



# SN

SCIENCE NEWS MAGAZINE  
SOCIETY FOR SCIENCE & THE PUBLIC

SEPTEMBER 2, 2017

Next-Gen  
Birth Control

Human  
Embryos  
Edited

Diamonds  
in 2-D

It's a Wrap  
for Archaea  
DNA

# ONE LAST LOOK

Cassini's tour of Saturn comes to an end

Urgent: Special Summer Driving Notice

To some, sunglasses are a fashion accessory...

# But When Driving, These Sunglasses May Save Your Life!

**Drivers' Alert:** Driving can expose you to more dangerous glare than any sunny day at the beach can... do you know how to protect yourself?

The sun rises and sets at peak travel periods, during the early morning and afternoon rush hours and many drivers find themselves temporarily blinded while driving directly into the glare of the sun. Deadly accidents are regularly caused by such blinding glare with danger arising from reflected light off another vehicle, the pavement, or even from waxed and oily windshields that can make matters worse. Early morning dew can exacerbate this situation. Yet, motorists struggle on despite being blinded by the sun's glare that can cause countless accidents every year.

## Not all sunglasses are created equal.

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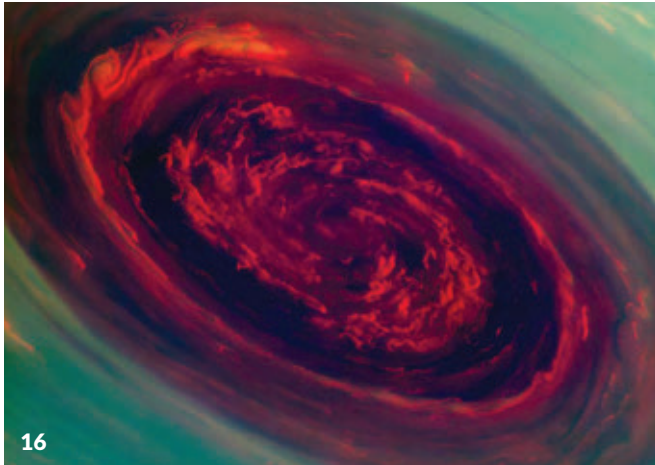
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# ScienceNews



## Photo Essay

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**COVER STORY** As Cassini prepares to plunge to its death, *Science News* celebrates the spacecraft's discoveries and breathtaking images of Saturn, its rings and moons.

By Lisa Grossman

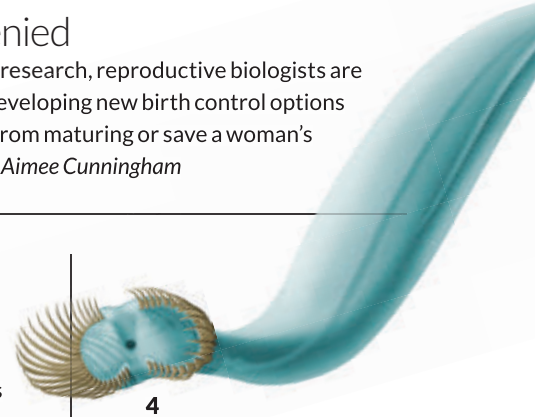
## Feature

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After decades of research, reproductive biologists are on the verge of developing new birth control options that stop sperm from maturing or save a woman's eggs for later. By Aimee Cunningham

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**COVER** Cassini took this picture of Saturn's iconic rings bathed in sunlight on January 28, 2016. JPL-Caltech/NASA, Space Science Institute



## Patience is one virtue scientists must embrace

There's a lot of waiting in science. Collecting and interpreting evidence demands skill and commitment, creativity and curiosity — and time. Though Saturn has been known since ancient times, Galileo first observed it with a telescope in 1610. He saw the rings, but didn't identify them as such.

Not until the 1650s did Dutch astronomer Christiaan Huygens report a flat ring around Saturn. The first mission to Saturn had to wait until 1973, with the launch of Pioneer 11. It took six more years before that craft arrived at Saturn, where it flew through the outer rings.

Fast-forward another several decades, and for the first time ever, a spacecraft is now diving *between* Saturn and its rings. It's been more than four centuries since the rings were first observed, and nearly two decades since the spacecraft, Cassini, launched from Cape Canaveral. Later this month, Cassini will enter Saturn's atmosphere — another first — as part of its final farewell, as described by astronomy writer Lisa Grossman on Page 16. Another probe probably won't return to the planet until sometime after 2030.

Budgets, shifting priorities and technological limitations can slow down space missions. And even if everything runs smoothly, the vastness of space introduces its own delays (thank you laws of physics). Data travel from Cassini to Earth at the speed of light, for example, but still take over an hour to arrive. And heavenly bodies swing on the grandest of scales, so astronomers are regularly waiting for the right moments to make their observations — for the sun to set, for instance, or for the moon to block the sun in a total solar eclipse. (Anyone who missed the total eclipse on August 21 will have to wait until 2024 to have another shot in North America.)

But astronomers aren't alone in their waiting. Microbiologists must wait for cell cultures to grow. Archaeologists count down the days until field season begins. Modelers benefit from boosts in computing power that come only with time, allowing them to capture all kinds of processes in much more detail. The waits might be most acute for researchers hoping to make advances in medicine. They know that waiting for new treatments can be painful, life-altering and even life-ending. On Page 6, molecular biology writer Tina Hesman Saey describes a milestone in the gene editing of human embryos, one that could ultimately help treat a potentially fatal heart disease. But there's a long way to go before clinical trials can begin. The same is true for the search for new contraceptives, described by biomedical writer Aimee Cunningham on Page 20. Many new approaches are still in testing in rodents. And even once a potential drug reaches clinical trials, there's no guarantee of success. As scientists wait, so too do doctors, their patients and the patients' families.

Perhaps anyone frustrated by the pace of science can take comfort in the words of physicist Chang Kee Jung. He expects an upcoming detector, DUNE, to offer clues to why matter — the very stuff of our existence — far outweighs antimatter in the universe (see Page 15). The detector won't be online until well into the 2020s, but Jung encourages patience. "We are dealing with really profound problems," he says. — *Elizabeth Quill, Acting Editor in Chief*

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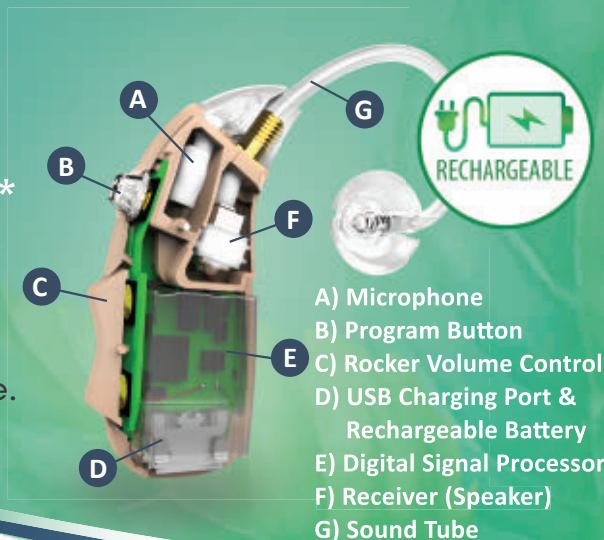
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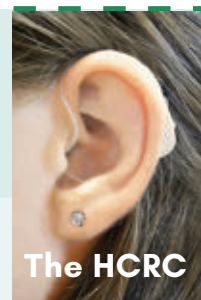
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Excerpt from the  
September 2, 1967  
issue of *Science News*

50 YEARS AGO

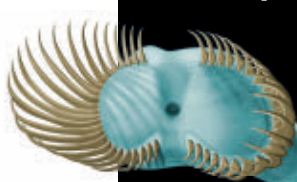
## Waste makes haste

Getting rid of bodily wastes during long space flights is a problem.... A bizarre possible solution ... involves whipping the wastes in with some other ingredients to produce the most unusual rocket fuel.... The four ingredients — carbon, ammonium, nitrate and aluminum — and the waste material are just blended together, and they're ready to go.... [The material] would probably be used to help a spacecraft change position or to nudge a long-life space station occasionally to keep it up in orbit.

**UPDATE:** Researchers are still trying to figure out how to turn astronaut excrement into something useful. Another process proposed in 2014 would use microbes to convert the waste and other organic material into fuel. But waste might have other uses that would be especially helpful during long-term flights. Synthetic biologists at Clemson University in South Carolina are working with NASA to use algae and genetically modified yeast to turn astronaut urine into 3-D printable plastics and nutritional omega-3 fats.

INTRODUCING

## Ancient sea worm had a head full of spines



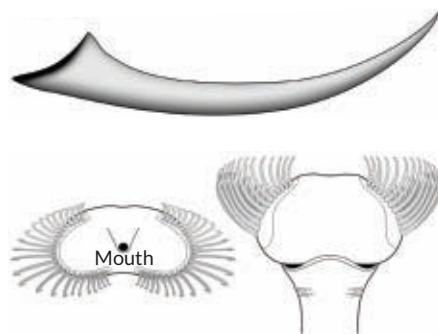
The arrow worm (illustrated) sported about 50 spines on its face, which helped the creature capture prey.

Predatory sea worms just aren't as spiny as they used to be.

These arrow worms, which make up the phylum Chaetognatha, snatch prey with Wolverine-like claws protruding from around their mouths. Researchers now report that a newly identified species of ancient arrow worm was especially heavily armed. Dubbed *Capinator praetermissus*, the predator had about 50 curved head spines, more than twice as many as most of its modern relatives. Arranged in two crescents, the spines could snap shut like a Venus flytrap to catch small invertebrates.

More than 100 species of chaetognaths are alive today, but evidence of their ancient relatives is spotty. *C. praetermissus* lived a little more than 500 million years ago during the Cambrian Period and was identified from 49 specimens found in the fossil-rich Burgess Shale in British Columbia, the scientists report in the Aug. 21 *Current Biology*. Often, only arrow

The spiny face of a bizarre marine worm called *Capinator praetermissus* was left behind in this roughly 500-million-year-old fossil from Canada.



The spines of a newly discovered worm curved like claws (closeup drawing, top) and attached to the head around the mouth (bottom).

worms' clawlike spines appear in the fossil record, without soft tissue. But many of the new finds had such tissue preserved, which provided clues to body size and shape.

*C. praetermissus* was different enough from other chaetognaths to be labeled not only a new species, but also a new genus. The animal was at the larger end of the scale for arrow worms: about 10 centimeters from spines to tail. And while today's arrow worms have teeth to mash up their meal after capturing it, this ancient species appears to have been toothless. But arrow worm teeth, which are found closer to the mouth, are quite similar to spines, says study coauthor Derek Briggs, a paleontologist at Yale University. Shorter spines seen on some ancient specimens could have functioned somewhat like teeth and might have been an early evolutionary step toward tooth development, Briggs proposes. — *Laurel Hamers*

## TEASER

## Sprites blast into space

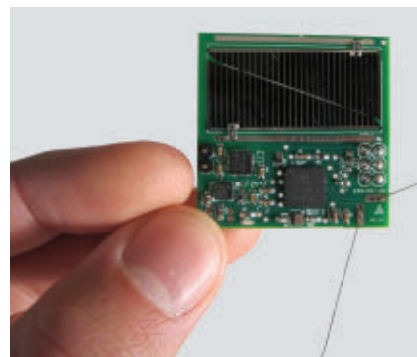
Spacecraft have gone bite-sized. On June 23, Breakthrough Starshot, an initiative to send spacecraft to another star system, launched half a dozen probes called Sprites to test how their electronics fare in outer space. Each Sprite, built on a single circuit board, is a prototype of the tiny spacecraft that Starshot scientists intend to send to Alpha Centauri, the trio of stars closest to the sun. Those far-flung probes would be the smallest working spacecraft yet.

“We’re talking about launching things that are a thousand times lighter than any previous spacecraft,” says Avi Loeb, an astrophysicist at Harvard University who is part of the committee advising

the initiative. A Sprite is only 3.5 centimeters square and weighs four grams, but packs a solar panel, radio, thermometer, magnetometer for compass capabilities and gyroscope for sensing rotation.

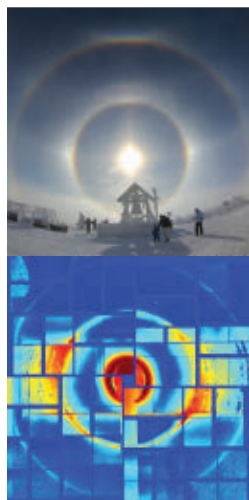
These spacecraft are designed to fly solo, but for this test, they hitched a ride into low Earth orbit on satellites named Max Valier and Venta-1. Each satellite has one Sprite permanently riding sidecar, and the Max Valier craft has another four it could fling out into space. Unfortunately, as of August 10, ground controllers haven’t yet been able to reach the Max Valier satellite to send a “Release the Sprites!” command. One of the permanently attached Sprites — probably the one on Venta-1 — is in radio contact.

Before sending next-gen Sprites off



There’s a new record-holder for the smallest spacecraft. It’s called a Sprite, and similarly tiny probes may someday fly to Alpha Centauri.

to Alpha Centauri, scientists plan to equip them with cameras, actuators for steering and other tools. “This was really just the first step in a long journey for Starshot,” Loeb says. — *Maria Temming*



Halos around the sun may appear when cube-shaped ice crystals in clouds in the upper atmosphere scatter light (top). In the lab, nearly cubic ice crystals scatter X-rays into similar-looking concentric circles (bottom).

## HOW BIZARRE

## Ice cubes go nano

Cube-shaped ice is rare, at least at the microscopic level of the ice crystal. Now researchers have coaxed typically hexagonal 3-D ice crystals to form the most cubic ice ever created in the lab. Cubed ice crystals — which may exist naturally in cold, high-altitude clouds — could help improve scientists’ understanding of clouds and how they interact with Earth’s atmosphere and sunlight, two interactions that influence climate.

Engineer Barbara Wyslouzil of Ohio State University and colleagues made the cubed ice by shooting nitrogen and water vapor through nozzles at super-

sonic speeds. The gas mixture expanded and cooled, and then the vapor formed nanodroplets. Quickly cooling the droplets further kept them liquid at normally freezing temperatures. Then, at around  $-48^{\circ}\text{C}$ , the droplets froze in about one millionth of a second. The low-temperature quick freeze allowed the cubic ice to form, the team reports in the July 20 *Journal of Physical Chemistry Letters*. The crystals weren’t perfect cubes but were about 80 percent cubic. That’s better than previous studies, which made ice that was 73 percent cubic. — *Ashley Yeager*

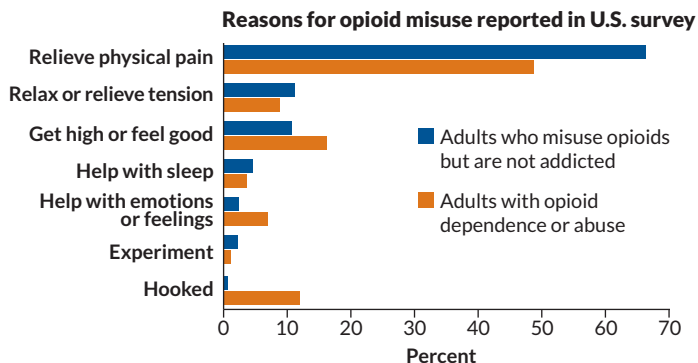
## SCIENCE STATS

## Quantifying opioid use and misuse

Nearly 5 percent of U.S. adults misused prescription opioids in 2015, a new study shows.

Based on the National Survey on Drug Use and Health, an in-person survey of more than 50,000 people, researchers estimate that 91.8 million, or 37.8 percent, of adults used prescription opioids in 2015. Some 11.5 million people misused the painkillers, and 1.9 million people reported opioid dependence or abuse, Beth Han of the Substance Abuse and Mental Health Services Administration in Rockville, Md., and colleagues report online August 1 in *Annals of Internal Medicine*.

Relieving pain was the most commonly cited reason for people’s most recent episode of misuse — for 66 percent of those reporting misuse, such as using without a prescription, and nearly 49 percent of those with opioid dependence or abuse. (Respondents could report more than one reason for their last misuse.) These results underscore the need for improved pain management, the authors say. — *Kate Travis*



## GENES & CELLS

# Heart mutation fixed in embryos

U.S. scientists test safety of germline editing in humans

BY TINA HESMAN SAEY

For the first time in the United States, researchers have used gene editing to repair a mutation in human embryos.

Molecular scissors known as CRISPR/Cas9 corrected a gene defect that can cause heart failure. The gene editor fixed the mutation in about 72 percent of tested embryos, scientists report online August 2 in *Nature*. Work with skin cells reprogrammed to mimic embryos had suggested that the mutation would be repaired in less than a third of cells.

The researchers also discovered a technical advance that may limit the production of patchwork embryos that aren't fully edited. That's important if CRISPR/Cas9 will ever be used to prevent genetic diseases, says study coauthor Shoukhrat Mitalipov, a developmental biologist at Oregon Health & Science University

in Portland. If even one cell in an early embryo is unedited, "that's going to screw up the whole process," Mitalipov says.

Scientists in other nations have edited human embryos to learn about early human development or to answer other basic research questions (*SN*: 4/15/17, p. 16). Mitalipov's group conducted the experiments to improve the safety and efficiency of gene editing for eventual clinical trials, which would involve implanting edited embryos into women's uteruses to establish pregnancy.

In the United States, such clinical trials are effectively banned by a rule that prevents the Food and Drug Administration from reviewing applications for any procedure that would introduce heritable changes in human embryos. Such tinkering with embryo DNA, called germline editing, is controversial because of fears that the technology will be used to create so-called designer babies.

"This paper is not announcing the dawn of the designer baby era," says R. Alta Charo, a lawyer and bioethicist at the University of Wisconsin Law School in Madison. The researchers did not add any new genes or change traits, other than fixing a disease-causing mutation. More than 10,000 diseases are known to be caused by mutations in single genes.

In the study, sperm from a man who carries a mutation in the *MYBPC3* gene

was injected into eggs from women with healthy copies of that gene. Carrying just one mutant copy of the gene causes hypertrophic cardiomyopathy (*SN*: 9/17/16, p. 8). That condition, which strikes about 1 in 500 people, can cause sudden death from heart failure. Doctors can treat symptoms, but there is no cure.

Along with the man's sperm, researchers injected into the egg the DNA-cutting enzyme Cas9. A piece of RNA directed the enzyme to snip the mutant copy of the gene. Another piece of DNA that was also injected into the egg was supposed to be a template that the fertilized egg could use to repair the breach made by Cas9. Instead, embryos used the mother's healthy copy of the gene to repair the cut.

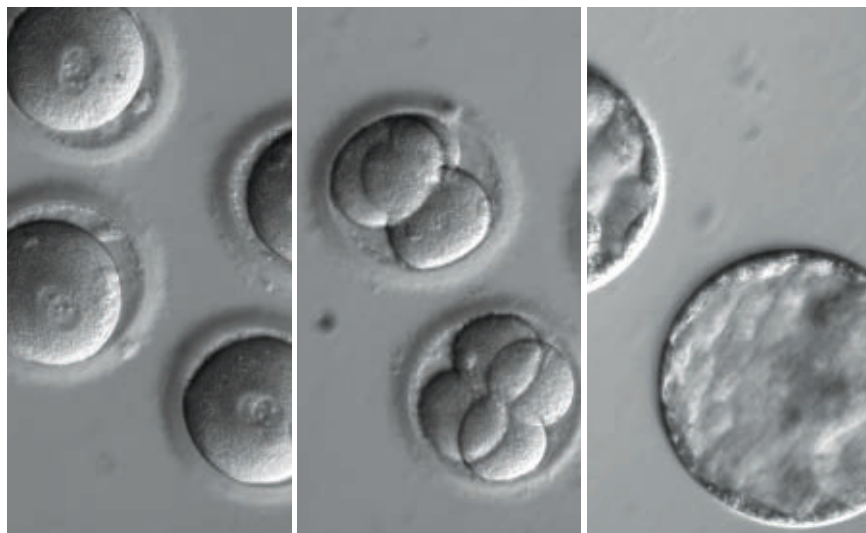
Embryos' self-healing DNA came as a surprise; gene editing in other types of cells usually requires an external template, Mitalipov says. The discovery could mean that it will be difficult to fix mutations in embryos if neither parent has a healthy copy of the gene. But the finding could be good news for those concerned about designer babies: Embryos may reject attempts to add new traits.

Timing the use of CRISPR/Cas9 is important. Initially, the team added the gene editor a day after fertilization. Of 54 embryos, 13 were patchwork, or mosaic, embryos with both repaired and unrepaired cells. Mosaic embryos probably arise when the fertilized egg copies its DNA before Cas9 is added, Mitalipov says.

Injecting Cas9 along with the sperm, before an egg could replicate its DNA, produced only one patchwork embryo. That embryo had repaired the mutation in all of its cells, but some cells used the mom's DNA for repair while others used the template supplied by the researchers.

None of the tested embryos showed any signs that Cas9 was cutting where it shouldn't be. "Off-target" cutting has been a safety concern because of the possibility of creating new DNA errors.

The study makes progress, but there's still a long way to go before clinical testing, says Janet Rossant, a developmental biologist at the Hospital for Sick Children in Toronto. "We need to be sure this can be done reproducibly and effectively." ■



CRISPR/Cas9 has corrected a gene defect in fertilized human eggs (left) without hampering embryo development. Four-cell embryos (middle) and 5-day-old blastocyst-stage embryos (right) carrying the CRISPR/Cas9 gene editor appeared normal in a new study.



# Neutrinos caught bouncing off nuclei

Physicists detect interaction predicted more than 40 years ago

BY EMILY CONOVER

Famously sneaky particles have been caught behaving in a new way.

For the first time, scientists have detected neutrinos scattering off the nucleus of an atom. The process, predicted more than four decades ago, provides a new way to test fundamental physics. It will also help scientists to better characterize the neutrino, a misfit particle that has a tiny mass and interacts so feebly with matter that it can easily sail through the entire Earth.

The finding, reported online August 3 in *Science*, “has really big implications,” says physicist Janet Conrad of MIT, who was not involved with the research. It fills in a missing piece of the standard model, the theory that explains how particles behave: The model predicts that neutrinos interact with nuclei. And, says Conrad, the discovery “opens up a whole new area of measurements” to further test the standard model’s predictions.

Scientists typically spot neutrinos when they interact with a single proton or neutron. But the new research measures “coherent” scattering, in which a low-energy neutrino interacts with an entire atomic nucleus at once, ricocheting away and causing the nucleus to recoil slightly in response.

“It’s exciting to measure it for the first time,” says physicist Kate Scholberg of Duke University, spokesperson for the COHERENT collaboration, which made the new finding.

In the past, neutrino hunters have built enormous detectors to boost their chances of catching a glimpse of the particles — a necessity because the aloof particles interact so rarely. While still rare, coherent neutrino scattering occurs more often than previously detected types of neutrino interactions.

That means detectors can be smaller and still catch enough interactions to detect the process. COHERENT’s detector, which includes a crystal of cesium and iodine, weighs only about 15 kilograms.

“It’s the first handheld neutrino detector; you can just carry it around,” says physicist Juan Collar of the University of Chicago.

Collar, Scholberg and colleagues installed their detector at the Spallation Neutron Source at Oak Ridge National Laboratory in Tennessee. The facility generates bursts of neutrons and, as a by-product, produces neutrinos at energies that COHERENT’s detector can spot. When a nucleus in the crystal recoils due to a scattering neutrino, a flash of light appears and is captured by a light sensor. The signal of the recoiling nucleus

is incredibly subtle — like detecting the motion of a bowling ball when hit by a ping-pong ball — which is why the effect remained undetected until now.

The amount of scattering the researchers saw agreed with the standard model.

But such tests are still in their early stages, says Leo Stodolsky, a physicist at the Max Planck Institute for Physics in Munich, who was not involved with the research. “We’re looking forward to more detailed studies to see if it really is accurately in agreement with the expectations.” Physicists hope to find a place where the standard model breaks down, which could reveal new secrets of the universe. More precise tests may reveal discrepancies, Stodolsky says. “That would be extremely interesting.”

Measuring coherent neutrino scattering could help researchers understand the processes that occur within exploding stars, or supernovas, which emit large numbers of neutrinos (*SN: 2/18/17, p. 24*). The process could be used to detect supernovas as well: If

Neutrinos scattering off atomic nuclei provide a new way to test fundamental physics.



A compact neutrino detector has measured a previously unseen type of neutrino interaction. The handheld detector is much smaller than those used in other experiments.

a supernova explodes nearby, scientists could spot its neutrinos scattering off nuclei in their detectors.

Similar scattering might also help scientists detect dark matter, an invisible source of mass that pervades the universe. Dark matter particles could scatter off atomic nuclei just as neutrinos do, causing a recoil. The study indicates that such recoils are detectable — good news since several dark matter experiments are attempting to measure recoils of nuclei (*SN: 11/12/16, p. 14*).

But the study also suggests a looming problem: As dark matter detectors become more sensitive, neutrinos bouncing off the nuclei will swamp any signs of dark matter.

Coherent neutrino scattering detectors also could lead to practical applications. Small-scale neutrino detectors could eventually detect neutrinos produced in nuclear reactors to monitor for attempts to develop nuclear weapons, for example.

Physicist Daniel Freedman of MIT, who predicted in 1974 that neutrinos would scatter off nuclei, is pleased that his prediction has finally been confirmed: “It’s a thrill.” ■

## HUMANS &amp; SOCIETY

# DNA reveals Canaanites' fate

Lebanese people descended from ancient Levant group

BY MARIA TEMMING

DNA is setting the record straight on ancient Canaanites.

For the first time, scientists have deciphered the complete genetic instruction manuals of Canaanites. By comparing five Canaanite genomes with those of other ancient and modern populations, the researchers identified the Canaanites' ancestors and revealed their descendants, modern Lebanese people.

The results, reported in the Aug. 3 *American Journal of Human Genetics*, give new insight into the origins and fate of a people whose story has largely been told through the secondhand accounts of its contemporaries.

The Canaanites emerged in the Levant, a region east of the Mediterranean Sea, 3,000 to 4,000 years ago. This cultural group, which established extensive trade networks and colonies across

the Mediterranean region, left behind few written records. So most knowledge of the Canaanites comes from ancient Egyptian, Hebrew and Greek documents.

But doubt surrounds some of those accounts. For one thing, Greek historians thought the Canaanites originated near the Persian Gulf, whereas archaeological records suggest they arose from farming communities that settled the Levant up to 10,000 years ago. For another, the Old Testament makes reference to the destruction of Canaanite communities, but some of their cities, such as Sidon in Lebanon, appear to have been continually inhabited through the present day.

Scientists reconstructed the genomes of five Canaanites unearthed in Sidon and who lived around 3,700 years ago. Comparisons of these genomes with those of other ancient Eurasian peoples indicate that Canaanite ancestry was split roughly 50-50 between the early farmers who settled the Levant and immigrants of Iranian descent who arrived later, between 6,600 and 3,550 years ago.

"You'd need a lot of migration for roughly half of the population to be



An analysis of genomes recovered from five Canaanite skeletons (one shown) reveals how these ancient Near East people fit into humankind's family tree.

replaced by the incoming Iranian-related populations," says Iosif Lazaridis, a geneticist at Harvard Medical School who was not involved in the study. "This must have been some important event in the history of the Near East." One possibility is the rise and fall of the Akkadian Empire, which controlled a region spanning from the Levant to Iran between 4,400 and 4,200 years ago. That connection may have presented the opportunity for interbreeding between these populations.

The researchers also determined that modern Lebanese people can attribute about 93 percent of their ancestry to the

## ATOM &amp; COSMOS

# Original asteroids came only in size XL

Planetary building blocks formed rapidly, new analysis suggests

BY MARIA TEMMING

The solar system's first asteroids were probably born big.

Rather than slowly amassing bulk over time, the original members of the asteroid belt rapidly formed into rocks hundreds of kilometers across, researchers propose. This finding, reported online August 3 in *Science*, may help resolve a long-standing debate over the origins of planetesimals — the giant space rocks that populated the asteroid belt and constructed the planets.

Astronomers set out to examine competing explanations for planetesimal formation. One says grains in the dusty disk surrounding the baby sun clumped

together bit by bit over millions of years to form objects that ranged from meters to hundreds of kilometers across — about the size range of asteroids today. The second idea argues that swarms of tiny pebbles almost instantaneously collapsed under their collective weight to create planetesimals hundreds of kilometers across. If true, asteroids today that are mere meters or kilometers across must be fragments from asteroid collisions.

To determine which theory is correct, the researchers needed to find some of the asteroid belt's original occupants to see how big they are. And to do that, the team first had to weed out asteroids that formed from later collisions, says study

coauthor Kevin Walsh of the Southwest Research Institute in Boulder, Colo.

Walsh and colleagues examined a region of the asteroid belt where many asteroids had already been flagged as members of asteroid families — that is, vestiges of the same smashed asteroids. Astronomers can recognize asteroids as belonging to a family because of their similar orbits and chemical makeup.

By combining data from several previous studies, the team identified one more asteroid family — remnants of a smashup about 4 billion years ago. The newly discovered family, along with the previously known families, accounted for almost every asteroid in this region. But a few loners remained. These rocks were too secluded to be members of any family, which meant they couldn't be collision fragments. Rather, they must be members of the belt's original

Canaanites. The other 7 percent comes from Eurasians who probably arrived in the Levant 3,700 to 2,200 years ago. Study coauthor Chris Tyler-Smith, a geneticist at the Wellcome Trust Sanger Institute in Hinxton, England, was surprised by how much Canaanite heritage dominated modern Lebanese DNA. He says he expected to see a more mixed gene pool because so many populations have crossed through the Levant in the last few thousand years.

Archaeologist Aaron Burke of UCLA points out that this study alone may not paint the complete picture of the Canaanite lineage, because the researchers examined the genomes of only five Canaanites at one location.

However, Lazaridis says, the Canaanite genetic data do provide “a snapshot of history in the area.” Identifying which populations crop up in the Canaanite lineage — and when — can help trace the historical movements of people throughout the Near East.

With DNA analyses of enough ancient people, Lazaridis says, “I think it will be possible to reconstruct the whole timeline of what happened in Lebanon and other parts of the world.” ■

population, the astronomers concluded.

These outsiders are all at least 35 kilometers across. The fact that none were just a few kilometers across undercuts the any-size-goes theory of gradual planetesimal formation, Walsh and colleagues argue. After accounting for the amount of rock expected to have chipped away during minor collisions over the solar system’s history, the researchers estimated these asteroids were all at least 100 kilometers across when they formed.

These findings lend credence to the theory of fast formation, says Joseph Masiero, an astronomer at NASA’s Jet Propulsion Lab in Pasadena, Calif. “Our solar system is the closest and best example we have that shows us how planets form throughout the rest of the universe,” he adds. So these insights could also advance astronomers’ understanding of exoplanet origins. ■

## BODY & BRAIN

# Spread of bad proteins tied to diabetes

Metabolic disorder may be transmissible, study in mice hints

BY AIMEE CUNNINGHAM

Type 2 diabetes and prion disease seem like an odd couple, but they have something in common: clumps of misfolded, damaging proteins.

Now new work finds that a dose of corrupted pancreas proteins induces normal ones to misfold and clump. This observation raises the possibility that, like prion diseases, type 2 diabetes could be triggered by deformed proteins spreading between cells or even individuals.

When the deformed pancreas proteins were injected into healthy mice, the animals developed symptoms of type 2 diabetes, including high blood sugar levels, researchers report online August 1 in the *Journal of Experimental Medicine*.

“It is interesting, albeit not surprising” that the deformed proteins could jump-start the process in other mice, says Bruce Verchere, a diabetes researcher at the University of British Columbia in Vancouver. But “before you could say anything about transmissibility of type 2 diabetes, there’s a lot more that needs to be done.”

Beta cells in the pancreas make the glucose-regulating hormone insulin. The cells also produce a hormone called islet amyloid polypeptide, or IAPP. This protein can clump together and damage cells, although how it goes bad is not clear. Most people with type 2 diabetes

accumulate deposits of misfolded IAPP in the pancreas. The clumps are implicated in the death of beta cells.

Deposits of misfolded proteins are a hallmark of such neurodegenerative diseases as Alzheimer’s and Parkinson’s, as well as prion disorders like Creutzfeldt-Jakob disease (*SN: 10/17/15, p. 12*).

Since IAPP misfolds like a prion, neurologist Claudio Soto of the University of Texas Health Science Center at Houston and colleagues wondered if type 2 diabetes could be transmitted between cells, or even between individuals.

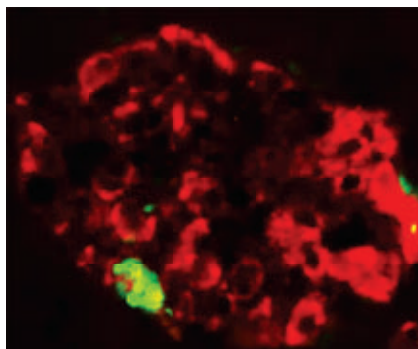
The mouse version of the IAPP protein cannot clump and mice don’t develop type 2 diabetes — a sign that IAPP accumulation is important in the development of the disease, Soto says. To study diabetes in mice, scientists need to engineer mice to produce a human version of IAPP. When pancreas cells containing clumps of misfolded IAPP, taken from engineered diabetic mice, were mixed in a dish of healthy human pancreas cells, the mouse cells triggered the clumping of IAPP in the human cells.

The same was true when nondiabetic mice got a shot made with pancreas cells from diabetic mice. The nondiabetic mice developed deposits of clumped IAPP that grew over time, and the majority of beta cells died. After the injection, over 70 percent of these mice had blood sugar levels beyond the healthy range.

“More work needs to be done to see if this ever operates in real life,” Soto says. His group is studying whether IAPP can be transmitted through blood transfusions between diabetic and healthy mice.

Even if transmission of the misfolded protein occurs only within an individual, “this opens up a lot of opportunities for intervention,” Soto says, “because now you can target the IAPP.”

Verchere also thinks IAPP is “a big player” in type 2 diabetes, and that therapies that prevent the clumps of proteins from forming are needed. ■



After a dose of misfolded proteins, a mouse developed clumps of deformed proteins (green) in a cluster of pancreas cells (red). Such clumps may play a role in type 2 diabetes in people.



## LIFE &amp; EVOLUTION

# Light pollution foils plant pollinators

For cabbage thistles, bright nights resulted in fewer seeds

BY SUSAN MILIUS

For flowers, too much light at night could lead to a pollination hangover by day.

Far from any urban street, researchers erected street lights in Swiss meadows to mimic the effects of artificial light pollution. In fields lit during the night, flowers had 62 percent fewer nocturnal visitors than flowers in dark meadows, researchers report in the Aug. 10 *Nature*.

For the most common flower, daytime pollination didn't make up for nightly losses, says ecologist Eva Knop of the University of Bern in Switzerland. In an accounting of the pollination life of cabbage thistles (*Cirsium oleraceum*), Knop and colleagues found that night-lit plants produced 13 percent fewer seeds overall than counterparts in dark places.

Night lights could affect the entire

network of plants and pollinators, the team says. In the test fields, nighttime pollination wasn't just the business of a few kinds of specialized moth-loving plants. Flowers that fed a wide range of nighttime visitors also attracted a broad buzzing circus of different kinds of daytime pollinators. If the daytime insects don't make up for nocturnal losses, a flower's population might dwindle. And a lot of insects might then feel the loss of nectar and foliage, Knop says.

More than 80 percent of flower species get some help from animals in making seeds, and none evolved with light after sundown. "I hope people start to realize that it's really something that changes the whole ecosystem," Knop says.

Getting a big-picture view of pollination wasn't easy. Finding dead-dark sites in highly developed Europe to set up LED lamps was impossible, so researchers worked in 14 dark-as-possible remote meadows in land rising toward the Alps.

Donning night-vision goggles when needed, researchers measured pollination by patrolling set paths and catching any insect wriggling on a flower.



A cabbage thistle bloom hosts a beetle after dark, the kind of plant-pollinator interaction that is threatened by artificial lights at night.

Besides paying special attention to the cabbage thistle, the researchers pieced together the whole network of which pollinator species visited which plant species day or night. Analysis of this data suggested that changes in the night crew could affect daytime visitors.

The idea that night light has broad knock-on effects on daytime pollinators is still speculation at this point, says ecologist Darren Evans of Newcastle University in England. But the risk of such spillover warrants more attention. ■

## EARTH &amp; ENVIRONMENT

# South Asia faces future of deadly heat

High temps and humidity may put hundreds of millions at risk

BY ASHLEY YEAGER

India and Pakistan are no strangers to extreme temperatures. In 2015, two heat waves killed more than 3,500 people there. But by the end of the century, new climate simulations suggest, extreme heat and humidity could put hundreds of millions at risk of death.

The simulations, published August 2 in *Science Advances*, show where future heat waves will be most dangerous if greenhouse gas emissions continue unabated: densely populated agricultural areas in South Asia, particularly in Pakistan, India, Bangladesh and Sri Lanka.

"The results of this study are of concern," says climate scientist Christoph Schär of ETH Zurich. In the affected areas, most people live in rural coastal

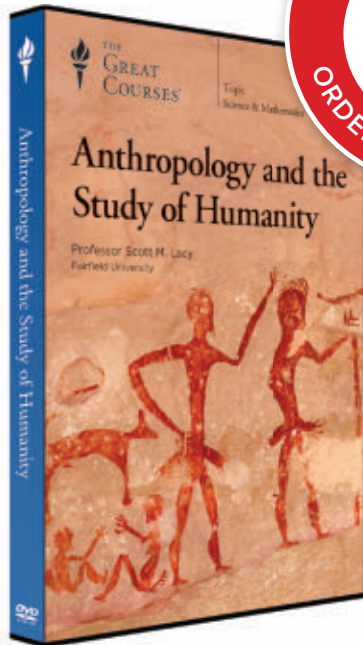
regions and low-lying river valleys. Many are poor with limited access to air conditioning and other infrastructure to combat the health risks of rising temperatures.

The new study accounts for the combination of temperature and humidity, which reduces the body's ability to cool itself through evaporation of sweat. If the ambient temperature in humid conditions, known as the wet-bulb temperature, exceeds skin temperature of 35° Celsius (95° Fahrenheit), a person quickly overheats. This temperature can equate to well over 38° C (100° F) in standard, or dry-bulb, temperature. Not even the fittest person would survive a few hours in these conditions, even in well-ventilated, shaded areas, says study

coauthor Jeremy Pal, an environmental engineer at Loyola Marymount University in Los Angeles.

If greenhouse gas emissions are not stemmed, average global temperatures by 2100 could rise by 4.25 degrees C compared with current temperatures. Under this scenario, 4 percent of the South Asian population would experience deadly wet-bulb temperatures exceeding 35° C, the simulations show. About 75 percent of this population would experience humid temperatures higher than 31° C, which are dangerous but rarely experienced by many people now, Pal and colleagues say.

However, that 75 percent figure would drop to 55 percent if climate change mitigation strategies were enacted, similar to those pledged in the 2015 Paris climate accord (*SN: 1/9/16, p. 6*). "It is important to take the global projections and zoom them in to regional and local levels to better understand the societal impacts of climate change," Pal says. ■



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## MATTER &amp; ENERGY

# Diamond's newest cut: thin 2-D sheets

When squeezed, graphene makes 'diamondene,' study suggests

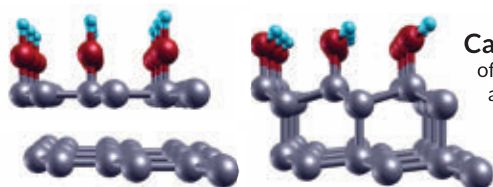
BY EMILY CONOVER

Diamonds are going 2-D. The superhard form of carbon can be forged in thin films called diamondene, new evidence suggests. While graphite, the form of carbon found in pencils, can come in atom-thick sheets known as graphene, scientists have struggled to create two-dimensional films of its relative, diamond.

When a pair of graphene sheets are

squeezed to pressures tens of thousands of times that of Earth's atmosphere, the crystal structure appears to change, hinting that it has morphed from graphite to diamond. Physicist Luiz Gustavo Cançado of the Federal University of Minas Gerais in Belo Horizonte, Brazil, and colleagues report the new finding July 21 in *Nature Communications*.

"It's the thinnest possible diamond,"



**Carbon crush** Under pressure, two sheets of graphene (illustrated at left, with carbon atoms in gray) combine into a single sheet of diamondene (right). Atoms of hydrogen (blue) and oxygen (red) come from water used in the squeezing process.

## ATOM &amp; COSMOS

# On Titan, possible life ingredient seen

Vinyl cyanide could create 'cell' membranes for microbes

BY TINA HESMAN SAEY

A molecule that could help build otherworldly life is present on Saturn's moon Titan, researchers have discovered.

Vinyl cyanide, a compound predicted to form membranelike structures, is created in Titan's upper atmosphere, scientists report July 28 in *Science Advances*. The researchers calculate that there's enough vinyl cyanide ( $C_2H_3CN$ ) in Titan's methane seas to make about 10 million cell-like balls per cubic centimeter of ocean. On Earth, about a million bacteria are in a cubic centimeter of coastal ocean water.

"It's very positive news for putative Titan life studies," says Jonathan Lunine, a planetary scientist at Cornell University who was not involved in the study.

Frigid Titan has no water, usually considered a prerequisite for life. Instead, the moon has liquid methane. But Titan is so cold — usually about  $-179^\circ$  Celsius — that

the smallest unit of life on Earth, the cell, would shatter in the moon's seas.

In 2015, Lunine and colleagues proposed a way life might exist. Computer simulations predicted that vinyl cyanide could make flexible bubbles that would be stable in liquid methane (*SN*: 4/30/16, p. 28). Those bubbles might act much as cell membranes do, sheltering genetic material and concentrating biochemical reactions needed for life.

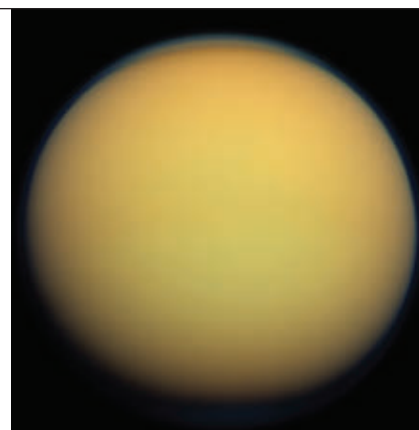
Carbon, hydrogen and nitrogen had already been detected in abundance in the moon's atmosphere when the researchers suggested the presence of such bubbles on Titan. But no one knew whether those atoms joined to make vinyl cyanide.

Evidence for the compound was buried in archived data from a large radio telescope, Maureen Palmer of Catholic University of America in Washington, D.C., and colleagues now report. Palmer, an astrochemist and astrobiologist, combed data collected for a few months in 2014 by the Atacama Large Millimeter/submillimeter Array, or ALMA, in Chile.

Astronomers point ALMA at Titan to calibrate the telescope because the moon has known brightness levels, says Palmer, who also works at NASA's

says theoretical physicist Pavel Sorokin of the National University of Science and Technology MISiS in Moscow, who was not involved in the new study. Diamond is known for being extremely hard and stiff, he says, and "now we can use the exciting properties of diamond in the nanoworld." Diamondene is also predicted to be magnetic and may be useful for spintronics, a technique that uses the spin of electrons to store data.

Cançado and colleagues monitored the structure of the carbon crystal using a technique called Raman spectroscopy, shining laser light on the material to see how the atoms' vibrations changed under pressure. This method provided indirect evidence that diamondene had formed. A next step is to scatter X-rays or electrons off the material to be sure of its structure. ■



Saturn's moon Titan may have enough vinyl cyanide in its methane seas to form an abundance of cell-like balls, researchers report.

Goddard Space Flight Center in Greenbelt, Md. The team used that calibration data to detect the signature of vinyl cyanide at specific wavelengths of light and to calculate its abundance.

"This is a pretty secure detection," says Ralph Lorenz, a planetary scientist at the Johns Hopkins University Applied Physics Laboratory in Laurel, Md.

Telescopes probably won't be able to tell whether cell-like bubbles form on Titan, Lunine says. A probe would need to sample the methane seas to detect the structures. And even finding bubbles, Lorenz says, wouldn't mean there's life. ■



# Fossil offers clues to ape evolution

Ancient species may have been close relative of modern apes

BY BRUCE BOWER

A 13-million-year-old infant's skull, discovered in Africa in 2014, comes from a new species of ape that may not be far removed from the common ancestor of living apes and humans.

The tiny find, about the size of a lemon, is one of the most complete skulls known of any extinct ape that inhabited Africa, Asia or Europe between 25 million and 5 million years ago, researchers report in the Aug. 10 *Nature*. The fossil provides the most detailed look to date at a member of a line of African primates that may have been central players in the evolution of present-day apes and humans.

Most fossils from the more than 40 known extinct ape species amount to no more than jaw fragments or a few isolated teeth. A local fossil hunter spotted the nearly complete skull in rock layers located near Kenya's Lake Turkana. Members of a team led by paleoanthropologist Isaiah Nengo estimated the fossil's age by assessing radioactive forms of argon in surrounding rock, which decay at a known rate.

Comparisons with other ape fossils found in Africa indicate that the infant's

skull belongs to a new species that the researchers named *Nyanzapithecus alesi*. Other species in this genus, previously known mainly from jaws and teeth, date to as early as about 25 million years ago.

"This skull comes from an ancient group of apes that existed in Africa for over 10 million years and was close to the evolutionary origin of living apes and humans," says Nengo, of Stony Brook University in New York and De Anza College in Cupertino, Calif.

He and colleagues looked inside the skull using a powerful type of 3-D X-ray imaging. This technique revealed microscopic enamel layers that had formed daily from birth in developing adult teeth that had yet to erupt. A count of those layers indicates that the ape was about 16 months old when it died.

Based on a presumably rapid growth rate, the scientists calculated that the ancient ape would have weighed about 11.3 kilograms as an adult. Its adult brain volume would have been almost three times larger than that of known African monkeys from the same time, the researchers estimate.

*N. alesi*'s tiny mouth and nose, along with several other facial characteristics, would have made it look much like small-bodied apes called gibbons. But the researchers doubt that *N. alesi* was a direct ancestor of living gibbons. Faces resembling gibbons evolved independently in several extinct monkeys, apes and their relatives, and probably in *N. alesi*, too, the team concludes.

No lower-body bones turned up with the new find. Even so, it's possible to tell that *N. alesi* did not behave as present-day gibbons do. In gibbons, a part of the inner ear called the semicircular canals is large relative to body size. The semicircular canals help coordinate balance and allow the apes to swing acrobatically from one tree branch to another. *N. alesi*'s small semicircular canals indicate that it moved cautiously in trees, Nengo says.

Several of the infant skull's features, including those small semicircular canals, connect it to a poorly understood, 7-million- to 8-million-year-old ape called *Oreopithecus*. Fossils of that



X-ray scans offer a peek inside an ancient infant ape's skull (top). Teeth that hadn't erupted (gray in reconstruction) allowed scientists to estimate age at death. Inner ear anatomy (green) gave clues to the ape's life in the trees.

primate, discovered in Italy, suggest it walked upright with a slow, shuffling gait. If an evolutionary relationship existed with the older *N. alesi*, the first members of the *Oreopithecus* genus probably originated in Africa, Nengo proposes.

Without any lower-body bones for *N. alesi*, it's too early to rule out the possibility that *Nyanzapithecus* gave rise to modern gibbons or to determine its exact relationship with *Oreopithecus*, says paleontologist David Alba of the Catalan Institute of Paleontology Miquel Crusafont in Barcelona. Gibbon ancestors are thought to have diverged from precursors of living great apes and humans between 20 million and 15 million years ago, Alba says.

Despite the age and unprecedented completeness of the new skull, no reported tooth or skull features clearly place *N. alesi* close to the origins of living apes and humans, says paleoanthropologist David Begun of the University of Toronto.

Further studies of casts of the inner braincase, which show impressions from surface features of the brain, may help clarify *N. alesi*'s position in ape evolution, Nengo says. Insights are also expected from back, forearm and finger fossils of two or three ancient apes, possibly also *N. alesi*, found near the skull site in 2015. Those specimens also date to around 13 million years ago. ■

The fossilized skull of an ape named *Nyanzapithecus alesi* dates to about 13 million years ago. The well-preserved skull, a rare find in the ape fossil record, sheds new light on ape evolution.



## EARTH &amp; ENVIRONMENT

# Timing of Europe's river floods shifting

Earlier and later overflows linked to changes in climate variables

BY LAUREL HAMERS

Across Europe, rivers aren't flooding when they used to.

Long-term changes in temperature and precipitation are making some rivers flood days, weeks or even months earlier than they did 50 years ago, and flooding in other areas happens much later, researchers report in the Aug. 11 *Science*. Those changes could impact people, wildlife and farms near rivers.

Previous studies have shown that climate change will probably increase the severity and frequency of coastal floods, but it can be tricky to link river flooding to climate change, says Günter Blöschl, a hydrologist at the Vienna University of Technology who led the study.

Coastal flooding is worsened largely by one overriding variable that can be tracked: sea level rise. But river flooding is affected by a complex set of factors, says policy analyst Rob Moore of the Natural Resources Defense Council in Chicago, who specializes in water issues. Both the timing and quantity of precipitation

matter, as do the type of soil and whether it's dry or waterlogged when rain hits. What's more, changes in land use around a river or engineering projects such as dams can also affect flood risk — but aren't necessarily related to the climate.

So instead of tracking the size or frequency of river floods, the researchers examined the seasonal timing of floods. That measurement is less affected by factors that have nothing to do with climate. Blöschl and colleagues analyzed hydrological data collected at 4,262 sites across Europe from 1960 to 2010.

Flood season shifted as many as 13 days earlier or nine days later per decade, the researchers found. Over the study period, that shift added up to floods in some regions occurring as many as 65 days earlier or 45 days later. Those differences happened alongside changes in climate factors such as long-term temperature, precipitation and air-movement patterns.

The biggest changes were in western Europe, where a quarter of the monitoring sites recorded flood timing shifts of more than 36 days over the 50-year period. Elsewhere, effects were more moderate: In northeastern Europe, for instance, half of the stations showed shifts of more than eight days.

The effect varied because not all parts of Europe experience the same sorts of floods, Blöschl says. In southern Sweden and the Baltics, floods are mostly driven by spring snowmelt. Higher local temperatures can make snow melt earlier in the year and shift up flood season. But in southern England, flooding is driven more by soils getting too wet in fall to take on more moisture in winter.

Off-season flooding could have far-reaching effects. Animals that rely on certain river conditions at a certain time of year to breed or find food could be affected by surprise floods. Unexpected floods or dry spells could damage crops. Plus, Moore says, people are less prepared when floods happen off-season. ■

## GENES &amp; CELLS

# Archaea fold DNA like animals do

Discovery hints at origins of genetic packing scheme

BY MARIA TEMMING

Single-celled microbes may have taught plants and animals how to pack their genetic baggage.

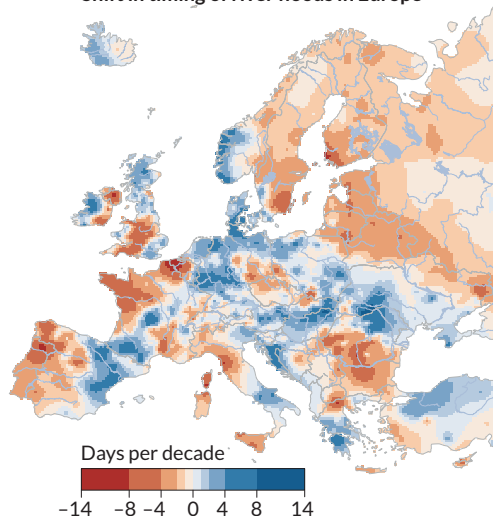
Archaea, a type of single-celled life-form similar to bacteria, keep their DNA wrapped around proteins in much the same way as more complex organisms, researchers report in the Aug. 11 *Science*. This finding provides new insight into the evolutionary origins of the DNA-packing process and the secret to archaea's hardiness, which enables some types to live in acid, boiling water or other extreme environments.

All eukaryotes, including plants and animals, store their genetic material in cell compartments — nuclei. Such organisms cram meters of genetic material into the tiny nuclei by wrapping strands of DNA around clusters of proteins called histones (*SN: 1/10/15, p. 32*). "It doesn't really matter which eukaryote you look at, whether it's amoebas or plants or humans or fish or insects or anything," says John Reeve, a microbiologist at Ohio State University. "They all have exactly the same structure."

Unlike bacteria, some archaea also contain histones, but researchers weren't sure whether these microbes spool DNA around these proteins the way eukaryotes do. So Reeve and colleagues used X-ray crystallography to discern, for the first time, the precise shape of archaea DNA bound to histones.

The researchers saw that archaea DNA coils around the histones, similar to the way DNA does in eukaryotes. "It's a big deal actually seeing this," says Steven Henikoff, a molecular biologist at the Fred Hutchinson Cancer Research Center in Seattle who was not involved in the work. The resemblance between archaea and eukaryote DNA wrapping suggests that the first organism that used

Shift in timing of river floods in Europe



**Fickle floods** Many rivers across Europe now typically flood at different times in the year than they did 50 years ago, new research examining trends from 1960 to 2010 shows. Those changes vary widely. In red regions, floods happen earlier; in blue regions, later.

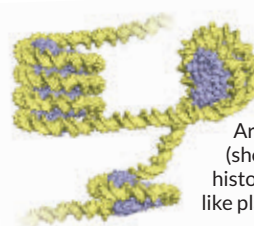
this storage scheme was an ancestor of both modern archaea and eukaryotes, the researchers say.

But the way archaea DNA twists around histones isn't identical to the coils of DNA seen in eukaryotes. In eukaryotes, a strand of DNA loops twice around a cluster of eight histones to create what's called a nucleosome, and connects many of these nucleosomes like beads on a string. Archaea DNA string together bundles of proteins, too. But while eukaryotes always tether eight-protein clumps, archaea DNA can spiral around stacks of many more histones to create rod-shaped structures of various lengths. "So it's not as uniform as in

eukaryotes," says study coauthor Karolin Luger, a biophysicist and Howard Hughes Medical Institute investigator at the University of Colorado Boulder.

Researchers tested the importance of that rodlike architecture by tampering with the histone-DNA structures of some archaea and then observing how these mutant archaea fared in different conditions. "We tried to mimic some real-life situations," Luger says.

For instance, some types of archaea that live in volcanic vents that emit sulfur gases sometimes get spewed out and have to survive sans sulfur. Archaea with normal histone-DNA shapes can



Archaea wrap their DNA (shown in yellow) around histone proteins (purple) much like plants and animals do.

handle that kind of crisis. But when researchers cut their mutant microbes off sulfur, the microorganisms' growth was stunted. These microbes may not have been able to adapt to sulfur deprivation as well as their wild counterparts "because they can't unpackage their DNA as readily if the structure has been changed," Reeve says.

Henikoff calls it "a pretty cool experiment." It showed that the archaea's DNA-histone architecture was "biologically relevant, not just a novelty." ■

## NEWS IN BRIEF

### GENES & CELLS

#### Gene-editing approach creates piglets without viruses

Pigs are a step closer to becoming organ donors for people.

Researchers used molecular scissors known as CRISPR/Cas9 to snip embedded viruses out of pig DNA. Removing the viruses — called porcine endogenous retroviruses, or PERVs — creates piglets that can't pass the viruses on to transplant recipients, geneticist Luhan Yang and colleagues report online August 10 in *Science*.

Yang, a cofounder of eGenesis in Cambridge, Mass., and colleagues had previously sliced 62 PERVs at a time from pig cells grown in the lab (*SN*: 11/14/15, p. 6). Many of those embedded viruses, however, were already damaged and wouldn't make copies of themselves to pass on in an infection to a transplant recipient. So in the new study, the researchers removed only the 25 viruses that were actually capable of infecting other cells.

The team had to overcome several technical hurdles to make PERV-less pig cells that still had the normal number of chromosomes. In a process similar to the one that created Dolly the Sheep (*SN*: 3/1/97, p. 132), researchers sucked the DNA-containing nuclei from the virus-cleaned cells and injected them into pig eggs. The technique, called

somatic cell nuclear transfer, is better known as cloning. Embryos made from the cloned cells were transplanted to sows to develop into piglets.

The process is still not very efficient. Researchers placed 200 to 300 embryos in each of 17 sows. Only 37 piglets were born, and 15 have survived. The oldest are several months old. Such virus-free swine could be a starting point for further genetic manipulations to make pig organs compatible with humans.

— Tina Hesman Saey

### ATOM & COSMOS

#### Physicists find signs of matter-antimatter differences

A new study hints that neutrinos might behave differently than their antimatter counterparts. The result amplifies scientists' suspicions that the lightweight elementary particles could help explain why the universe has much more matter than antimatter.

In the Big Bang, 13.8 billion years ago, matter and antimatter were created in equal amounts. To tip that balance to the universe's current, matter-dominated state, matter and antimatter must behave differently, a concept known as charge-parity, or CP, violation.

CP violation can be measured by observing how neutrinos — which come

in three types, electron, muon and tau — oscillate, or change from one type to another. Researchers with the T2K experiment in Japan found that muon neutrinos morphed into electron neutrinos more often than expected, while muon antineutrinos became electron antineutrinos less often. That suggests that the neutrinos were violating CP, the researchers concluded August 4 at a colloquium at the High Energy Accelerator Research Organization, KEK, in Tsukuba, Japan.

T2K scientists had previously presented a weaker hint of CP violation. The new result is based on about twice as much data, but the evidence is still not definitive. In physicist parlance, it is a "two sigma" measurement, an indicator of how statistically strong the evidence is. Physicists usually require five sigma to claim a discovery.

Even three sigma is still far away — T2K could reach that milestone by 2026. A future experiment, DUNE, now under construction at the Sanford Underground Research Laboratory in Lead, S.D., may reach five sigma. It is worth being patient, says physicist Chang Kee Jung of Stony Brook University in New York, who is a member of both the T2K and DUNE collaborations. "We are dealing with really profound problems." — Emily Conover



### An icy track

Cassini showed that Saturn's celebrated rings are more like a Roller Derby track than a record album. Chunks of ice as small as sand and larger than houses zip and collide, guided by the gravity of Saturn itself, as well as some of its small moons. A ring disturbance photographed on April 8, 2016, (in the outer ring below) was most likely due to a small embedded object rather than the pull of the tiny bystander of a moon Pandora (bottom right).

# CASSINI'S Curtain Call

# The spacecraft that put Saturn and its moons in the spotlight bids adieu **By Lisa Grossman**

**T**ake a bow, Cassini. It's been a marathon performance: 20 years in space, more than 200 orbits around Saturn, and hundreds of thousands of images of the giant planet, its splashy rings and its many moons. On September 15, the veteran spacecraft will use its last burst of fuel to plunge into the sixth planet from the sun. Scientists and space enthusiasts around the world will watch it go with awe and nostalgia.

"It's hard not to anthropomorphize the spacecraft," says Matthew Tiscareno of the SETI Institute in Mountain View, Calif., who has been working on Cassini since it entered Saturn's orbit in 2004. "We've been riding on its back for these 13 years, and it's done everything we've asked. I think it's the most spectacularly successful mission that NASA has ever run."

Cassini was designed to train its 12 scientific instruments on the Saturn system for a short four years, but NASA extended the mission twice. Even with the extra time, Cassini's 13-year run is less than half of a year on Saturn, where a year lasts 29 Earth years.

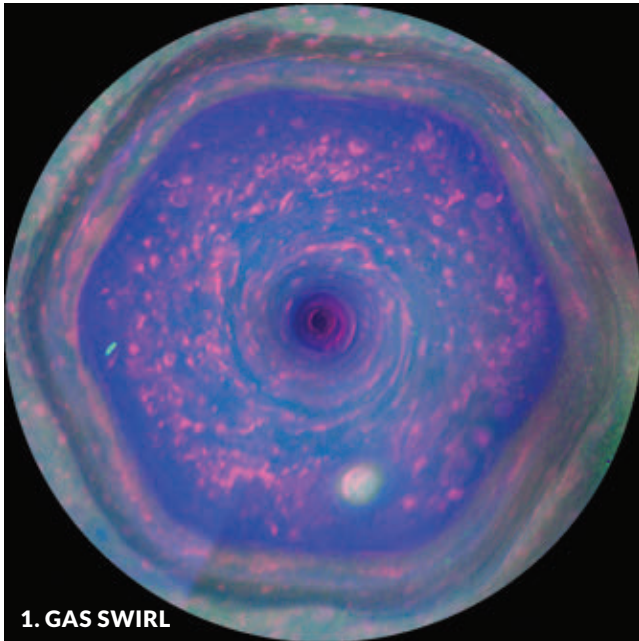
After all this time, we've witnessed only the transitions to Saturnian spring and summer, the equivalent of January to June on Earth. And yet we've seen so much. Cassini has revealed massive churning storms that rage for decades, rings that may be the best laboratory for studying how planets form and details of some of Saturn's more than 60 moons. Two of those satellites, Titan and Enceladus, surprised Cassini scientists by having many of the right ingredients for life (see Page 12). The craft has revamped our picture of Saturn and its celestial family.

"It's taken the entire mission to get to a point where we feel like we're starting to understand Titan," says Elizabeth Turtle of Johns Hopkins University's Applied Physics Laboratory in Laurel, Md., who has been planning Cassini's observations of Titan since before the spacecraft arrived at Saturn. "And it still surprises us."

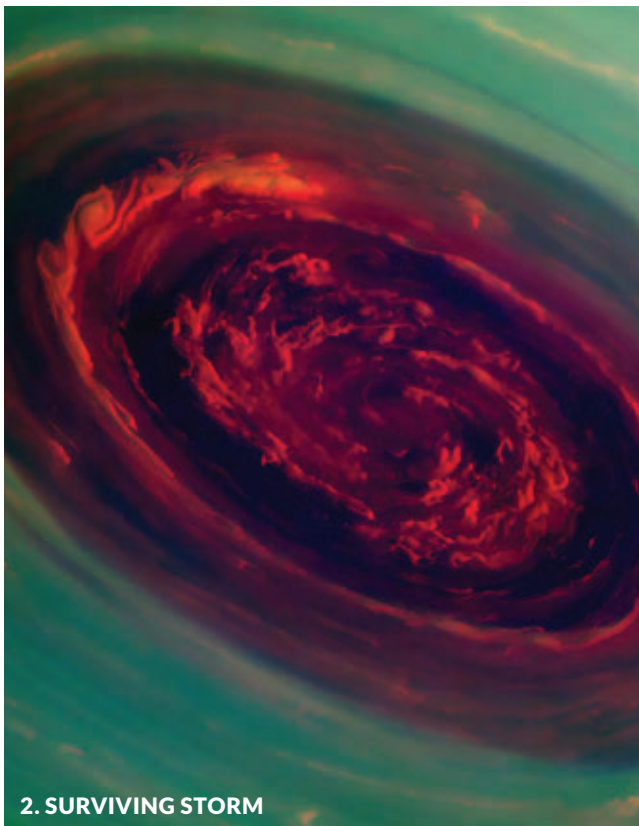
Saturn's potentially habitable moons are the reason Cassini must meet a dramatic end. The Cassini mission team decided it was safer to crash the craft into Saturn itself than to risk the craft wandering off and brushing up against Enceladus or Titan, spreading its earthly germs to any nascent ecosystems there.

But the craft will be busy until the very end. Since April, Cassini has been making weekly dives into the possibly rubble-strewn region between Saturn and its rings, a zone the team hadn't dared explore before. Plus, the craft will collect data during its last hurtle into the gas giant's atmosphere. Those final measurements should help solve some of the most basic mysteries about the planet, including when it got its iconic rings.

"Cassini data," says team member Ralph Lorenz of the Applied Physics Lab, "is going to keep us busy for decades."



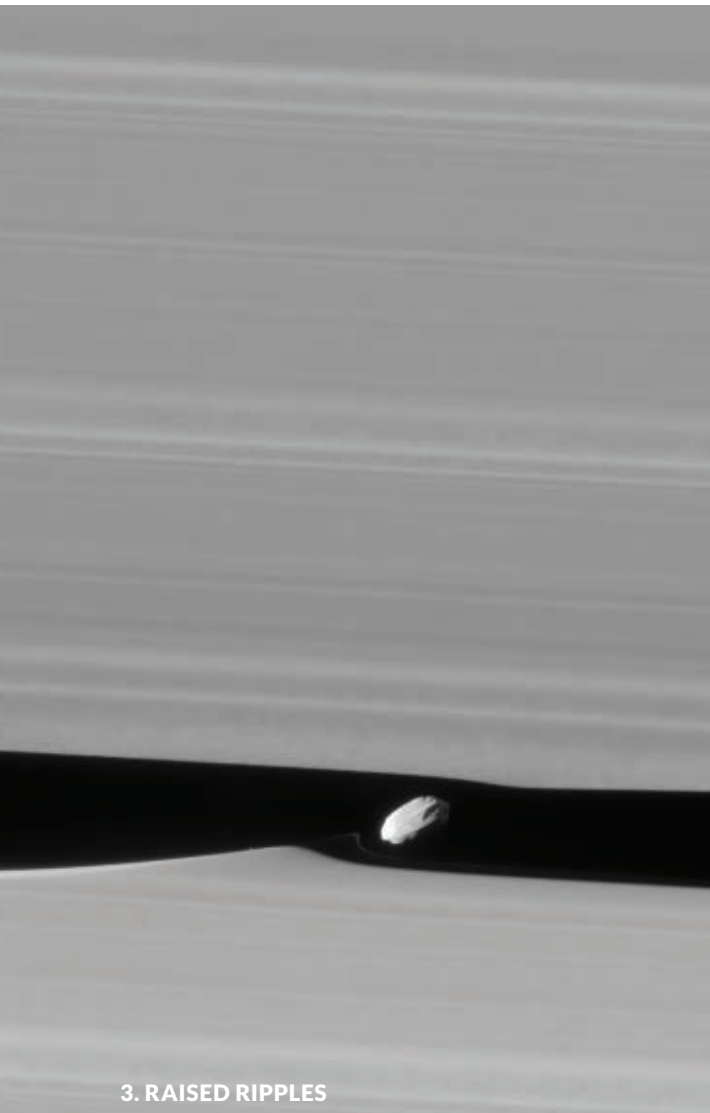
**1. GAS SWIRL**



**2. SURVIVING STORM**

**1. GAS SWIRL** Saturn's north pole was dark when Cassini arrived in 2004. But as the seasons changed, light illuminated a bizarre six-sided swirl of gases at the pole (shown in false color). The hexagon, known since the 1980s, is about 30,000 kilometers wide (SN: 1/11/14, p. 10).

**2. SURVIVING STORM** In the eye of Saturn's hexagon swirl, cloud speeds can reach 150 meters per second. The storm, shown here in false color from 2012, has probably been there for decades, if not centuries. Saturn has no mountains or oceans to interrupt the storm.



3. RAISED RIPPLES

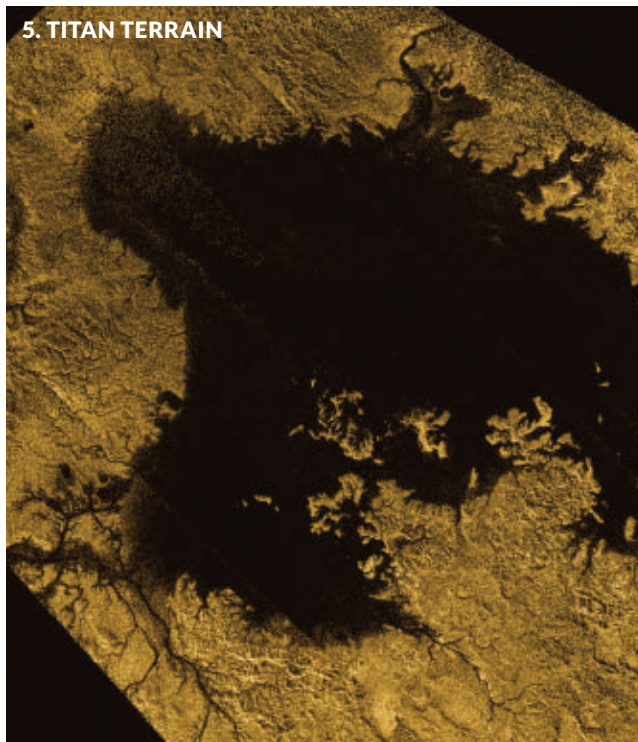


4. RING SPIKES

**3. RAISED RIPPLES** Saturn's tiny moon Daphnis orbits within the 42-kilometer-wide Keeler Gap between rings. The moon, imaged in January as Cassini grazed Saturn's rings, is only 8 kilometers across, but its gravitational pull is enough to raise ripples in the rings around it. These waves were first noticed in 2009, around the time of Saturn's spring equinox. Daphnis has a ridge around its equator, which is probably made of fine particles it has gathered from the rings.

**4. RING SPIKES** Saturn's rings are "arguably the flattest structure known to man," says astronomer Matthew Tiscareno. Over a span of hundreds of thousands of kilometers, their vertical thickness typically varies by only about 10 meters. But Cassini snapped these structures, as tall as 2.5 kilometers, in 2009, when sunlight struck the rings at a perfect angle to cast long shadows.

**5. TITAN TERRAIN** Cassini mission scientist Ralph Lorenz has this false color image of Ligeia Mare, a large sea on Saturn's moon Titan, hanging in his office. Cassini's radar peered through the moon's thick orange haze to reveal an Earthlike surface with seas, rivers and clouds filled with liquid ethane and methane. The moon could possess the ingredients for life. "Titan has been doing prebiotic chemistry experiments for us for a huge amount of time," says team member Elizabeth Turtle. She and Lorenz are working with others on a proposed mission called Dragonfly that would land drones on the moon to sample its surface.



5. TITAN TERRAIN

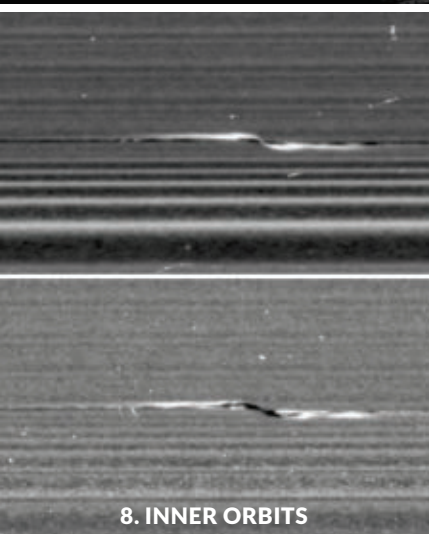




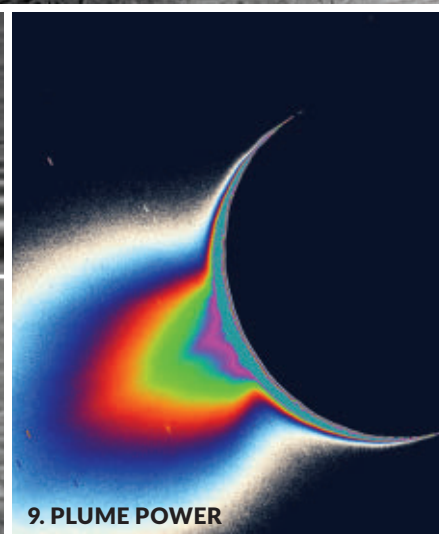
6. MOTHER EARTH



7. ICY JETS



8. INNER ORBITS



9. PLUME POWER

**6. MOTHER EARTH** This iconic Cassini image is known as “The Day the Earth Smiled.” On July 19, 2013, Cassini turned back toward its planet of origin and shot a picture with Saturn’s rings and Earth and its moon all in the same frame (SN: 8/24/13, p. 8). It was the third time Earth was imaged from the outer solar system but the first time humankind got a heads-up, so people could look up and smile or wave for the camera.

**7. ICY JETS** One of the biggest surprises of the Cassini mission was that the icy moon Enceladus is spewing its guts into Saturn’s rings. These jets from the moon’s south pole, snapped in 2010, come from a subsurface ocean, which may have the right chemistry for life. The jets also supply icy material to one of Saturn’s rings.

**8. INNER ORBITS** By guiding tiny particles around themselves, small moons embedded in Saturn’s rings create the propeller-like features seen here. Scientists have followed these objects for over a decade, naming the larger ones after pioneers of aviation. These images, taken February 21, 2017, show two views of Santos-Dumont, named for a Brazilian-French aviator. “This is the only time in the history of astronomy that we’ve tracked the orbit of an object that is orbiting in a disk,” says astronomer Matthew Tiscareno. Studying the propellers can help reveal how planets forming in the disk of gas and dust around a young star grow.

**9. PLUME POWER** This false color image from 2005 shows the reach of the spectacular plumes on the moon Enceladus. Later sampling by Cassini revealed that the plumes contain ammonia, a variety of organic compounds and molecular hydrogen — all signs that the moon might be habitable. NASA is considering a mission to go back and sample the plumes.



# Access Denied

Scientists seek innovative ways to block the union of egg and sperm **By Aimee Cunningham**

**M**ention “the pill,” and only one kind of drug comes to mind. The claim that oral contraceptives have on that simple noun testifies to the pill’s singular effect in the United States. Introduced in 1960, the pill gave women reliable access to birth control for the first time. The opportunity to delay having children opened the door to higher educa-

tion and professional careers for many women.

More than 50 years later, the most commonly used form of reversible contraception in this country is still the pill. Additional methods have been developed for women — such as implants, patches, vaginal rings and injectables — but most do basically the same thing as the pill: use synthetic versions of sex steroid hormones to suppress



ovulation. The method has proved its merit, but the current crop of contraceptives doesn't work for everyone. Some women can't tolerate the side effects stemming from manipulation of the hormones. Others can't use hormonal contraceptives at all, because of underlying health conditions.

And what's new for men? Their main mode of contraception, the condom, has been around for at least 400 years, perhaps longer. Alternatively, men who want to take the lead on family planning can go the surgical route with a vasectomy.

The dearth of alternatives is not due to a lack of research. Reproductive biologists and other researchers have made many exciting discoveries since the pill was introduced. But taking a promising finding in cells or in mice to human testing is hard for any drug. And for contraceptives, there's an extra wrinkle: "You're developing products for very healthy people, so you have to make sure [the drugs] are incredibly safe, and the side effect profile is acceptable," says Diana Blithe, a biochemist and chief of the contraceptive development program at the National Institute of Child Health and Human Development in Bethesda, Md.

Even with the long road to human testing, odds are that by the time the pill turns 75, there will be new options stocking the contraceptive cabinet. Researchers are currently exploring a method that keeps women's eggs in a state of suspended animation for later use. For men, there could be nonhormonal methods that stop sperm from developing and launching their epic journey. The impact of these novel methods might ripple out into society much as the pill's once did.

## Room for improvement

There were 6.1 million pregnancies in the United States in 2011. Forty five percent of them, or a whopping 2.8 million, were not intentional, according to a 2016 report in the *New England Journal of Medicine*.

Unplanned pregnancies can have consequences for parents and kids, studies find. Women's education can be cut short. Unwanted pregnancies are linked to delayed prenatal care — probably because moms don't realize they're pregnant — as well as low birth weight in infants. Postpartum depression is more common for mothers who did not intend to have a baby than for those who did.

The numbers also suggest that the contraceptives available aren't meeting everyone's needs. Some methods are expensive. And some users

have health concerns or just don't stick with an option. In 2008, about 40 percent of unintended pregnancies were in couples that used contraception, but inconsistently, according to the Guttmacher Institute, a reproductive health research and policy organization in New York City.

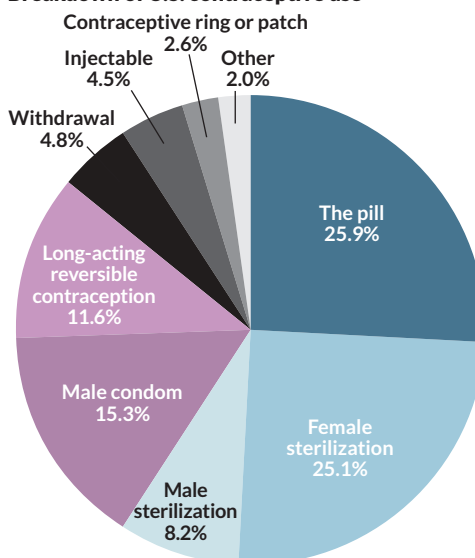
From 2011 to 2013, the most popular reversible contraceptive choice for women ages 15 to 44 was the pill, with use at nearly 26 percent. The pill and other hormonal contraceptives contain the female sex steroid hormones estrogen and progesterone, or progesterone alone, usually in synthetic forms. These hormones prevent ovulation by suppressing the brain's release of follicle-stimulating hormone and luteinizing hormone.

Some women find that hormonal contraceptives work well; other women experience side effects such as headaches, nausea, mood changes and acne. Oral contraceptives also increase the risk of blood clots, taking the drugs off the table for women with a history of blood clots, stroke or cardiovascular disease. The pill is also a no-go for women with severe hypertension or who have ever had breast cancer.

Relying on hormones to halt sperm production can also work. A new hormone-based gel for men, applied to the skin, is in human testing. It combines the male sex steroid testosterone with a synthetic progesterone. Plans are under way for couples to test the gel as their only form of birth control. But giving men hormones can come with side effects, such as reduced muscle mass and a drop in sexual function.

45  
percent  
Proportion of  
U.S. pregnancies  
in 2011 that were  
unplanned

Breakdown of U.S. contraceptive use



**In control** In a survey, 62 percent of U.S. women ages 15 to 44 reported using contraception in 2011 to 2013. The pill was the most popular form of birth control, followed by female sterilization (which permanently blocks the fallopian tubes). Rounding out the top five methods were the male condom, long-acting reversible contraception (like intrauterine devices and implants) and male sterilization (vasectomy). In the survey, if women used more than one method, only the most effective method was counted.



Discoveries that are beginning to explain the earliest stages of egg development and the finishing touches of sperm growth may lead to steroid-free alternatives.

### Snooze button

Hormonal contraception disrupts ovulation, and the egg that was scheduled for departure from an ovary dies. But what if there was a method that preserved the egg for later?

When women are born, their ovaries have a full set of oocytes, or eggs — a million or so. Each is housed within a sac of cells called a follicle. The outer portion of each ovary is filled with the earliest, dormant form of these egg-carrying follicles, called primordial follicles. The sleeping cells are waiting to be woken up, so they can begin growing in preparation for ovulation. But why the alarm clock goes off for one primordial follicle and not another is an open question, says reproductive biologist David Pépin of Massachusetts General Hospital and Harvard Medical School.

Today's hormonal contraceptives act on ovarian follicles that are already growing, and once that starts, there is no going back — if ovulation doesn't happen, the egg dies. Aiming contraception at the sleeping eggs could mean putting off pregnancy, while holding on to the eggs. By preventing that first wake-up call, "actually, you keep the egg," Pépin says. "You could potentially preserve that pool of eggs for later in life, theoretically."

Meet the biological agent that could keep eggs

asleep: Müllerian-inhibiting substance, or MIS. Also known as anti-Müllerian hormone, MIS is not a sex steroid hormone. It is produced in the developing testes and prevents male embryos from growing female reproductive parts. In adult female mice, MIS can also be a perpetual snooze button for primordial follicles, Pépin and colleagues, including Mass General and Harvard pediatric surgeon Patricia Donahoe, reported in the Feb. 28 *Proceedings of the National Academy of Sciences*.

Hundreds of follicles are estimated to be in various stages of development at any given time. The active growers release MIS locally, which limits the number of primordial follicles that wake up. This process allows the body to control and maintain the supply of eggs over a woman's reproductive life span.

In their study, Pépin, Donahoe and colleagues used a virus to introduce a modified version of the MIS gene into certain cells in mice. This permanent change gave the mice a higher dose of

MIS protein than is found normally in females. The follicles that had already been growing completed their development, but after that, no new follicles were activated, leaving a collection of sleeping-beauty primordial follicles.

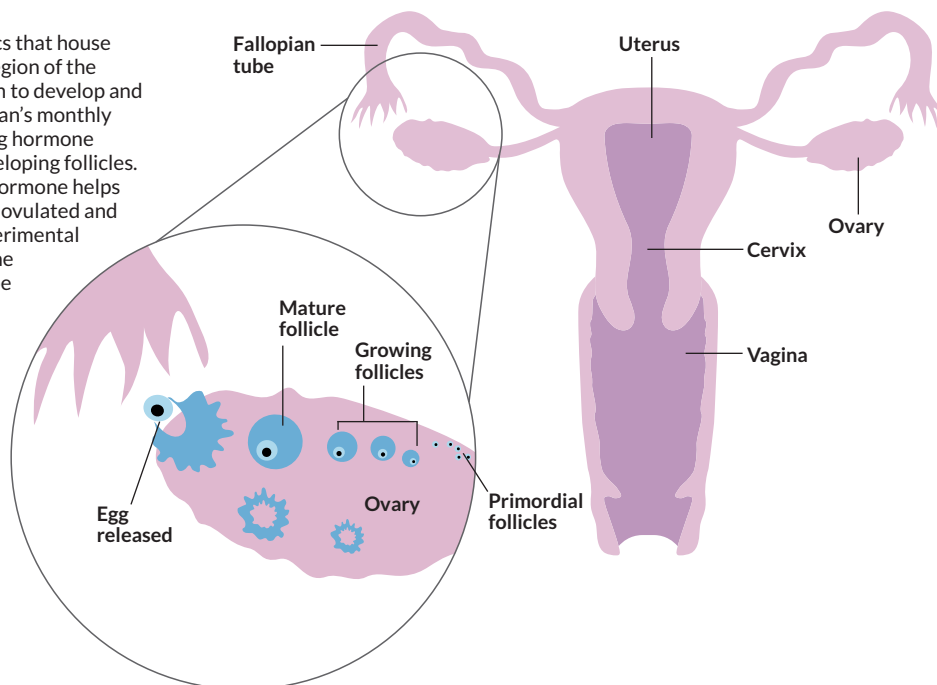
When the researchers paired female mice treated with the gene therapy with males, the females were still able to become pregnant — and have healthy babies — within the first six weeks, because of those follicles that had already started growing in the ovaries. Once that supply was used up, the females were infertile.

"You could potentially preserve that pool of eggs for later in life, theoretically."

DAVID PÉPIN

**Egg basket** Primordial follicles, the sacs that house immature eggs, reside in the outermost region of the ovary. When follicles "wake up," they begin to develop and move farther into the ovary. When a woman's monthly menstrual cycle begins, follicle-stimulating hormone prompts additional growth of certain developing follicles. A dominant follicle matures. Luteinizing hormone helps the mature follicle open up, and the egg is ovulated and released into the fallopian tube. New experimental approaches to birth control aim to keep the primordial follicles dormant, so they can be available later in a woman's life.

IMAGE SOURCE: NIH



“You’re just stopping the horses that haven’t yet come out of the gate,” Donahoe says.

To test a nonpermanent approach, the team gave normal female mice the MIS protein as a twice-daily shot. Activation of primordial follicles stopped. When treatment ended, the ovaries got back to business and follicles began growing again.

Pépin and Donahoe see several uses for MIS as a contraceptive. The permanent gene therapy method could be a nonsurgical contraceptive approach for pets or stray animals. The research team is working with the Cincinnati Zoo to study this method in cats.

Frequent shots of the MIS protein are too expensive for broad use, but they could help protect the reserve of ovarian follicles in young cancer patients. “Growing follicles are dividing quite rapidly, so they are very sensitive to chemotherapy,” Pépin says. Chemo can kill off the growing follicles, which means there is no more MIS to stop activation of other primordial follicles. Too many follicles wake up, which can deplete a woman’s egg supply. In mice given chemotherapy drugs, MIS-treated animals were left with more primordial follicles than untreated animals, the researchers found.

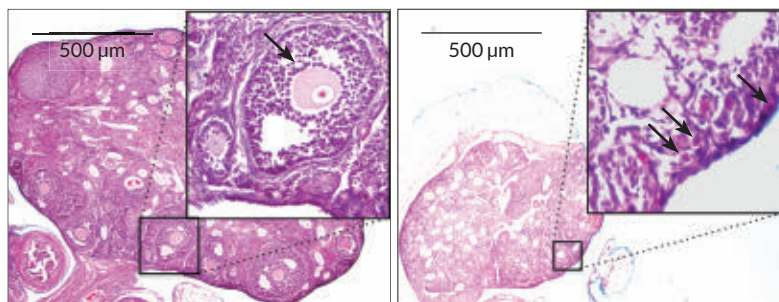
Still eager to make an MIS-like contraceptive for all women that is cheap and easy to use, perhaps as a pill, the researchers are searching libraries of small molecules to find one that mimics the action of MIS. “Maybe it would be an already existing [U.S. Food and Drug Administration] approved medication — that’s the first screen we are performing — or maybe it’s a very simple molecule, very cheap to synthesize,” Pépin says.

## Sperm stoppers

In men, vitamin A does more than promote healthy eyes. It’s essential for sperm production, too. The testes take up vitamin A from carrots and other foods and convert it to retinoic acid. The acid binds to the retinoic acid receptor, which is found in cells throughout the body.

In the 1990s, scientists reported that when they disrupted the gene for one version of the retinoic acid receptor, referred to as alpha, in mice, “the animals are fine, but the males are sterile,” says geneticist Debra Wolgemuth of Columbia University Medical Center. Wolgemuth and her colleagues, who study the biology of sperm production, set out to find a drug that could interfere with the receptor, rather than permanently knocking out the gene.

Wolgemuth came across a paper from 2001 by a group studying a drug that could bind to all three



In the ovary of a normal mouse (left), a large follicle is shown at a late stage of development (a light pink oocyte surrounded by follicular cells, inset). In the ovary of a mouse treated with Müllerian-inhibiting substance, follicle development ceased and only primordial follicles were found (arrows, right).

versions of the receptor, including alpha. The drug inactivates the receptor and shuts down the series of events that typically follow. Although tests in rats showed the drug could be taken orally and broken down safely by the body, the researchers highlighted one notable side effect. “They called it testicular ‘toxicity,’” Wolgemuth says.

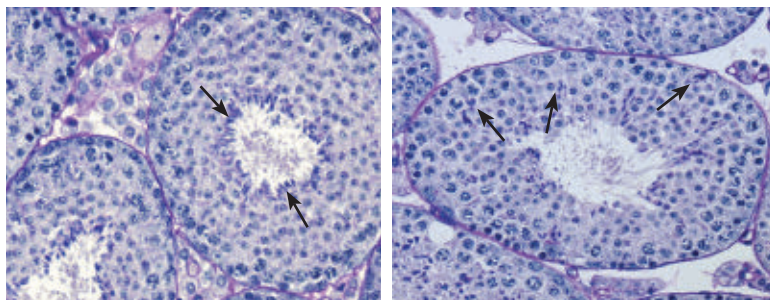
Rather than a negative, Wolgemuth saw the toxicity as a sign of a potential male contraceptive. With molecular biologist Sanny Chung of Columbia and colleagues, she gave the drug to male mice for seven days, then examined their testes.

Sperm go through many stages of development as they transition from round germ cells to their final shape with a characteristic head and tail. Before sperm are released to “begin their journey through the male reproductive system,” says Wolgemuth, “they line up like little soldiers in a battalion to leave the testes.”

In mice treated with the drug, the sperm don’t align properly, Wolgemuth and colleagues reported in 2011 in *Endocrinology*. The sperm aren’t released, so they die in the testes. The researchers found no evidence of harm to other organs. Male mice given the drug once a day for four weeks became infertile by the end of treatment and remained that way for four weeks after treatment stopped. By 12 weeks after treatment, the mice regained their mojo and successfully mated with females.

Later, the team gave mice a smaller dose of the drug for 16 weeks, over a quarter of their reproductive lives, notes Chung. The treated mice became sterile, but once off the drug, they soon became papas to healthy pups that grew into fertile adults, the researchers wrote in *Endocrinology* last year.

Next step: Wolgemuth plans to test the drug in nonhuman primates. Her group is also collaborating with a team of medicinal chemists to look for compounds that target only the alpha version of



In healthy mice, normal sperm line up at the center of a part of the testes known as the seminiferous tubule, ready for release (left, arrows). Mice treated with a drug that blocks what's known as the retinoic acid receptor have defective sperm that don't line up (right, arrows).

the retinoic acid receptor. Even though the tested drug did not lead to side effects, having an option that doesn't interfere with the other two versions of the receptor would be ideal, says Wolgemuth.

### Untethered sperm

Another nonhormonal male contraceptive is the result of a long research career dedicated to such a product. In the late 1960s, Joseph Tash had two tours as a summer student in an obstetrics and gynecological department at Michael Reese Hospital in Chicago. He saw how heavily the burden of birth control fell to women. "I felt it was important to try to expand the contraceptive and family planning choices to men," he says.

In 2013, the compound H2-gamendazole became the first nonhormonal contraceptive to receive FDA regulatory guidance, a crucial thumbs-up along the drug development road. It's a kind of checklist of the testing conditions and experiments necessary to proceed with preclinical and human trials.

Tash, now at the University of Kansas Medical Center in Kansas City, and colleagues began with an anticancer drug that, during clinical trials, severely cut down on sperm production. But there were a lot of side effects, Tash says, which would be "totally unacceptable to otherwise healthy males." So the researchers designed similar drugs to minimize the side effects, including H2-gamendazole. Rats given a single oral dose of the drug once a week for six weeks became sterile after two weeks of use. By 10 weeks after the dosing stopped, all of the animals were fully fertile again.

The drug interferes with the last stage of sperm development, when the cells acquire their familiar sperm features. At this stage, as well as throughout the developmental process, sperm are tended to by Sertoli cells, which feed and support the growing sperm. The sperm are actually tethered

to the Sertoli cells to prevent them from leaving the reef before they can swim.

H2-gamendazole disrupts the junctions between the sperm and the Sertoli cells, releasing the sperm prematurely and leading to their destruction. "The testes have a built-in cleaning system, so to speak, that gets rid of the abnormal sperm," Tash says.

Tash's team has also tested H2-gamendazole in mice, rabbits, dogs and monkeys. In each animal, there was a "block in sperm production just exactly like we see in the rats," Tash says. The team has also found that the drug can be taken as a pill and is rapidly taken up by the testes, at levels 10 to 20 times higher than in other tissues. "I think this explains to a large extent why we haven't seen any remarkable side effects," Tash says.

The work on H2-gamendazole, yet to be published, led to the FDA's regulatory guidance, a show of confidence in the drug. If Tash and colleagues can demonstrate to the FDA that the drug is safe and well tolerated, that might pique the interest of pharmaceutical companies to handle the final stages of testing and to take the drug to market. "It's going to have to be a squeaky clean compound for pharma to become interested," Tash says.

Birth control methods born of these projects might shake things up outside the bedroom. If further testing finds that eggs kept asleep by an MIS-based contraceptive remain healthy and viable, delaying pregnancy may not necessarily lead to reduced fertility. "A lot of women 35 and older are faced with reduced fertility," Pépin says. "A method to target the activation of primordial follicles so you could keep them for later—I think that would be beneficial."

Any new contraceptive options for men could shift the conversation men and women have about birth control. A multinational survey published in 2005 found more than half of men would be willing to use a new method of male birth control. "There is an increasing number of men who are willing to help carry that burden," Tash says.

"When that first product gets out there for men," Blithe adds, "I think that will be a turning point." ■

### Explore more

- Diana Blithe. "Pipeline for contraceptive development." *Fertility and Sterility*. November 2016.
- Motohiro Kano *et al.* "AMH/MIS as a contraceptive that protects the ovarian reserve during chemotherapy." *Proceedings of the National Academy of Sciences*. February 28, 2017.



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As its mission comes to an end, the Cassini spacecraft (illustrated) is the focus of a new documentary.

## TELEVISION

## Cassini spacecraft gets a proper send-off

For over 13 years, the Cassini spacecraft has orbited Saturn, beaming back dazzling images from the ringed planet and its diverse moons (see Page 16). On September 15, the mission will go out in style by dive-bombing the planet. In “Death Dive to Saturn,” the TV series *NOVA* looks back at Cassini’s successes and takes us behind the scenes for the spacecraft’s final months.

Featuring interviews with scientists, footage from mission control and a cornucopia of space pictures, the *NOVA* special tells Cassini’s story, from its launch in 1997 to its impending demise. The documentary reviews what scientists have learned and what mysteries they hope to crack as the mission ends.

Cassini commenced its end game in late April, a series of orbits nicknamed the Grand Finale. Repeatedly passing between the planet and its rings, each orbit nudges the spacecraft closer to Saturn’s atmosphere. After its final orbit, Cassini will plummet through the clouds, taking measurements until it succumbs to the crushing pressure.

“The mysteries we want to solve with the Grand Finale mostly have to do with revealing Saturn from the inside out,” Cassini project scientist Linda Spilker tells viewers. Researchers will try to gain insight into what lurks beneath the opaque cloud deck and to learn whether

**“Death Dive to Saturn”**  
PREMIERES  
SEPTEMBER 13  
PBS | NOVA

Saturn has a solid core. By providing a fresh look at the rings, the close orbits could also lead to a better understanding of how and when the rings formed.

Despite its title, the documentary focuses on more than Cassini’s dramatic finale. Highlights from the mission take center stage. And the episode puts the mission into historical context, harkening back to observations made by 17th century scientist Giovanni Cassini, who lends his name to the probe, and his contemporary Christiaan Huygens. Both men discovered the first batch of moons around Saturn and made the first detailed surveys of the planet’s rings.

The interviews are engaging, and the researchers’ excitement is infectious. Arresting visuals — some from the spacecraft, some concocted in

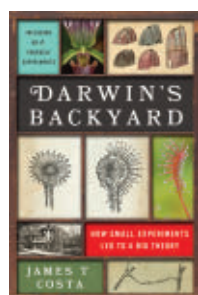
computer programs on Earth — bring the story to life. One fun segment pieces together what we’ve learned about the

moon Titan to create a vivid illustration of what it might be like to stand on the shores of the moon’s hydrocarbon lakes. After the actual dive, footage will be added to the streaming and DVD versions of the show, documenting Cassini’s final moments. — *Christopher Crockett*

## BOOKSHELF

## Famous naturalist was an experimenter, too

The story of how Charles Darwin’s trip around the world on the *HMS Beagle* inspired his ideas about evolution is well-known. Less familiar, however, may be the decades of detailed research that he conducted after that 1830s voyage. As biologist James Costa chronicles in *Darwin’s Backyard*, many of those studies took place at Down House,



**Darwin’s Backyard**  
James T. Costa  
W.W. NORTON & CO.,  
\$27.95

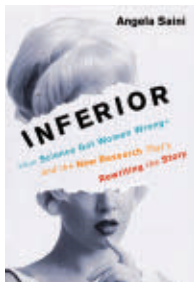
Darwin’s country home southeast of London.

The estate’s relative isolation enabled Darwin to conduct in-depth anatomical analyses of everything from barnacles to birds. Darwin supplemented that work with hands-on experiments. He bred and raised 16 varieties of pigeons, trying to show that the fancy types preferred by breeders had developed from only a few ancestral wild types.

In his gardens, Darwin laid out intricate plots where he studied the diversity and growth of grasses and weeds, as well as how earthworms churn the soil. On nearby hillsides, he investigated orchid pollination and reproduction. (Not all of his experiments were successful: One year, cows ate and trampled his orchids.) Some experiments were considered quirky by 19th century standards, but the work provided data supporting Darwin’s notions about trait variability in a population and how natural selection drives changes in populations over time.

Stories of Darwin’s rich — and in some cases, tragic — family life are woven throughout Costa’s account. Without appreciating this aspect of his life, Costa claims, neither Darwin nor his accomplishments can be fully understood. For example, he enlisted his wife, cousins and nieces — and even his butler and governess — in assisting with his homespun field studies.

One outstanding aspect of the book: Each chapter ends with a description of some of Darwin’s experiments that nonscientists can perform on their own. Readers will enjoy the tales Costa tells and the experience of re-creating some of the famous naturalist’s most enlightening work. — *Sid Perkins*



**Inferior**  
Angela Saini  
BEACON PRESS, \$25.95

## BOOKSHELF

### How science has fed female stereotypes

Early in *Inferior*, science writer Angela Saini recalls a man cornering her after a signing for her book *Geek Nation*, on science in India. “Where are all the women scientists?” he asked, then answered his own question. “Women just aren’t as good at science as men are. They’ve been shown to be less intelligent.”

Saini fought back with a few statistics on girls’ math abilities, but soon decided that nothing she could say would convince him. It’s a situation that may feel familiar to many women. “What I wish I had was a set of scientific arguments in my armory,” she writes.

So she decided to learn the truth about what science really does tell us about differences between the sexes. “For everyone who has faced the same situation,” she writes, “the same desperate attempt to not lose control but have at hand some real facts and a history to explain them, here they are.”

In *Inferior*, Saini marshals plenty of facts and statistics contradicting sexist notions about women’s bodies and minds. She cites study after study showing little or no difference in male and female capabilities.

But it’s the book’s historical perspective that makes it most compelling. Only by understanding the cultural context of the men whose studies and ideas first pointed to gender imbalances can we see how deeply biases run, Saini argues.

Charles Darwin’s influential ideas reflected his times, for instance. In *The Descent of Man*, he wrote that “man has ultimately become superior to woman” via evolution. To a woman active in her local women’s movement, Darwin wrote, “there seems to me to be a great difficulty from the laws of inheritance ... in [women] becoming the intellectual equals of man.”

If that idea sounds absurd now, don’t fool yourself into thinking it has vanished. Saini’s book is full of examples right up to today of scientists who have started from this and other flawed premises, which have led to generations of flawed studies and results that reinforce stereotypes. But the tide has been turning, as more women have entered science and more scientists of both sexes seek to remove bias from their work.

Saini does an excellent job of dissecting research on evolution, neuroscience and even the long-standing notion that women’s sexual behavior is driven by their interest in stable, monogamous relationships. By the end, it’s clear that science doesn’t divide men and women; we’ve done that to ourselves. And as scientists become more rigorous, we get closer to seeing ourselves as we really are. — *Erika Engelhaupt*

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# Innovative nonprofits receive \$20,000 in STEM Action Grants

Society for Science & the Public is proud to support organizations that encourage a love of science, technology, engineering and math (STEM) in their communities with our STEM Action Grants Program. We are excited to demonstrate this support by providing a total of \$20,000 in STEM Action Grants to five innovative nonprofits that are sparking a lifelong interest in STEM among members of underrepresented populations. These organizations use unique programming to inspire students of all backgrounds to pursue careers in STEM.

In June, Society for Science & the Public proudly announced our partnerships with these grassroots organizations that make STEM accessible for all.

**CODELLA** (Miami) works to inspire Hispanic middle school girls to enter STEM fields and helps girls build pathways and skills to meaningfully engage in a 21st century global economy. The grant will fund podcasting equipment CODELLA will use to produce weekly STEM news podcasts in Spanish and English by and for the girls.

**Electric Girls** (New Orleans) is dedicated to transforming girls into technology leaders during summer camps, after-school programs, in-school programs, one-day workshops and weekend programs. The funding will be used to purchase materials and pay instructors to teach circuit building at four after-school sites in New Orleans in fall 2017.

**Learn Fresh** (Denver) aims to improve student engagement and achievement, particularly among low-income students of color, through innovative, fun and effective educational tools. Learn Fresh's primary program is NBA Math Hoops, a basketball board game and supplemental math curriculum that uses real statistics about professional basketball players. The funding will support a pilot project that would adapt the NBA Math

Hoops board game for football with a game and program called "First and 10." The program is being developed with the help of the Denver Broncos.

**LITAS for Girls** (Scottsdale, Ariz.) guides and inspires middle school girls to pursue computer science and STEM careers through incubators that encourage the girls to code with purpose. The funding will support LITAS summer incubators, chapters and a technology showcase. LITAS is led by Anvita Gupta, a 2015 alumna of the Intel Science Talent Search and 2013 alumna of the Intel International Science and Engineering Fair — programs founded and produced by the Society.

**ProjectCSGIRLS** (Potomac Falls, Va.) works to close the gender gap in computer science and technology through a national computer science competition for middle school girls. The funding supported a national gala that took place in coordination with the 2017 competition held in June. The organization is headed by Pooja Chandrashekar, a 2015 alumna of the Intel Science Talent Search. This is the third grant ProjectCSGIRLS has received from the Society.



Left: Electric Girls teaches leadership, electronics and computer programming skills. Above: Learn Fresh uses educational games and programs to make learning fun for everyone.

FROM LEFT: COURTESY OF ELECTRIC GIRLS;  
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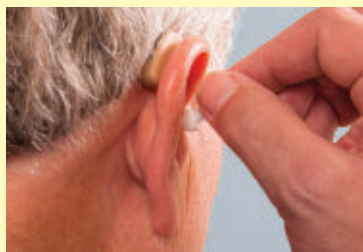
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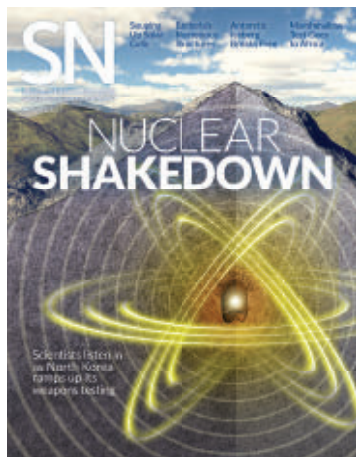
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AUGUST 5, 2017

## Curious about Curiosity?

Since landing on Mars five years ago, Curiosity has revealed a lot about the Red Planet. But the NASA rover (pictured below) still has work to do. Read about what Curiosity is up to now and watch a video highlighting its achievements at [bit.ly/SN\\_Curiosity5](http://bit.ly/SN_Curiosity5)



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### Locked up

*Simulations suggest that heat from an infant Earth, the sun and the moon could have vaporized the moon's metals into a thick atmosphere, **Lisa Grossman** reported in "Metallic air may have swaddled moon" (SN: 8/5/17, p. 7). One way to test the idea would be to look for a ring of extra sodium in rocks around the moon's twilight zone, where sodium snow would have accumulated. This zone exists between the moon's light and dark sides, which result from one side always facing Earth—a circumstance known as tidal locking.*

Online reader **Idhbk** wondered if the early molten moon would have had a consistent face to show Earth at all. "I'm having trouble conceptualizing a ball of liquid being tidally locked," the reader wrote. And if the surface was changing, would the sodium band be in the twilight zone where scientists expect?

Yes, a ball of magma can be tidally locked, says **Prabal Saxena** of NASA's Goddard Space Flight Center in Greenbelt, Md. "A liquid body would have no rigidity and would be very responsive to locking," **Saxena** says. The early moon's roiling magma wouldn't necessarily move the sodium band, either—the twilight zone would be in the same spot and would get more sodium deposits than other regions, **Grossman** says. But that's only if the moon never showed Earth another side of itself.

Online reader **Stargene** asked if the moon's tidal locking could have shifted over billions of years, and if such a shift might affect the sodium band's location.

There's no definitive answer on how the moon's tidal locking evolved, says **Saxena**, but there are some theories. If the side of the moon facing Earth shifted as the two drifted apart, that could affect where the band may be found. Excess sodium would still end up in the twilight zone, but not the twilight zone as we know it today, **Grossman** says.

### Light-hearted rodents

*Light-harvesting bacteria can provide oxygen to rats' blood-starved hearts, **Tina Hesman Saey** reported in "Photosynthesis treats ailing hearts" (SN: 8/5/17, p. 8).*

*Researchers performed surgeries in the dark and under light to measure the bacteria's activity.*

"How were the photosynthetic bacteria able to produce oxygen in the dark?" asked online reader **Ivo Fernandes**.

Bacteria did not produce oxygen in the dark, **Saey** says. Baseline oxygen levels around the heart increased during surgery in the dark because rats' chest cavities were open to the air. Bacteria carried out photosynthesis only when bright lights were on, causing oxygen levels around the heart to shoot up.

### Go the distance

*A satellite sent entangled particles to two Chinese cities 1,200 kilometers apart, **Emily Conover** reported in "Quantum satellite sets distance record" (SN: 8/5/17, p. 14). The experiment brings scientists another step closer to developing a quantum internet, which would allow for ultrasecure communications.*

Online reader **Maia** wondered how quantum communication would be ultrasecure.

"Quantum communication allows two people to share a secret string of random numbers by sending a series of entangled particles, with the surety that no one could have snooped on the random numbers," **Conover** says. That's because measuring entangled particles changes their properties. If anyone intercepts the particles, that action would leave telltale signs, and the pair would know their numbers had been compromised. "The string of numbers, in turn, serves as a secret code that can be used to encrypt further communications sent by normal means," **Conover** says.

### Patched up

*Patches studded with microneedles safely and effectively delivered flu shots to a small group of U.S. adults, **Aimee Cunningham** reported in "Patch could someday replace flu shot" (SN: 8/5/17, p. 8).*

Online reader **Mark S.** wondered how long the patch had to stay on to work.

The patch was effective 20 minutes after being applied, **Cunningham** says.





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## Cosmic Frontiers

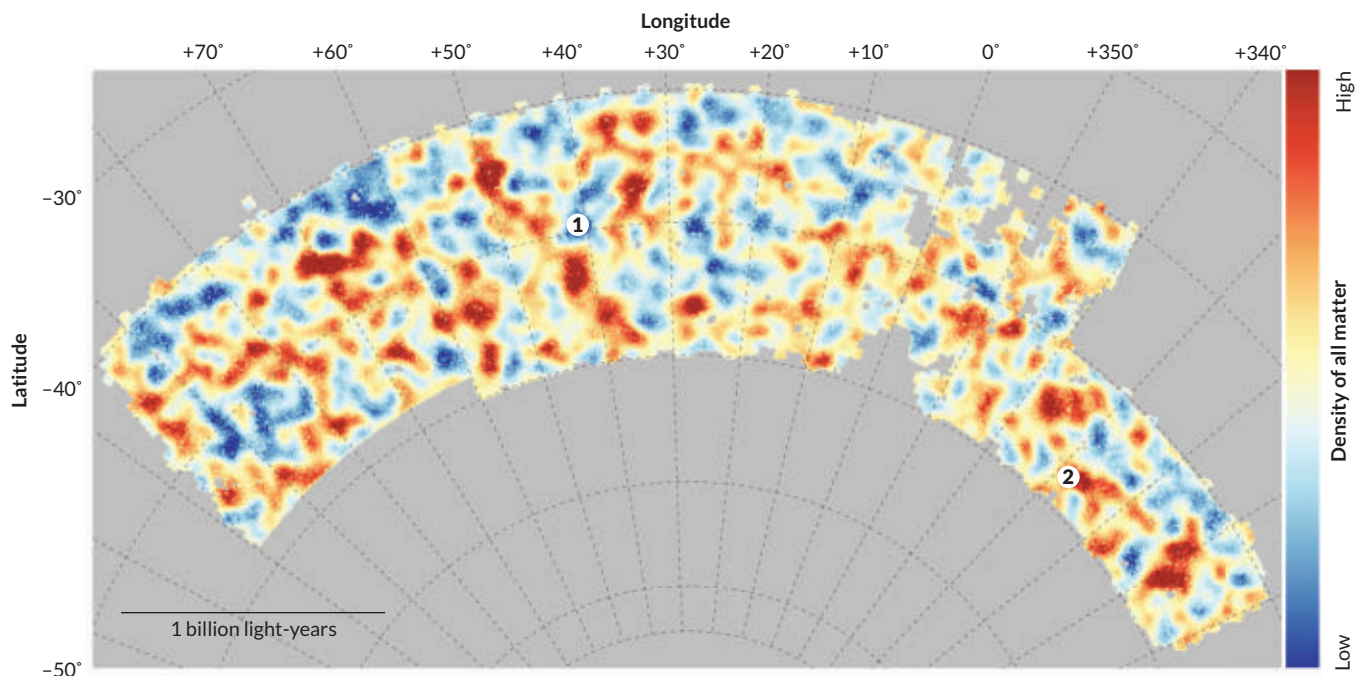
Scientists seek clues to the universe's greatest mysteries

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ScienceNews



## Charting the dark side of the universe

Scientists have created the largest map of dark matter yet, part of a slew of new measurements that help pin down the universe's dark contents. Covering about a thirtieth of the sky, the map (above) charts the density of both normal matter — the stuff that's visible — and dark matter, an unidentified but far more abundant substance that pervades the cosmos.

Matter of both types is gravitationally attracted to other matter. That coupling organizes the universe into more empty regions of space (No. 1 at right and blue in the map) surrounded by dense cosmic neighborhoods (No. 2 at right and red in the map).

Researchers from the Dark Energy Survey used the Victor Blanco telescope in Chile to survey 26 million galaxies in a section of the southern sky for subtle distortions caused by the gravitational heft of both dark and normal matter. Scientists unveiled the new results August 3 at Fermilab in Batavia, Ill., during a meeting of the American Physical Society.

Dark matter is also accompanied by a stealthy companion, dark energy, an unseen force that is driving the universe to expand at an increasing clip. According to the new inventory, the universe is about 21 percent dark matter and 5 percent ordinary matter. The remainder, 74 percent, is dark energy.

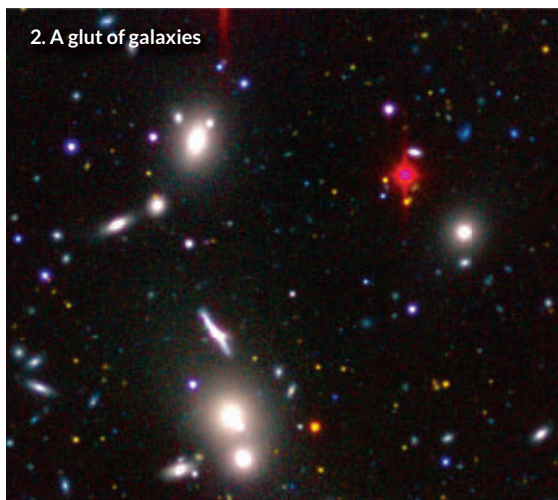
The new measurements differ slightly from previous estimates based on the cosmic microwave background, light that dates back to 380,000 years after the Big Bang (*SN: 3/21/15, p. 7*). But the figures are consistent when measurement errors are taken into account, the researchers say.

"The fact that it's really close, we think is pretty remarkable," says cosmologist Josh Frieman of Fermilab, who directs the Dark Energy Survey. But if the estimates don't continue to align as the survey collects more data, something might be missing in cosmologists' theories of the universe. — *Emily Conover*

1. A view of the void



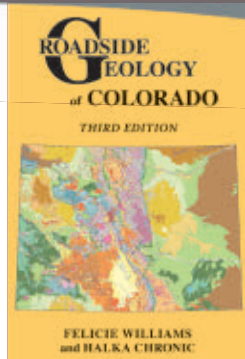
2. A glut of galaxies



MAP: CHIHWAY CHANG/UNIV. OF CHICAGO; DES COLLABORATION; IMAGES: DES COLLABORATION



# » GEOLOGIC ROAD TRIP OF THE MONTH



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## **MESA VERDE NATIONAL PARK**

Mesa Verde National Park was established to preserve and display unusual archeological remains—clustered dwellings on the mesa surface and cave-sheltered apartment houses of people who inhabited this area from A.D. 900 to 1250. But the dramatic mesa with its high shale slopes and nearly impregnable sandstone cliffs is as distinctive geologically as the archeological sites it preserves.

Forming the lower slopes of Mesa Verde, the Mancos Shale is well exposed along the entrance road. This brownish gray shale accumulated as mud in the shallow sea that spread across the center of the continent in Cretaceous time. Many small faults offset its thin sandstone layers. It slides extremely easily, necessitating never-ending road repairs. In addition to removing landslide debris from the highway, repairs involve stabilizing slides by unloading their tops, buttressing their lower ends, and adding drainage pipes to lessen wetting of the shale. The ditch on the inner edge of the road catches small slides and rockfalls and helps drain rainwater and snowmelt from slide areas.

Above the Mancos Shale are shoreline sandstones of the Mesaverde Group, deposited as the Cretaceous sea retreated eastward. Originally defined as a single formation, the Mesaverde is now given group status and subdivided into three formations. The lowest of these, the Point Lookout Sandstone, forms the cliffs that top the northern end of Mesa Verde. Farther south it is overlain by the shale-coal sequence of the Menefee Formation, deposited in marshes and swamps close to the sea's edge. Above the Menefee Formation is the Cliffhouse



*Slope-forming Mancos Shale and cliff-forming sandstones of the Mesaverde Group characterize Mesa Verde National Park. Erosion of the soft shale undermines resistant, blocky sandstone layers that form the upper cliffs. —Lucy Chronic photo*

*The cliff dwellings of Mesa Verde were built in sheltering recesses in the Cliffhouse Sandstone. Springs emerging at the bottom of the porous sandstone supplied water to the villages. The springs also promoted cave formation, weakening and undermining the rock. —Felicie Williams photo*



Sandstone. The strata dip southward here; the Cliffhouse Sandstone and Menefee Formation have eroded off the high northern prow of Mesa Verde.

The Menefee Formation erodes easily, undermining the massive, light-colored Cliffhouse Sandstone. Rainwater percolating through the porous sandstone reaches the less permeable shales of the Menefee Formation and flows sideways along the layers. Weakened by seepage from small springs where this flow emerges from the cliffs, the sandstone falls away or spalls off in great arcs to create the arched caves that sheltered early inhabitants. What could be more convenient than a weatherproof shelter furnished by nature, complete with a supply of running—or at least seeping—water? The cliffs of the Point Lookout Sandstone below sufficed to keep out enemies and provided a ready disposal system: refuse was just tossed over the edge. Archeologists searching for clues to the daily life of early inhabitants often look along the base of the cliffs.

Streams that drain Mesa Verde are typical of plateau areas. Upstream, each major stream branches again and again to form a treelike or dendritic pattern. Stream erosion is not severe here now, but during times of more intense rainfall, as in the rainy cycles that accompanied Ice Age glaciation, each small stream worked its way headward into the plateau, branching and rebranching, following joints in the rock to carve the narrow, steep ravines. As a result, the mesa is shaped something like a human hand, with deep canyons draining southward between its long fingers.

The first inhabitants of Mesa Verde lived on the surface of the plateau, where they built pit houses, farmed, and hunted. Farming was facilitated by a thin coating of fine, even-grained soil, wind-deposited silt dating back to Pleistocene times. Later, cave dwellings gave protection from both weather and enemies; farming still continued on the top of the mesa. Cave dwellings were occupied for less than one hundred years before their abandonment, which may have been caused by a twenty-four-year drought dated by tree-ring studies. Many other ruins in the Southwest were abandoned at about the same time.

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