't much data to go on," says Kelin Whipple, a geomorphologist at Arizona State University in Tempe. "It's a completely erosional system, so it hasn't left much trace of how fast things happened."

In the case of the Colorado, Aslan got lucky. Not far from Rifle, atop a mountain known as Grand Mesa, he and his colleagues discovered thick layers of gravel left behind by the ancient river. At one point a nearby volcano had erupted, burying the gravel in lava that hardened to solid rock. The researchers looked at the steady decay of radioactive elements in the hardened lava to deduce that it flowed atop Grand Mesa 10.7 million years ago. That means the river gravel it buried must be even older — and that the Colorado must have been flowing in this region by about 11 million years ago, the team reported in a 2010 Geological Society of America field guide.

Now Aslan wants to look even further back in time. He's pinning his hopes on the mesas around Rifle, and getting a helping hand from the recent boom in natural gas exploration. The countryside is studded with drill rigs, and as Aslan gathers visiting geologists around him, drill truck after drill truck rattles by on the high country road. Soon the group is joined by Barbara Allen, a student in a bright pink Colorado Mesa hoodie. She's working toward a geology degree while holding down a job at WPX Energy, a company that is drilling atop a neighboring mesa called Flatiron.

Aslan begins leading the group uphill, loping toward an outcrop of Colorado River gravel he promises is just over the next rise. Allen points out elk droppings for visitors to avoid as she describes the geology she and Aslan are hunting.

As at Grand Mesa, volcanic flows have covered and preserved Colorado River gravel in places. WPX has been drilling repeatedly through the mesas, plunging thousands of feet below ground in search of natural gas. Allen's job is to race out to the mesa when engineers are spudding, or starting, the wells — and gather up precious samples of river gravel that the drillers would otherwise discard as useless. "They see me coming and they know what I'm looking for," she says.

Aslan hopes to find drill cuttings that contain

Arizona's Marble Canyon, just upstream from the Grand Canyon, is part of an ongoing dispute over when exactly the Grand Canyon was carved.

TOM GRUNDY/SHUTTERSTOCK

Colorado River gravel deposits going back millions of years. Though he eventually learns that the river's gravel wasn't preserved in the layers the WPX drill punched through, he continues to explore the mesas near Rifle, hunting for more signs of the Colorado flowing across this part of the country millions of years ago.

## Signs of the ancient river

To find the other bookend to the story of the Colorado, you have to travel way down near the Arizona-California-Mexico confluence. Here, geologists have pieced together the story of a flood appearing a little more than 5 million years ago. That water, they say, must be the full-blown arrival of the Colorado.

In far southern California and northern Mexico, the movement of the San Andreas fault has caused a huge chunk of land, known as the Salton Trough, to drop below sea level. Rebecca Dorsey, a geologist at the University of Oregon in Eugene, has been scouting this region for signs of the ancient river. Because of its low elevation, the land serves as a sort of sink where sediments accumulate. Dorsey has found massive layers of river deposits dating to 5.3 million years ago; studies of the mineral grains show that they came from all across the watershed of the modern Colorado River.

Over the last 10 million years, some 340,000 cubic kilometers of rock washed across the western United States downstream to this part of the Southwest — enough to fill NASA's enormous Vehicle Assembly Building in Cape Canaveral almost 100 million times. "This huge volume of rock eroded out of the Colorado Plateau, and it's the river that did the job," says Dorsey. She and Greg Lazear, of the Grand Junction Geological Society of Cedaredge, Colo., described the calculations in the August *Geosphere*.

So the river started in western Colorado at least 11 million years ago, and its waters reached California after 6 million years ago. In between, rivers may have drained off the Colorado Plateau to the north, through Idaho and beyond. Or they may have ponded in huge lakes like today's 4,400-square-kilometer Great Salt Lake. In this scenario, the lakes existed until a river captured their waters and spilled off the plateau to form the Colorado.

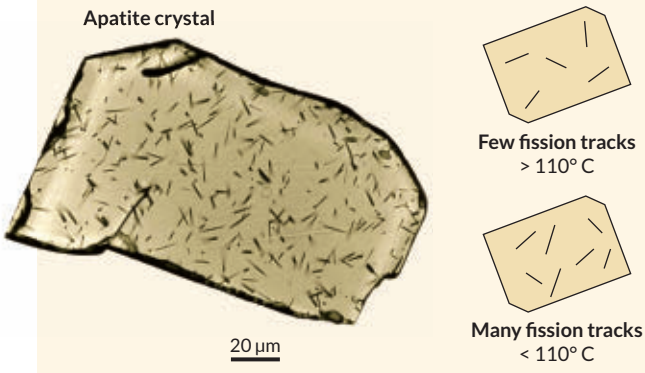
This may also have been the time when, according to classical theories, the river began carving the Grand Canyon. Most geologists hew to the idea that the Colorado River started to cut through the rocks that form the canyon beginning about 6 million years ago. (The rocks exposed in the canyon walls are far more ancient, dating back as much as 1.8 billion years.)

## Dueling dates

But some geologists say that the carving of the canyon took place way before that. The evidence comes in the form of crystals of apatite, a mineral commonly found in rocks along the canyon's 433 kilometers. Starting in 2008, Rebecca Flowers of the University of Colorado Boulder and her colleagues studied helium inside the apatite, which is created when uranium decays. This helium can be used to record the cooling history of the rocks.

The key is that helium diffuses out of apatite crystals, and is permanently lost, when temperatures are hotter than about 50° Celsius. If you find helium in an apatite crystal, you know the rock has been cooler than 50°. The more helium, the longer it has been cool. Rocks get cool when they move from being buried deep within the Earth to the surface — like when a river erodes away the overlying rock layers. Flowers and her colleagues used helium in rocks exposed in the Grand Canyon to calculate how long they had been cool, and thus how long ago the canyon was carved.

"These rocks have been cold for a very, very long time," says Flowers, about 70 million years. She and Kenneth Farley of Caltech published their




### Colder near the surface

Damage marks left by radioactive uranium decaying in the mineral apatite can be used to trace how warm or cold a rock has been. If the rock containing the apatite is warmer than about 110° Celsius, the marks heal themselves and vanish. But if the rock cools below 110°, the tracks are preserved. Because rocks grow cooler the closer they are to Earth's surface, geologists can use apatite fission tracks to calculate how deeply and for how long a rock was buried.

SOURCE: RYAN CROW/UNIV. OF NEW MEXICO

findings in 2012 in *Science* (*SN: 1/12/13, p. 15*).

Flowers runs a highly regarded geochronology laboratory. But Karlstrom, who grew up hiking and rafting the Grand Canyon, didn't let her calculations go unchallenged. "It just goes against decades of geological understanding," he says. Karlstrom fired off a technical response to *Science*, cross-questioned Flowers at a conference weeks after her paper was out and organized four follow-up sessions for a Geological Society of America meeting last October in Denver.

Those sessions at the Denver conference were as close as geologists get to friendly fire. Flowers, Karlstrom and other players in the canyon dating game lined up against a meeting-room wall and passed a microphone back and forth, arguing over what apatite grains were telling them.

> "These rocks have been cold for a very, very long time."
>
> **REBECCA FLOWERS**

Flowers stood by her dates, even as Karlstrom whipped out another set of data.

Last April, he and colleagues led by John Lee of the U.S. Geological Survey in Denver published a paper in *Geosphere* with additional helium dates from dozens of rock samples from the canyon. The researchers used the same helium dating method that Flowers employs, as well as a second technique: They looked at marks left behind by radioactive atoms spontaneously fissioning and plowing through the apatite crystal.

If the crystal is hotter than about 110° C, it naturally heals itself and very few of these "fission tracks" are preserved. As temperatures start to cool below 110°, though, more and more of the tracks remain in the crystal. That means the existence of the tracks can be used like a stopwatch to calculate when and how fast the apatite cooled. Lee's team reported that, for the eastern Grand Canyon at least, there could have been no canyon as deep as today's until after about 25 million years ago — and probably much more recently than that.

There's no clear answer for why the "young canyon" and "old canyon" proponents are so far apart. In part, the disagreement involves how to interpret the record in the apatite crystals. In places, the helium data from Flowers' team and Lee's team are essentially identical; the difference is in how scientists infer a temperature history for the rock. Use a slightly different temperature for how cool the surface of the Earth is, for instance, and suddenly an apatite crystal might look like it's been buried for much longer.

Karlstrom thinks there may be ways to "honor all the datasets," as he puts it. One possibility is that different small canyons formed at different times. "Variable cooling histories along the river corridor reflect a ragged escarpment where places are cooling faster or slower," he says. And those smaller bits could be confusing the much grander story of the river as a whole.

In the end, the answer may come by combining the best geologic mapping with additional rock-cooling dates. Some researchers are beginning to use a third dating method, which measures the ratio of helium isotopes within apatite. It can be used to track the final part of a rock's cooling history, between about 60° and 30° C. Only by "triple dating" lots of rocks with all three methods, Karlstrom says, can geologists begin to agree on the canyon's history.

Whatever happens with the fight over the Grand Canyon's age, the Colorado River will continue to flow, as much as it can, given all the demands on its water. It will trickle down from the western slope of the Rockies, past the high mesas of the Colorado Plateau and through the Grand Canyon, until it empties into the sea. ■

## Explore more

■ Wayne Ranney. *Carving Grand Canyon: Evidence, Theories, and Mystery.* Grand Canyon Association, 2nd edition, 2012.

FROM LEFT: UNIV. OF BERGEN, NORWAY; R. CROW, ADAPTED BY S. EGTS

The Jurassic Coast along England's southwest shore is a rich hunting ground for beginning or experienced fossil hounds.

EXPERIENCES

# Hunting fossils in England

As rain plopped onto our jackets, my tour group huddled against the side of the Lyme Regis Museum on the southwest coast of England, struggling to hear our fossil-hunting guide over the sound of wind and waves.

"This is really the weather you want for fossil collecting," said marine biologist Chris Andrew, the museum's education director. "It lets the fossils wash down from the cliffs." And, he explained, "a bit of rain keeps everyone else at home."

A friend and I spent a week hunting fossils along the Jurassic Coast, a 150-kilometer stretch of English coastline just a few hours by train from London. In the 18th and 19th centuries, geologists came to the region to study the neatly stacked layers of rock, which date to 250 million to 65 million years ago and provided evidence that the Earth was much older than the 6,000 years many thought at the time. But it's the fossils that have proved the long-term draw. Now, science tourists find not only some of the easiest fossil hunting for beginners, but one of few places where they will be encouraged to take fossils home.

On Monmouth Beach, just west of the center of Lyme Regis, amateur and professional collectors have been making discoveries for more than two centuries. The rocks are some 200 million years old and hold the remains of an ancient deep sea. Ammonites are the most common finds, their coiled, nautilus-like shells easy to spot on the rocky shore. There's even an ammonite graveyard, where hundreds of large coils are still buried in the rock. These invertebrates were once at the base of the marine food web, providing meals for large vertebrates such as plesiosaurs and ichthyosaurs, Andrew explains to our group.

Famed fossil hunter Mary Anning discovered the world's first complete plesiosaur along this coast in 1823, a dozen years after her family uncovered the first ichthyosaur. The region holds the remains of more than just sea life, though. Among Anning's other discoveries were an early Jurassic pterosaur, called *Dimorphodon*. And the bones of an armored dinosaur called *Scelidosaurus* were discovered washing out of the cliffs near Charmouth in the 1850s. The cliffs are still releasing important finds, such as a new 130-million-year-old crocodile species named for Rudyard Kipling in 2012.

Andrew and his co-leader, geologist Ben Brooks, show examples of what to look for: the pointed tips of belemnites, semicircles or bathtub shapes that indicate bivalve shells and the starfish-shaped stems of sea lilies. Round or hexagonal black rocks, indented on both sides, are ichthyosaur vertebrae.

But before we could look for fossils, Brooks gave a lesson on safety and the fossil code. There are dangers, such as cliff falls and tides. Most collecting from the beach is legal because whatever isn't picked up just washes into the sea. Yet it's not quite a free-for-all, and digging directly into the cliffs requires permission. "We don't want scientifically important specimens disappearing," Brooks said.

Only the children were guaranteed fossils on this guided trip, courtesy of Brooks and Andrew. But that afternoon and the following ones, my friend and I tested Andrew's best piece of advice: "You're looking for regular patterns in the rock," he told us. We quickly met success along the beaches at Lyme Regis and nearby Charmouth, finding dozens of ammonites, pieces of belemnites, bits of ichthyosaur rib and sea lilies, and even a globelike sea urchin. The prize find went to my friend, now the proud owner of a coprolite: a piece of fossilized excrement. —*Sarah Zielinski*

## To visit

Fossil walks available from:

**Lyme Regis Museum**
www.lymeregismuseum.co.uk

**Charmouth Heritage Coast Centre**
www.charmouth.org/chcc

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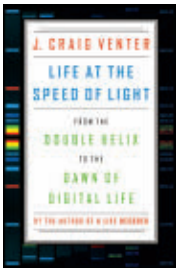
BOOKSHELF

## Life at the Speed of Light

From the Double Helix to the Dawn of Digital Life

*J. Craig Venter*




Biology has come a long way from the days of mixing things in petri dishes and hoping something interesting happens. In his new book, Venter introduces readers to a future of precise biological engineering, guided by DNA and targeted to create life forms never before thought possible.

Venter has the scientific chops to back up these claims. His first book related the story of how he led a private effort that raced a government-funded consortium to decipher the DNA sequence that makes up the human genome. His second book focuses on a later lab triumph: the creation of Synthia, the first life-form with a synthesized genome.

Synthia, announced in 2010, is a bacterial mash-up. Venter's team stitched together a genetic code for one bacterial species from scratch, then inserted it into a second species and booted it up. The result was a living, self-replicating cell that essentially cribbed synthetic DNA to function.

In relating Synthia's story, Venter illuminates the twists and turns that are a hallmark of modern science. Time and again the researchers go down blind alleys, only to start again using a different tack — such as ditching one simple but slow-growing bacterial species in favor of another more complex one that will replicate faster in petri dishes.

This description of science-as-process is perhaps the most notable aspect of *Life at the Speed of Light*. Venter embeds the story of Synthia in the deep history of molecular biology, laying out discoveries by previous generations of scientists and clarifying how those advances made way for modern investigations. It's a story with many blind turns and dead ends, but one that triumphs in the end. —*Alexandra Witze*
*Viking, $26.95*

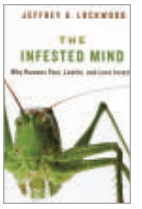
SCREENTIME

## Tracking fireballs for science

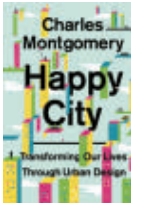
A free app lets you log a meteor just after seeing it


PHONE: HOCUS-FOCUS/ISTOCKPHOTO; APP: FIREBALLS IN THE SKY/DESERT FIREBALL NETWORK

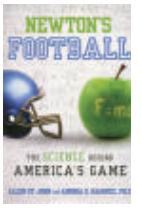
Watching a meteor race across the night sky is a romantic experience. And now it can be a scientific one as well. The new Fireballs in the Sky app lets you track fiery objects and enter them into a research database. Scientists at Curtin University in Australia are tracking fireballs (meteors that are very large and bright) using cameras across Australia in a project called the Desert Fireball Network. Their new app harnesses cell phone cameras all over the world to gather data on meteor and fireball sightings. When you see one, point your phone at the sky and click where it began and ended, then adjust settings for size and brightness. You can see if other people logged the same object, and the data help scientists determine where the meteor came from and, hopefully, where it ended up. The app is available free in iTunes for iOS devices and in the Google Play store for Android devices. — *Bethany Brookshire*



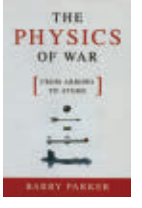

**The Infested Mind**
*Jeffrey A. Lockwood*
When it comes to feelings about insects, humans are rarely neutral. An entomologist evokes Kant, Dali, Jung and a host of scientific research in his exploration of our fascination with and revulsion of arthropods, plus the environmental costs of battling insects. *Oxford Univ., $24.95*




**Happy City**
*Charles Montgomery*
Some neighborhoods make people slimmer and some apartment designs make residents dislike their neighbors, a journalist and self-styled urban experimentalist argues. Hopping from Bogotá to Paris, the author interviews architects, mayors and residents to explore how humans might design cities for a healthier existence. *Farrar, Straus & Giroux, $27*




**Newton's Football**
*Allen St. John and Ainissa G. Ramirez*
Connections between better helmets and greater injury and between the West Coast offense and quantum physics are just a couple of the insights revealed in this marriage of science and pigskin (or "prolate spheroid," as the authors call it). *Ballantine, $26*




**The Physics of War**
*Barry Parker*
Breakthroughs in physics have historically led to innovations in warfare. The author, a science writer, reveals the characters, technology and narratives behind our militarized present. *Prometheus, $26*

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NOVEMBER 30, 2013

DECEMBER 14, 2013

" 'Candidates for dark matter bite the dust' (*SN: 11/30/13, p. 9*) brought to mind a quote by Confucius that 'the most difficult thing is to find a black cat in a dark room, especially if there is no cat.' "

**JEFFERY MILLER, LOS ANGELES**

## Healing talk

**Bruce Bower** described efforts to bring mental health services to the poor in developing nations, especially in times of war, in "Heal thy neighbor" (*SN: 12/14/13, p. 22*). "We will have to come forward and join hands to help these people," **Dee Baig** said on the *Science News* website. "The idea that the famous poet Saadi described in the following lines more than 700 years ago is as relevant today as it was then: 'If one member is afflicted with pain, other members uneasy will remain. If you have no sympathy for human pain, the name of human you cannot retain.' "

## Putting it all in perspective

Readers have lately taken us to task for not indicating the sizes of objects in photographs and diagrams.

One reader's letter summed up the problem nicely: "One of the greatest challenges to popular science education is conveying a sense of scale," **Paul H. Smith** e-mailed. "Our culture poorly grasps the relationship of human-scale objects to those normally designated astronomical. It is difficult to find opportunities to highlight such relationships with the illustrations and graphic designs generally found in publications such as *Science News*. I therefore urge *SN* editors to watch carefully for such occasions, and offer a recent example to make this point. "Science Visualized" on Page 32 of your November 30 issue provides such an opportunity. What an impact this spectacular photo of a solar explosion would make if it included an image of planet Earth to scale. Of course a designer would have a bit of work to do to create the "box" necessary to showcase the tiny object, but I am sure a little experimenting would yield results. And I also urge that someone on your staff routinely screen *SN* illustrations for similar opportunities."

We have heard from other readers about the scale of objects we have displayed, large and small, from a canyon on Mars to fly embryos. In some cases, detailed scale information is not available from the original scientific sources, and we don't want to imply a level of precision that we cannot justify. But your concerns are noted and we are making every effort to include a sense of size, whether as a scale bar or a mention in the text, whenever possible.

## Man's most contentious friendship

In "Modern dogs originated in Europe" (*SN: 12/14/13, p. 6*), **Tina Hesman Saey** reported on new genetic research suggesting that hunter-gatherers domesticated dogs from European wolves between about 18,000 and 32,000 years ago. How and when dogs were domesticated has been hotly debated, as editor in chief **Eva Emerson** discussed in her editor's note in the same issue. Getting to the bottom of the story will take "all the clues we have, plus a healthy dose of imagination," Emerson wrote.

Some readers, like **Victoria Ava** on Facebook, suggested that there is room for more than one answer to the question of where and when dogs originated. "I wouldn't be surprised if they were domesticated in various areas at various times," she wrote. Or maybe it's all half-truth, suggested **bf1x@comcast.net** in an online comment: "What this really demonstrates is that certain areas of science are riven with speculation and storytelling. The popular stories become the accepted "truth" until someone else spins a better story."

As for dogs' current relationship with wolves, **Steve Raith** e-mailed to challenge a question Emerson raised in her editor's note: "How different are [dogs] from their fiercer canine relatives, the wolves?" That question makes the presumption that wolves are in fact fiercer than dogs, Raith writes. "Is there a study giving actual evidence that wolves are fiercer? There seem to be many more dog attacks on humans than wolf attacks. In addition, neighborhood dogs act in packs, chasing down and killing deer and also attack livestock. Is this [mind-set] a carryover from 'Little Red Riding Hood'?"

## Join the conversation

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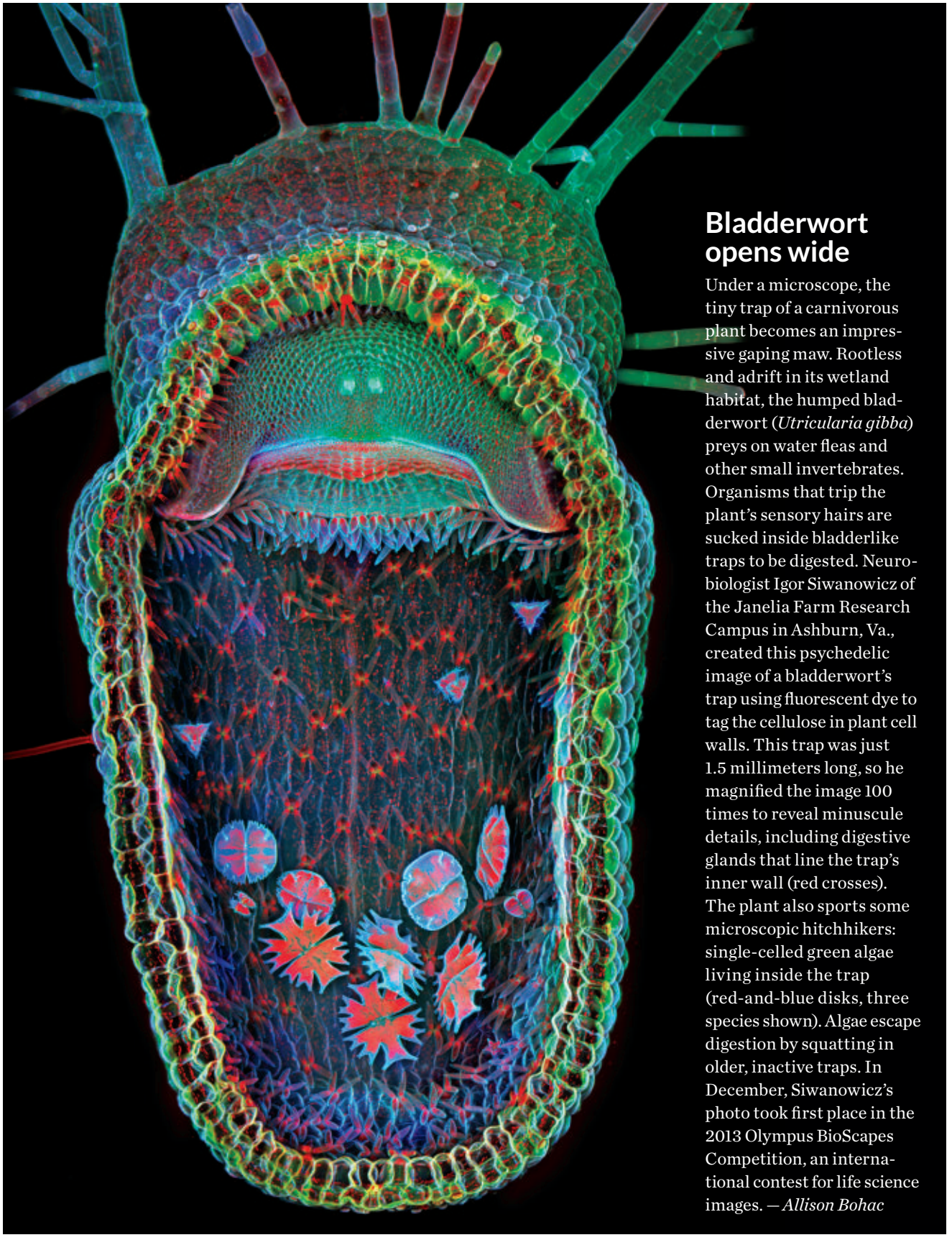

## Bladderwort opens wide

Under a microscope, the tiny trap of a carnivorous plant becomes an impressive gaping maw. Rootless and adrift in its wetland habitat, the humped bladderwort (*Utricularia gibba*) preys on water fleas and other small invertebrates. Organisms that trip the plant's sensory hairs are sucked inside bladderlike traps to be digested. Neurobiologist Igor Siwanowicz of the Janelia Farm Research Campus in Ashburn, Va., created this psychedelic image of a bladderwort's trap using fluorescent dye to tag the cellulose in plant cell walls. This trap was just 1.5 millimeters long, so he magnified the image 100 times to reveal minuscule details, including digestive glands that line the trap's inner wall (red crosses). The plant also sports some microscopic hitchhikers: single-celled green algae living inside the trap (red-and-blue disks, three species shown). Algae escape digestion by squatting in older, inactive traps. In December, Siwanowicz's photo took first place in the 2013 Olympus BioScapes Competition, an international contest for life science images. —*Allison Bohac*

I. SIWANOWICZ/HHMI JANELIA FARM RESEARCH CAMPUS



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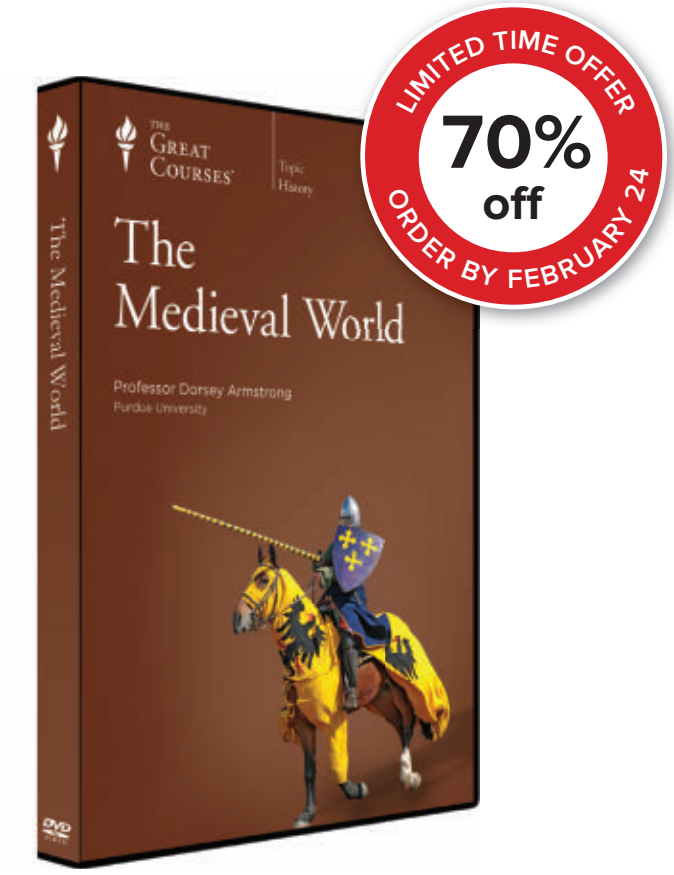


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