SN
SCIENCE NEWS MAGAZINE
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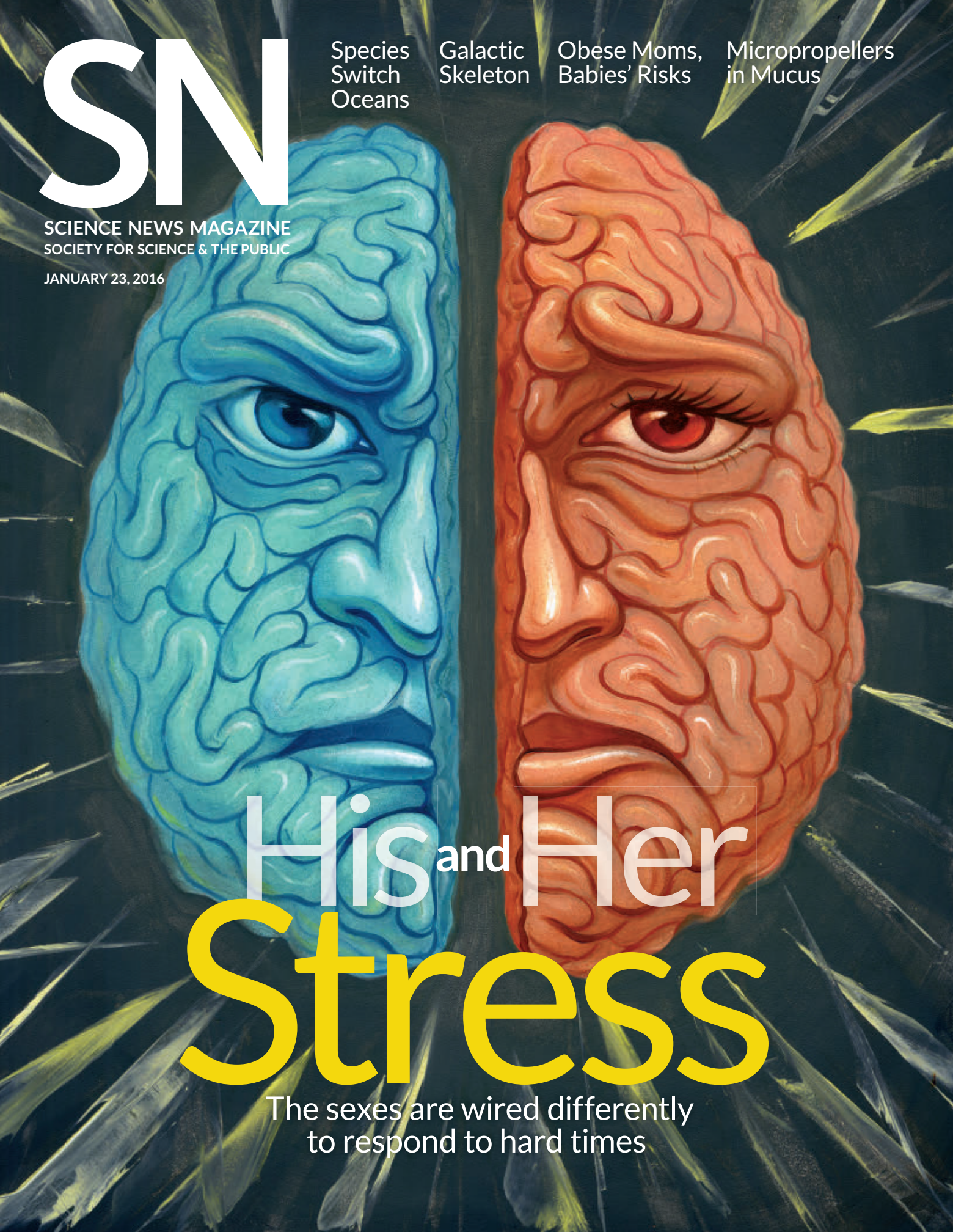
JANUARY 23, 2016

Species Switch Oceans

Galactic Skeleton

Obese Moms, Babies' Risks

Micropropellers in Mucus



His and Her Stress

The sexes are wired differently to respond to hard times

Can Your Sunglasses Do Yoga?

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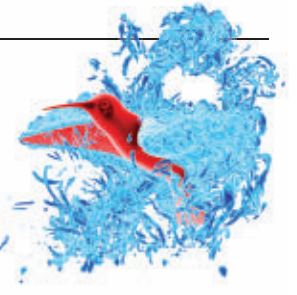
Features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News


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Departments

COVER The brain responds to stress differently in male and female animals, hinting at why men may have lower rates of depression. *Chris Buzelli*

Insights into sexes' differing responses to stress

Chronic stress takes its toll on everyone. But it may hit women harder (or at least differently) than men, much research finds. New studies in rodents show that females remain sensitive to ongoing stress longer than males do, as Susan Gaidos reports on Page 18. It remains to be seen whether such results can explain the differences in rates of depression and anxiety disorders in men and women. (Perhaps women are more likely to discuss their symptoms and be diagnosed. Men, on the other hand, are more likely to abuse drugs and alcohol, disorders which may also be related to stress.) Still, the new work offers an intriguing idea: If stress induces distinct biochemical signaling in men and women, perhaps therapies should also be tailored to each sex.

Another fascinating line of research mentioned in Gaidos' story involves altering female mice's response to chronic stress (making it more like a male's) by targeting DNA modifications known as epigenetic tags. Consisting of chemicals such as methyl groups, these tags are attached to DNA and influence gene activity. They seem like a perfect target for drugs. Epigenetic tags don't change the underlying genes, just the instructions for turning those genes on or off, up or down. In the mice, scientists used enzymes to alter the chemical tags on genes involved in the response to chronic stress. It's an exciting approach, one I'm sure many scientists will try in efforts to modulate the body's response, not just to stress, but also to other threats to health. Maybe even to fat.

A woman's extra fat can trigger metabolic changes in a developing fetus, Laura Beil reports on Page 22. Beil describes the latest research about the risks faced by children of obese moms or moms who have gained too much weight while pregnant. Neurological effects are the new twist, and a scary one, given the prevalence of obesity among women of childbearing age. If borne out in further research, these studies will add yet another consequence to an already difficult problem: the U.S. obesity epidemic. That's a problem that public health researchers have yet to solve. The new work suggests a reason for more urgency. — *Eva Emerson, Editor in Chief*

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Excerpt from the January 22, 1966, issue of *Science News Letter*

50 YEARS AGO

Search for water, oil aided by spacecraft

The secret sources of water, fuel and minerals ... may be discovered by using a new tool for geologists — an orbiting spacecraft. Cameras which detect infrared, ultraviolet and visible light and which orbit at a height of 100 or more miles will be an immense aid to geologists mapping the contours ... of the Earth's surface.

UPDATE: Six years later, in 1972, NASA and the U.S. Geological Survey launched the first of the Landsat satellites, spacecraft built to gather images of Earth. The latest, Landsat 8, debuted in 2013 and sends a minimum of 400 scenes a day. Its specialized cameras can monitor plankton and sediment in shallow waters, measure land temperatures and track dust and smoke moving through the atmosphere. Data from the Landsat satellites have informed climate and carbon cycle research, disaster recovery and urban planning. Last April, NASA announced that work had begun on Landsat 9, planned for launch in 2023.

Some of the most elaborately spiked and contorted terrestrial snail shells, as on this *Plectostoma concinnum*, are among the smallest, 5 millimeters or less.

THE SCIENCE LIFE

The fine art of hunting microsnails

There's a trick to finding new species of miniature snails: a bucket of water.

"Microsnail" is the term for the creatures with shells measuring 5 millimeters or less, sometimes much less. A species described from China, photographed perched in the eye of a needle, ranked as the world's smallest known land snail for five days in the fall of 2015. Then the journal *ZooKeys* described an even smaller species, from Borneo.

"The very tiny ones you wouldn't see even if you put your nose on the ground," says Menno Schilthuizen, who described the Borneo miniature with colleagues. To avoid dirty noses, the researchers drop soil and leaf litter into a bucket of water, and shells float to the top. The shells are empty, alas, but "you can easily find thousands in just a few liters of soil," he says.

Even scooping bucket flotsam has its complications. Schilthuizen, of the Naturalis Biodiversity Center and Leiden University in the Netherlands, has been studying the snails of Borneo's limestone hills and caves since 1997. "Sometimes people bury their dead in a cave," he says. So they're reluctant for anyone to enter, even for snail science. Bird nest collecting gets in the way as well. Families harvest cave swiftlet nests, a sought-after ingredient in exorbitantly priced bird's nest soup. "These nests are very valuable and there's a lot of poaching going on," he says. Disputes are often settled with "a lot of shooting with homemade guns."

Borneo's limestone, shown here in the pinnacles of Mount Api, offers habitat for snails because of its abundance of calcium for shell construction.

Of the 48 new species of snails from Borneo that Schilthuizen and colleagues named in November, the world's smallest "was the most boring in terms of shell shape," he says. In contrast, the region's *Plectostoma* microsnails curl in fat whorls, like tubing that vents a clothes dryer. Some loop back on themselves or flare out like a tuba. "Sometimes, they tie themselves in knots," he says. Perhaps the contortions make it more difficult for a predator to get a good grip.

Snails typically have small, or even micro, habitat ranges. At some of Borneo's isolated limestone peaks, "you can actually stand in front of the hill and see the whole world population of one particular snail species," he says. The sad part of microsnail hunting, Schilthuizen says, is discovering that a company blasting a hill to extract the limestone has wiped out the entire world population. RIP, *Plectostoma sciaphilum*. — *Susan Milius*

FROM TOP: PETER KOOMEN; © GABBRO/ALAMY STOCK PHOTO

THE -EST

Iceman has the world's oldest tattoos

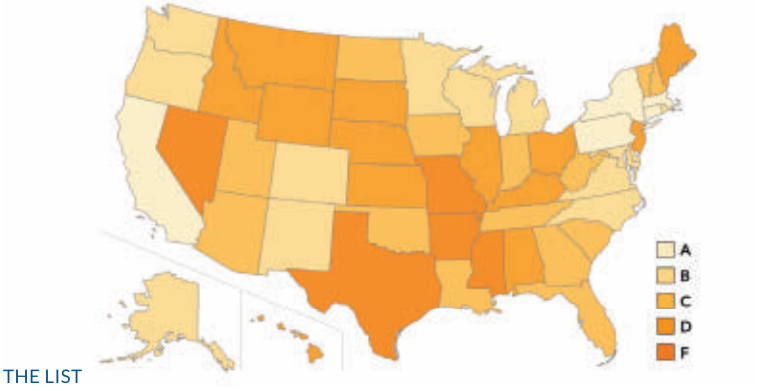
In a battle over which of two mummified guys possesses the world's oldest known tattoos, Ötzi the Iceman has triumphed.

Hikers found Ötzi's 5,250-year-old body poking out of ice in the Italian Alps in 1991. Ötzi's 61 tattoos — groups of dark lines on his left wrist, lower legs, back and ribs — were produced by rubbing charcoal into skin incisions.

A mummified man from South America's Chinchorro culture sports mustachelike lines of tattooed dots on each side of his nose, which some researchers regard as the world's oldest tattoos. But a new analysis of previous radiocarbon dating indicates that the Chinchorro man — whose body was excavated in Chile in the 1980s — lived no more than 4,563 years ago, say archaeologist Aaron Deter-Wolf of the Tennessee Division of Archaeology in Nashville and his colleagues.

Multiple misinterpretations of the dating had put the Chilean man at 6,000, then 8,000 years old. However, the scientists conclude in the February 2016 *Journal of Archaeological Science: Reports* that Ötzi is at least 500 years older than his inked competitor from the south. — *Bruce Bower*

Report card on climate change preparedness, by state



FROM LEFT: CLIMATE CENTRAL AND ICF INTERNATIONAL; E.F. FOWLER

THE LIST

States ranked on climate change preparation

SAN FRANCISCO — Report cards are out and some states are better prepared for climate change threats than others. America's Preparedness Report Card (statesatrisk.org), released in November, tabulates letter grades by comparing the precautionary steps a state has taken relative to the climate threats it is expected to face. States with a high ranking, like California, shouldn't slack off, though, says climate scientist Rita Yu of the nonprofit Climate Central, which coproduced the report.

"An 'A' doesn't mean California is fully prepared for climate change and doesn't need to do any more," Yu said on December 15 at the American Geophysical Union's fall meeting. "California is well ahead of other states ... but there's always room for improvement." Arkansas, on the other hand, has taken fewer actions to prepare for wildfires due to heat and drought than any state studied, despite having more than 1.3 million residents living in areas with elevated wildfire risk. — *Thomas Sumner*

The five states with highest and lowest grades:

1. California
2. New York
3. Massachusetts
4. Pennsylvania
5. Connecticut

....

46. Missouri
47. Mississippi
48. Nevada
49. Texas
50. Arkansas

INTRODUCING

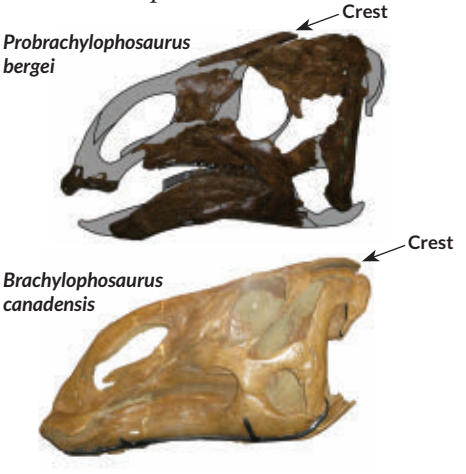
'Superduck' dino had mini crest

"Superducks" once roamed the Montana landscape. Montana State University paleontologists Elizabeth Freedman Fowler and Jack Horner described the large duck-billed dinosaurs with strangely tiny nasal crests November 11 in *PLOS ONE*.

Unearthed in 2007, *Probrachylophosaurus bergei*'s most notable feature is a small, triangular crest that runs from the snout up to the forehead. Its bones resemble a hybrid of earlier noncrested dinosaurs with flat snouts, *Acristavus*, and their crested descendants, *Brachylophosaurus*, which sported a more pronounced profile.

Fowler and Horner say the new species lived between 79.8 million and 79.5 million years ago — between the heydays of the other two groups. In fact, the researchers argue, *P. bergei* is a missing link between duck-billed dinosaurs with and without crests.

"We're seeing a trend over millions of years, in many different lineages, of crests evolving and getting larger," Fowler says. Even the skull of a juvenile *P. bergei* showed signs of a wee crest. Fowler suspects that crests may have served as a way to recognize members of the same species or potential mates. — *Helen Thompson*



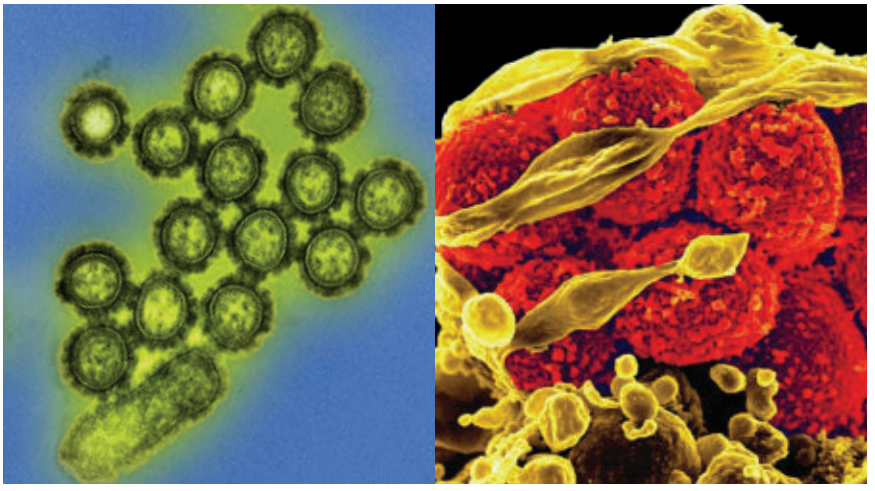
Estimates based on its skull (top) and skeleton put *P. bergei* at about 9 meters long. Its descendants, *B. canadensis* (bottom), didn't have much bigger skulls, but their crests grew larger.

BODY & BRAIN

Test tells viruses from bacteria

Gene behavior can distinguish what's causing an infection

BY LAURA SANDERS



Certain gene behavior changes in people can reveal whether an infection is caused by a virus, such as the H1N1 influenza virus (left), or bacteria, such as methicillin-resistant *Staphylococcus aureus*, or MRSA (yellow, right).

Coughs, fevers and green mucus can accompany an infection, but most of the time, doctors can only guess whether the culprit is bacterial or viral. A new study points out a way to identify the perp.

An infection changes the behavior of the afflicted person's genes, and that host response differs depending on whether bacteria or viruses are doing the damage, scientists report in the Dec. 15 *Immunity*. This virus-bacterium distinction could ultimately help doctors quickly figure out what ails a person, and whether the best treatment is antibiotics, antiviral drugs or just chicken soup and sleep.

To find the viral fingerprints, computational immunologist Purvesh Khatri of Stanford University and colleagues combed through a wide variety of publicly available datasets that included information about how human genes behaved after an infection of influenza, human rhinovirus and respiratory syncytial virus, or RSV. The researchers churned these diverse datasets through a series of sophisticated mathematical analyses, a process that ultimately pinpointed a consistent viral calling card — a list of nearly 400 genes, each of which grew either more or less active during a viral attack. Many of those genes make proteins known to be involved in virus responses and inflammation.

Khatri and colleagues then tested whether the behavior of these genes could distinguish viral infections from bacterial infections, or no infection at all. Looking at separate datasets that weren't used to generate the gene list, the researchers found that the virus signature could predict whether a person was infected with a virus, ruling out a bacterial cause. "This was a very robust host response," Khatri says.

That response is "the most solid signature people have found," says systems immunologist Shai Shen-Orr of Technion-Israel Institute of Technology in Haifa. And because the signature was consistent across a wide array of studies, the results have added heft. "It's like this has just been lying here, waiting for someone to pick up," he says. "The signal just jumped out."

Further studies could pinpoint whether the virus was flu, Khatri says. The behavior of just 11 genes served as a signature of flu, revealing whether a person was infected with influenza rather than other viruses.

Using data from studies in which healthy people were infected with the flu, the researchers showed that the viral signature showed up hours before symptoms appeared. The method even caught an asymptomatic carrier — someone who didn't feel ill but was shedding virus nonetheless. "We could pick up a person walking around, not showing any symptoms," Khatri says.

The analysis also offers clues about how well the flu vaccine works. The body's response to vaccines was similar to the response to an actual flu infection: The behavior of the 11 genes reliably changed in both cases, a result that could allow doctors to track the effectiveness of a flu shot.

Khatri and his team have already turned up a curious difference between men and women. In men, the influenza signature peaked in response to a flu vaccine the first day after the shot. Women's responses, however, showed up three days after the shot. Some vaccine studies that have concluded that men have weaker reactions may have waited too long to look for a response, Khatri says. A simple difference in timing may explain those observations.

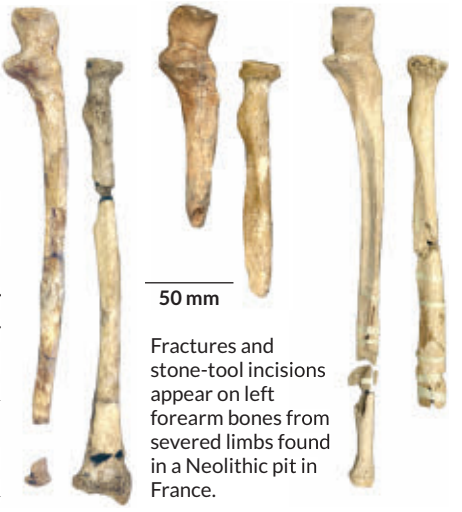
The strength of the study comes from its reliance on diverse and numerous datasets, says systems immunologist John Tsang of the National Institute of Allergy and Infectious Diseases in Bethesda, Md. "The key here is that after you look across all of [the datasets], you see a coherent signal," he says. "That's the encouraging sign."

Tsang cautions that before this method could be useful in clinics, it will need to be tested in a large prospective trial, one designed to capture changes in gene behavior in people over time.

Khatri and colleagues are already working to design a test that could tell doctors whether a patient has a viral or bacterial infection. Such a test would cut down on unnecessary antibiotic use, Khatri says. ■

Death pit deepens Neolithic mystery

Ancient victims of violence add to debate over circular graves



Fractures and stone-tool incisions appear on left forearm bones from severed limbs found in a Neolithic pit in France.

BY BRUCE BOWER

A gruesome discovery in eastern France casts new light on violent conflicts that took lives — and sometimes just limbs — around 6,000 years ago.

Excavations of a 2-meter-deep circular pit in Bergheim revealed seven human skeletons and part of an infant's skull strewn atop the remains of seven human arms, say anthropologist Fanny Chenal of Antea Archéologie in Habsheim, France, and her colleagues.

Two men, one woman and four children were killed, probably in a raid or other violent encounter, the researchers report in the December *Antiquity*. The bodies were piled in a pit that already contained a collection of left arms hacked off by axes or other sharp implements. Scattered hand bones at the bottom of the pit suggest that hands from the severed limbs had been deliberately cut into pieces.

It's unclear who the arms belonged to. All of the Bergheim skeletons have both of their arms except for a man with skull damage caused by violent blows. His skeleton lacks a left arm, the researchers say. They have been unable to determine whether that arm ended up in the pit.

Chenal's group doesn't know whether attackers targeted victims' left arms for a particular reason. The arms could have been taken as war trophies, the team speculates.

Radiocarbon dating of two bones indicates that individuals in the Bergheim pit lived roughly 6,000 years ago. From 6,500 to 5,500 years ago, during what's known as the Neolithic period, one of the many ways of disposing of the dead in farming communities throughout Central and Western Europe was in circular pits.

Discoveries of human and nonhuman bones, as well as pottery, in such pits go back more than a century. The Bergheim pit provides the first evidence that people killed and mutilated in raids or battles were sometimes buried in circular pits, too, says study coauthor Bruno Boulestin, an anthropologist at the University of Bordeaux in France.

Unusual deposits in Neolithic circular pits, such as attack victims and severed limbs at Bergheim, "may have been more common than previously expected," says biological anthropologist Silvia Bello of the Natural History Museum in London, who did not participate in the new study. She suspects, for instance, that closer inspection of human bones previously found in circular pits elsewhere in Europe will reveal additional instances of violent deaths from a time when armed conflicts occurred between some communities (*SN: 9/19/15, p. 8*).

A circular pit excavated in France contains the remains of eight people probably killed in a violent attack around 6,000 years ago. Seven more severed left arms lie at the bottom of the pit.

FROM TOP: F. CHENAL *ET AL/ANTIQUITY* 2015; © BERTRAND PERRIN/ANTEA

Bergheim's brutalized victims energize attempts to make sense of Neolithic circular pits. Many researchers regard these pits as remnants of storage silos that were put to other uses, possibly as receptacles for the bodies of people deemed unworthy of formal burials.

Others argue that a large proportion of pits were dug as graves for high-ranking individuals, whose servants or relatives were killed to accompany them. Or, slaves might have been killed and put in pits as displays of wealth or as sacrifices to gods.

Of 60 circular pits excavated in Bergheim in 2012 in advance of a construction project, 14 contained human bones. The researchers found skeletons or isolated bones of at least one to five individuals in each of 13 pits. The final pit contained the bodies and limbs described in the new paper.

Joints of severed arms and skeletons in that pit were well-preserved, indicating that they had all been placed there at or around the same time with a minimum amount of jostling disturbance. The pit also contained remains of a piece of jewelry made with a mussel's valve, as well as a stone arrowhead, a fragment of a pig's jaw and two hare skeletons. The skeleton of a woman who had been put in the pit later lay on top of a sediment layer encasing those finds.

Neither that woman nor human remains in the other Bergheim pits showed signs of violent death or limb loss. ■

ATOM & COSMOS

Exoplanets require right stuff for life

Wrong makeup could nix tectonic activity needed for biology

BY THOMAS SUMNER

For some exoplanets, just being in the Goldilocks zone isn't enough. Planets need to be made of the right stuff to become a cradle of life.

Planets composed of certain element cocktails can't host a continual recycling of Earth-like tectonic plates, new simulations of exoplanet interiors indicate. Measuring the compositions of stars could help astronomers narrow the list of potentially habitable planets, said Cayman Unterborn, who presented the work December 18.

"This is a new way of thinking — astronomers don't think in geology terms," said Unterborn, an extrasolar planetary scientist at Ohio State University. Exoplanet hunters currently treat an exoplanet as potentially habitable if it orbits the right distance from its sun for water to exist in liquid form.

"When we talk about habitable planets, it may not be wise to just say Goldilocks zone — there may be a Goldilocks composition as well," Unterborn said.

Earth's surface is divided into a jigsaw puzzle of shifting rigid plates. When two plates collide, one can dive under the other down into the mantle. This subduction helps regulate carbon dioxide levels in the atmosphere. Without plate tectonics, CO_2 from volcanic eruptions would accumulate unchecked and cook the planet, as on Venus.

A descending plate is initially too light to sink all the way into the mantle. As pressures mount during descent, however, the atoms in the plate undergo a reorganization that makes the plate denser. This phase change, at roughly 40 kilometers below ground, allows the plate to sink deeper into the mantle. Without this phase change, the sinking plate would stall and shut down plate tectonics.

Phase change properties depend on the composition of the planet. Astronomers currently can't measure the compositions of exoplanets, but they can for stars. Since stars share very similar compositions with their planets, Unterborn and colleagues can use data from a star to estimate a planet's elemental mix.

Key elements for rocky planets include magnesium and silicon, which together provide 29 percent of Earth's mass. The mix of the two is crucial for which minerals form. Simulating exoplanets with various compositions, Unterborn and

EARTH & ENVIRONMENT

Earlier origin for Earth's center

Innermost core formed soon after planet did, study finds

BY THOMAS SUMNER

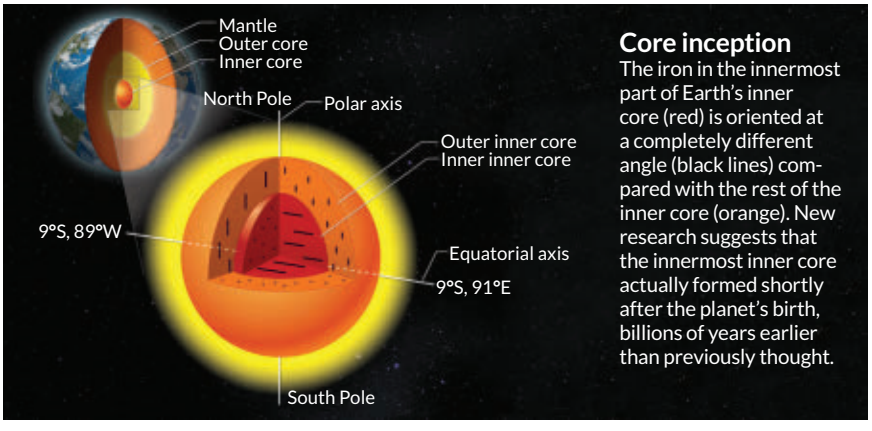
Earth's deepest realm may be billions of years older than previously thought. New simulations of the planet's formation suggest that the innermost part of the inner core solidified shortly after Earth's assembly, rather than roughly 3 billion years later alongside the rest of the inner core.

Though not all scientists are convinced, the new proposal offers insights into the early days of Earth and other rocky planets such as Mars, said geophysicist George Helffrich, who presented the findings December 17. "This early inner core might actually be one of the most ancient solid objects we have in the whole entire planet," said Helffrich, of the Tokyo Institute of Technology.

Earth's innards are divided into layers: a solid iron-rich inner core, a molten iron-rich outer core, a gooey mantle and a rigid crust. Earthquake waves ricocheting off boundaries between layers allow scientists to infer the planet's structure.

In 2002, scientists discovered that the 2,440-kilometer-wide inner core had layers of its own. The orientation of the iron in the core depends on what conditions were like when the iron solidified. Scientists can measure that orientation by seeing how quickly earthquake waves move at different angles: They move faster when they're aligned with the iron's orientation. Earthquake waves revealed that the center of the inner core, a region about 1,200 kilometers across, has a different orientation compared with that of the rest of the inner core. The cause of this off-kilter core became an unsolved mystery in the geophysics community.

Helffrich and Ramon Brasser, also a geophysicist at the Tokyo institute, simulated large rocks that slammed into the early Earth roughly 4.5 billion years ago. These rocks contributed material that became the innermost inner core: Metal from these impactors dropped into the planet's interior, releasing heat while descending. As the planet grew, metal from additional impactors also sunk deep



Core inception
The iron in the innermost part of Earth's inner core (red) is oriented at a completely different angle (black lines) compared with the rest of the inner core (orange). New research suggests that the innermost inner core actually formed shortly after the planet's birth, billions of years earlier than previously thought.

PHOTO COURTESY OF LACHINA PUBLISHING SERVICES

colleagues found that silicon-rich planets with a magnesium-to-silicon ratio about 40 percent smaller than Earth's can't support plate tectonics. Sinking plates on such planets still undergo phase changes but wouldn't become denser than the surrounding material.

Even the proper element mix doesn't guarantee plate tectonics. Among our solar system's four rocky planets, only Earth is known to currently have plate tectonics. The findings provide a way to cross exoplanets off the potentially habitable list, not put them on the list in the first place, Unterborn said.

The new work is a step in "just the right direction," said planetary scientist Lindy Elkins-Tanton of Arizona State University in Tempe. But confirming the results will be hard. "It's almost impossible for us to detect whether exoplanets have plate tectonics," she said. "It's not going to happen in the coming couple of decades." ■

into the interior. Because this metal had farther to sink, it got hotter than the old metal from those first rocks already in the core, creating a hotter layer surrounding a relatively cool center.

About 100,000 years after Earth's accretion began, rising pressures inside the planet caused the cooler innermost core to solidify, simulations showed. The work predicted this core to be 300 to 2,000 kilometers across, a relatively good fit for the actual size of the innermost core. More than 3 billion years later, the rest of the solid inner core grew around the ancient layer as heat dissipated (*SN: 9/19/15, p. 18*), the team proposes.

This process should apply to other rocky planets such as Mercury, Venus and Mars, Helffrich and Brasser suggest.

While interesting, the simulations ignore important processes that shaped Earth's evolution, says Peter Driscoll, a geophysicist at the Carnegie Institution for Science in Washington, D.C. Hot material surrounding the early Earth's center should have kept temperatures hot enough to prevent solidification at the time, he said. "I'm not sure [this explanation] works for the Earth," he says. ■

Climate change may cause sea ice in the Arctic to travel longer distances at faster speeds. That ice can carry pollution spilled from Arctic oil platforms.

EARTH & ENVIRONMENT

Arctic ice rafts traveling farther, faster

Contamination risks rise as embedded pollutants spread, too

BY THOMAS SUMNER

Climate change could turn the Arctic Ocean into an ice autobahn. Sea ice, much of it chunks of floating ice, is becoming younger and thinner as old ice melts. That new ice travels farther and faster than older ice, carrying dirt and pollution along for the ride, new research shows.

Tracking Arctic ice over several years, researchers noticed that ever larger areas of ice now make the trek from one side of the ocean to the other. That movement means the far-flung reaches of the Arctic are becoming more connected, oceanographer Robert Newton said December 16. That's a problem, as migrating ice will boost the risk of widespread environmental disaster from events such as oil spills, said Newton, of Columbia University's Lamont-Doherty Earth Observatory in Palisades, N.Y.

"You might imagine that the ice is this pristine environment, but that's not true," he said.

Airborne pollution swept in from lower latitudes settles into the ocean and onto sea ice. Industries along the Arctic, such as gold mining and oil extraction, can also pollute the region. As new ice forms in autumn and winter, that pollution, along with nearby sediment, gets trapped in the ice. In spring and summer, the ice melts and drops its payload back into the ocean.

Between formation and melt, winds and ocean currents can push ice across the Arctic. Young, thin ice is more likely to be prodded by these forces. Newton and colleagues wondered what the impact of shrinking sea ice cover (*SN Online: 8/3/15*) would be on these ice rafts. Less ice means less capacity to carry pollutants and debris, but a less crowded Arctic also lets ice travel farther and faster.

The team analyzed satellite photos of the Arctic with software that recognizes the edges of sea ice. With the aid of GPS-tracked buoys and atmospheric data, the team followed the movements of ice from formation to disintegration.

Most ice does not go far. About 60 percent travels less than 100 kilometers. But the remaining ice, equivalent to tens of thousands of square kilometers, can travel hundreds or thousands of kilometers. Newton estimates that a roughly 8 to 10 percent larger area of ice now travels a significant distance over its lifetime compared with 15 years ago. That ice also moves faster, traveling from Russia to Canada in four to five years or less, down from six to seven years in 2000.

The work may underestimate the amount of wandering ice, said sea ice geophysicist Andy Mahoney of the University of Alaska Fairbanks. Fresh, fast-moving ice forms in October and November, but satellites struggle to capture that young ice. An oil spill in summer could become trapped in this autumn ice and quickly move from one country's waters to another's, Mahoney said, rapidly relocating the spill's ecological impact. ■

ATOM & COSMOS

General relativity caught in action

Debris disk around black hole shows frame-dragging effect

BY ANDREW GRANT

An effect of general relativity that is barely measurable on Earth has been spotted in full force around a black hole.

Physicists detected the signature of a black hole twisting the fabric of spacetime around it. The discovery, reported December 16, is the best evidence yet of this effect, known as frame dragging, around a black hole.

Scientists detected the extreme frame dragging by analyzing a disk of star debris swirling around a black hole about 28,000 light-years away. X-rays from the disk suggest that its matter is on a wild ride as the spacetime it occupies gets yanked and warped by the spinning black hole.

Albert Einstein's century-old general theory of relativity describes gravity in terms of massive objects deforming the surrounding spacetime. For example, Earth creates a dent in spacetime much like a bowling ball would on a rubber sheet. Frame dragging is less intuitive: It stipulates that if the ball were spinning, it would drag the sheet along with it.

Physicists with the Gravity Probe B satellite measured Earth-induced frame dragging using gyroscopes (*SN: 12/26/15, p. 7*). Absent relativity's effects, the axis of each gyroscope's spin would have pointed in the same direction forever. But the axes deviated by about a hundred-thousandth of a degree per year due to Earth's rotation. The experiment required extreme sensitivity to capture such a subtle effect.

But frame dragging should be anything but subtle around a black hole, which packs an immense mass within a small volume. While scientists can't put a satellite into orbit around a black hole, they can study the stuff circling it. Adam Ingram, an astrophysicist at the University of Amsterdam, and colleagues zeroed in on H1743-322, a black hole that is stripping matter from an unlucky star. The disk of material orbits on a plane that is not quite perpendicular to the black hole's axis of spin.

Using data from the XMM-Newton space telescope, the researchers analyzed X-rays emitted by iron ions embedded in the swirling disk of stellar material. These ions emit X-rays at a frequency that grows and shrinks slightly depending on the direction the ions are moving in relation to the observer. Ingram and colleagues studied how the frequency of the iron-emitted X-rays fluctuated over time to chart the path of material in the disk.

In addition to orbiting the black hole, the disk is also wobbling, the researchers concluded. As the black hole spins, the disk's innermost material experiences a frame-dragging effect that's about 100 trillion times as strong as the effect experienced by the Earth-orbiting gyroscopes, Ingram reported. The axis of a gyroscope in black hole orbit would drift roughly 90 degrees each second.

"This result is very big," says Eugenio Bottacini, an astrophysicist at Stanford University. But he wants to see details of the analysis in Ingram's upcoming paper, which is under review for publication. ■

ATOM & COSMOS

A recipe for supermassive black holes

Slamming two primordial galaxies together could create collapse

BY ANDREW GRANT

Monster black holes in the early universe may have taken an unusual route to becoming so massive.

Giant gas clouds in some of the universe's first galaxies collapsed under their own gravity to form supermassive black holes, theoretical astrophysicist Lucio Mayer of the University of Zurich suggested December 15. The proposal offers a major shortcut to supermassive status, as black holes are generally thought to start small and gradually grow by merging with each other and gobbling up matter. The mechanism also doesn't rely on stars to spawn black holes in the first place.

If confirmed, Mayer's idea would solve the mystery of why astronomers keep spotting gargantuan black holes when the universe was less than a billion years old.

The first stars, some of them 100 times the mass of the sun, took shape a few hundred million years after the Big Bang. The largest ones soon exploded, leaving behind black holes of roughly the same mass. Yet telescope observations reveal that by 500 million years later, some black holes weighed in at 10 billion solar masses (*SN: 4/4/15, p. 5*). No matter how often black holes feasted and combined forces, they would have had trouble growing by a factor of 100 million so quickly.

Mayer's recipe requires getting huge amounts of matter to fall together until the collective gravity is strong enough to prevent light from escaping. Galactic gas seems like an ideal black hole–building ingredient, but it never seems to reach the necessary ultradense state; instead, it tends to cool and gather in small clumps that go on to become stars.

But if two primordial galaxies collided, Mayer proposes, then perhaps their gas wouldn't be able to build stars. The galactic merger would spark turbulent swells, warming the gas and preventing it from clumping. Computer simulations showed the growth of a dense disk of gas, largely immune to fragmenting into stars, that eventually became compact enough that it collapsed into a black hole hundreds of millions of times as massive as the sun. Mayer calls this direct progression from gas to shadowy abyss "dark collapse."

Mitchell Begelman, an astrophysicist at the University of Colorado Boulder, says he likes Mayer's line of thinking. But he worries that the factors stalling star formation, such as gas molecules rotating too quickly, would also prevent the disk from reaching critical mass. "I'm pretty skeptical you can get a collapse," he says. ■

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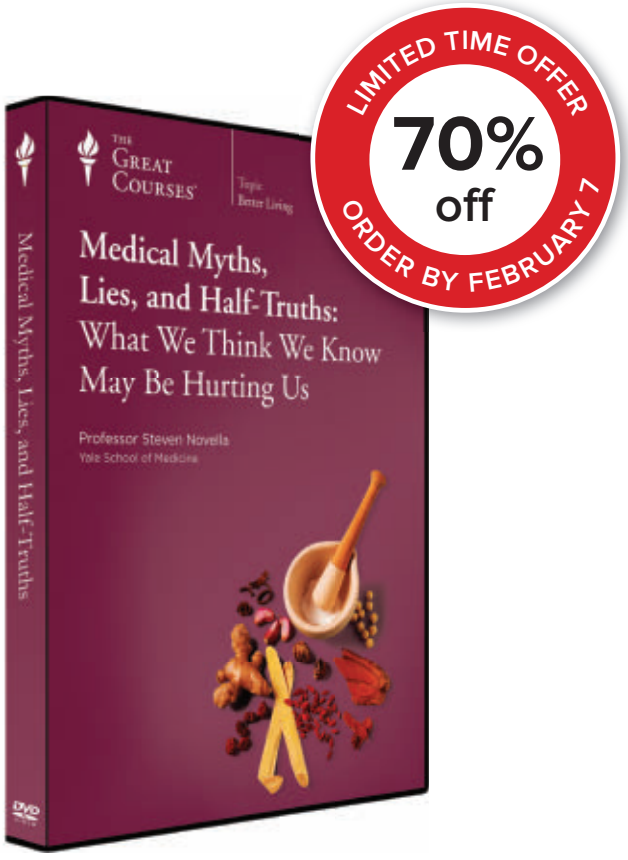

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BODY & BRAIN

To treat the heart, start with the gut

In mice, drug impairs reaction that leads to artery plaque

BY SARAH SCHWARTZ

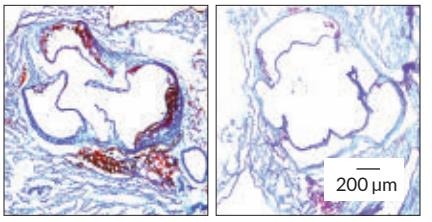
Blocking gut reactions could help defend against heart disease.

Intestinal microbes break down the nutrient choline, abundant in meat and eggs, into a compound that leads to hardening of the arteries. A drug candidate that prevents the microbes from making this conversion in mice can reduce both the amount of this compound and the extent of artery damage, researchers report December 17 in *Cell*.

Manipulating gut bacteria has clinical promise, says physician and microbiologist Martin Blaser of the New York University Langone Medical Center. "It's a very exciting idea that may change the future therapies that are available for doctors." He notes that this study addresses an important and common disease: atherosclerosis, in which fatty plaques build up inside arteries, increasing the risk of heart attack and stroke.

Some bacteria found in both mouse and human guts turn choline into trimethylamine, or TMA. In the liver, TMA is transformed into an artery-clogging compound that study coauthor Stanley Hazen and colleagues previously linked to atherosclerosis in humans (*SN: 5/18/13, p. 14*).

Now the researchers have discovered that a cholinelike compound can block TMA production. Instead of fueling bacteria's TMA-making activity, the potential drug suppresses some of the enzymes that microbes use to turn choline into TMA. This drug, nicknamed DMB, limits how much TMA mouse and human gut bacteria produce. In mice fed a diet high in choline or another TMA precursor, those given the drug in their drinking water developed less plaque-forming chemicals in their blood than those not given the drug. A high-choline diet caused plaques to build up in the arteries of mice genetically predisposed to atherosclerosis. But treating these mice with DMB completely prevented artery clogging, says Hazen, a physician scientist at the Cleveland Clinic.



Mice predisposed to heart disease and fed a high-choline diet had plaque (red) buildup in their arteries (blue). Mice also given a drug to prevent gut microbes from breaking down the choline had less artery clogging (right).

The drug compound, which occurs naturally in some olive oils and red wines, was nonlethal to the gut bacteria and didn't cause any harmful effects in the mice after four months of treatment.

But there's no guarantee that the gut microbes wouldn't develop drug resistance, Blaser says. TMA is an energy source for some microbes, and certain bacteria could evolve new ways of making the compound. He says that more research is needed to determine if the experimental drug will work in people. ■

GENES & CELLS

Micropropellers plow through goo

Tiny machines mimic trick used by ulcer-causing bacteria

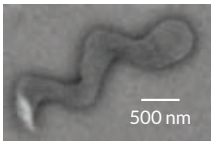
BY SARAH SCHWARTZ

By stealing a trick from bacteria, tiny human-made vehicles can cruise through goo.

Researchers in Germany have designed micropropellers that travel through mucus, in part by liquefying their surroundings. The metal and glass propellers could inform the design of microbots and drug delivery systems, the scientists report December 11 in *Science Advances*.

"It's a really nice example of this concept of bioinspired engineering: taking what's sort of a clever biophysical strategy from nature for overcoming a challenge," says biophysicist Jonathan Celli of the University of Massachusetts Boston.

Inspired by the bacterium *Helicobacter pylori*, the micropropellers are about two micrometers long and use corkscrewlike tails to move forward. The propellers are coated in the enzyme urease, which *H. pylori* releases to liquefy thick stomach mucus. Other bacteria get stuck in viscous mucus; without urease, so do the micropropellers.



This micropropeller has a silica bead head and a corkscrew-shaped glass tail; magnetic nickel (visible in bottom left) helps spin the propeller forward in a magnetic field.

Each micropropeller contains magnetic nickel in its tail so the corkscrew will spin forward in the presence of a rotating magnetic field. "It's like a remote drill that we don't need to contact," says study coauthor Peer Fischer, a physical chemist at the Max Planck Institute for Intelligent Systems in Stuttgart. Fischer and colleagues tested the propellers in a mixture of pig stomach mucus proteins and hydrochloric acid. To make the propellers move, the team added other ingredients, including urea, which fuels urease's liquefying power, and salts that prevent the propellers from getting tangled in chains of mucus molecules.

"It's very interesting from the technological point of view, but clearly has some limitations with regard to potential application," says food scientist Alan Mackie of the Institute of Food Research in Colney, England. The human stomach is usually more acidic than the propellers' test environment, he says.

The system is a "proof of concept" and probably not suitable for clinical use, says study coauthor Debora Walker, also a physical chemist at the Planck Institute. ■

FROM TOP: Z. WANG *ET AL*/*CELL* 2015; D. WALKER *ET AL*/*SCIENCE ADVANCES* 2015

MATTER & ENERGY

Elusive transition state captured

Crossover point in molecule's transformation detailed

BY LAURA SANDERS

A new technique offers a sharp picture of an elusive and ephemeral stage of a chemical's life. By precisely measuring the energy of a molecule at the instant it morphs from one form to another, scientists have revealed previously unseen details about the mysterious intermediates in chemical reactions.

Chemist Richard Zare of Stanford University calls the new insights "a major breakthrough."

During chemical reactions, molecules pass through a transition state — an unstable, high-energy form that immediately changes into the final product. "Transition states have always been thought of as these things that don't really exist," says Josh Baraban of the University of Colorado Boulder, a coauthor of the report, in the Dec. 11 *Science*. Now Baraban and colleagues have caught such states in action.

Transition states rest at the top of an energetically steep mountain. And the details of that landscape control the rate of a reaction. "It's like you have a mountain range between reactants and products, and the transition state is the path," says Baraban, who conducted the study at MIT. "It's the easiest way to get from one to the other."

The researchers worked with the molecule acetylene. Made of two carbon atoms each flanked by a hydrogen atom, the molecule can morph from a U-shape, with both hydrogens above the carbon-carbon bond, to a lightning bolt, with one hydrogen above the carbons and one below. This common type of shape-shifting is called isomerization.

Studying these elusive states is anything but easy. The team used lasers to pump energy into a jet of acetylene molecules, and laser spectroscopy to monitor changes in the molecules' vibrations and rotations. At a certain point, the predictable pattern of vibrational changes broke down. This breakdown, with unexpectedly low vibrational frequencies, is the key feature marking the transition state, study coauthor Robert Field of MIT says. "When you're going over a barrier, at the top, you basically stop."

In the transition state, these broken patterns were related to structural contortions of the shape-shifting molecule, the team found. That agrees with theoretical predictions, but "there's never been any independent way of looking at this problem," Baraban says. ■

ATOM & COSMOS

Galaxy's 'bones' map its structure

Gas tendrils trace the Milky Way's spiral arms, study finds

BY CHRISTOPHER CROCKETT

A galactic skeleton of dark interstellar gas tendrils might help map the scaffolding of our galaxy, a new study suggests.

Six of these "bones," each 40 to 150 light-years long and less than a light-year wide, appear to lie along nearby spiral arms of gas and stars that wind around the Milky Way. The bones' thinness potentially provides a precise tool for tracing the larger framework of our galaxy, a fiendishly difficult task for astronomers trapped in the Milky Way.

"Bones will not be useful just by themselves," says study coauthor Catherine Zucker of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. But combined with other methods, "they provide a way to pin down the locations of spiral arms." The study appears in the Dec. 10 *Astrophysical Journal*.

Much of what astronomers know about the Milky Way comes from measuring the speeds of gas clouds and, along with some assumptions about how the galaxy rotates, translating those speeds into distances. Seen from afar, the Milky Way resembles a pinwheel, with starlit bands spiraling away from a bulging core. Whether the spiral galaxy has two arms or four, whether those arms wrap all the way around the galaxy, and even the extent of the solar system's arm are up for debate.

JPL-CALTECH/NASA, UNIV. OF WISCONSIN

Galactic "bones," tendrils of gas and dust, may help scientists map the Milky Way. One of six new bone candidates (dark filament) lies about 11,000 light-years away.

In 2010, astronomer James Jackson of Boston University reported the discovery of the first known Milky Way bone, a dense ribbon of gas and dust. Astronomer Alyssa Goodman, also of the Center for Astrophysics and a coauthor of the new study, proposed that Jackson's bone could be a "spine" of the Scutum-Centaurus arm. Because it's denser and more compact than the relatively fluffy nebulas and star clusters that surround it, this spine and others like it could be more precise tracers of the larger galactic framework.

"It's not a crazy idea," Jackson says. Recent computer simulations suggest that lots of these bones should form along the arms of a spiral galaxy.

Zucker and colleagues narrowed their search to known nearby spiral arms just to see if the filaments existed and if they aligned with the arms. They now plan to widen their search. "We think that bones could form anywhere in a spiral galaxy," Zucker says. That's why bones alone can't solve the mapping woes. But with other cosmic cartography tools, the bones might help astronomers better understand how our galactic home is built. ■

LIFE & EVOLUTION

Arctic passageways let species mingle

Melting ice opening route for Pacific, Atlantic creatures to mix

BY SUSAN MILIUS

One whale spotted in the wrong ocean seemed merely odd. But a second misplaced whale looked more like a sign of an ecological shake-up: Pacific Ocean fauna moving into the Atlantic Ocean and vice versa. As the Arctic's icy barriers melt, new waterways may soon allow many formerly separated animals to move and mix.

"We do believe we're seeing a faunal exchange," says Seabird McKeon of the Smithsonian Marine Station in Fort Pierce, Fla.

Species moving from one ocean might disrupt life in the other — competing with some longtime residents, preying on others — or maybe change hardly anything. "We just do not know what's going to happen," McKeon says.

Using various sources, he and seven other scientists compiled several years' worth of wrong-ocean sightings of whales and birds suspected to have crossed the Arctic or mingled with counterparts from the opposite ocean. The compilation, published online November 30 in *Global Change Biology*, isn't big. But for long-lived creatures such as whales and some seabirds, a trickle of animals could establish a new population.

"Even if the strays are few, even if it's a very slow process, there is a chance of establishment," McKeon says. "That's why we're excited for people to really start watching this process."

Birders, whale watchers and other citizen scientists offer the best hope for catching early signs of any species moving across the Arctic. "If an individual bird ends up in an alternative ocean basin, that is not something that is likely to be picked up by standard scientific programs," McKeon says.

In the past, thick permanent sea ice in the Arctic plus potentially lethal water temperatures, scarce food, unusual salinity and other menaces have acted as a barrier between oceans, largely blocking animal journeys for the last 3 million years. But climate change is opening up a path. The 10 skimpiest minimums for summertime sea ice observed since the satellite era began have all occurred in the last 11 years, NASA analyses show.

Summer ice has dwindled enough on occasion, such as in 2012, to raise commercial hopes of workable waterway passages for shipping. Feasible paths are opening in successive years through the archipelago of islands in eastern Canada, and other routes may form, too, so trade ships in coming decades may be able to shortcut through the summertime Arctic.

Human commerce and the politics of climate change get more widespread attention than the chance that animals will venture along the new routes. But rearranging species' ranges could have sweeping consequences, too.

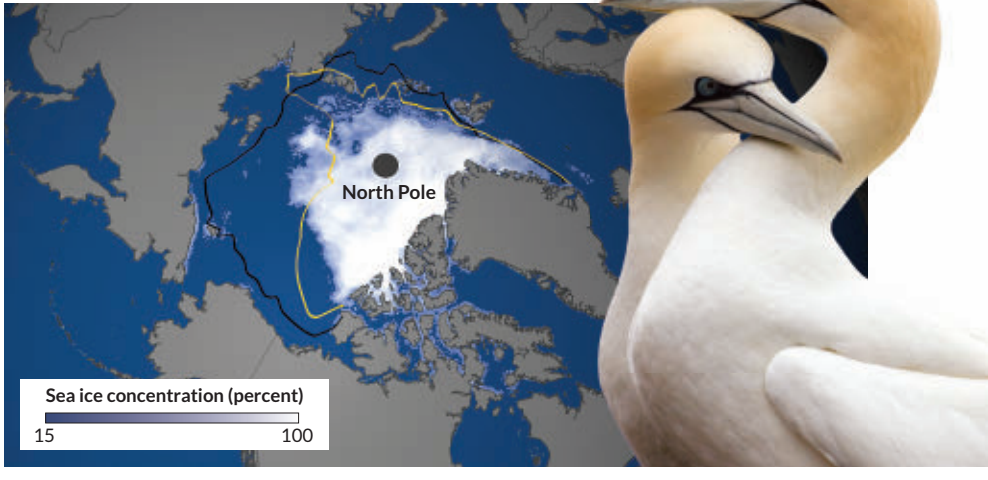
A notorious example of the unintended troubles that range changes can cause comes from the Suez Canal in Egypt. The canal "has been singularly successful as an invasion corridor," says Bella Galil of the National Institute of Oceanography in Haifa, Israel.

Of nearly 700 alien species now found in the Mediterranean Sea, half have arrived through the canal since it opened in 1869, Galil reported in the April *Biological Invasions*. In summer, swarms of nomad jellyfish (*Rhopilema nomadica*), originally from the Red Sea, clog fishing nets and block intake pipes at desalinization and power plants in Israel. Another newcomer, the poisonous *Lagocephalus sceleratus* puffer fish, puts several people in the hospital each year. And introductions such as the goldband goatfish and a kind of spiny oyster have wiped out their native counterparts.

In contrast, the Panama Canal shepherds traffic through locks filled with freshwater, which reduces the risk of saltwater Pacific species sloshing through to the Caribbean Sea and vice versa. And thank goodness. McKeon says he has heard discussions about whether a saltwater canal in Panama would have let the venomous sea snakes from the Pacific wriggle their way into the Caribbean.

In the rapidly changing Arctic, at least one Pacific species has already established populations on the North Atlantic side for the first time in about 800,000 years. Microscopic strings of silica-encased *Neodenticula seminae* diatoms turned up in the late 1990s in the Labrador Sea, an international

Lowest so far The smallest remnant of Arctic sea ice left after a summer of melting (since satellites started monitoring in the 1970s) was this tattered bit recorded September 16, 2012. The yellow line shows the second-lowest minimum, recorded in 2007 (2015 had the fourth-lowest minimum); the black line shows the median for the annual minimum for 1979 through 2000.



MAP: NOAA CLIMATE.GOV; NORTHERN GANNETS: KEITH MARSHALL/FLICKR (CC BY-NC-SA 2.0)

research team reported in 2007. The researchers argue against the notion that the diatoms merely hitchhiked in some ship's ballast water. Instead, the diatoms' presence could be a sign that ocean circulation patterns are changing in the Arctic, swirling water and its living residents across the pole. What the diatoms will do in the Atlantic isn't clear, but they have now spread to northern Nordic waters, a paper published in 2013 reported, where there's no sign they have ever been before.

Of perhaps more popular interest than transplanted diatoms are potentially Arctic-crossing whales. Gray whales persist in the Pacific but went extinct in the Atlantic more than two centuries ago.

In 2010, a marine-mammal monitoring program photographed a gray whale off the coast of Israel. "It was really a huge surprise to everybody," says Elizabeth Alter of York College CUNY in Jamaica, N.Y., a coauthor with McKeon on the new paper. "There was discussion at first of whether the photos might have been photoshopped." (They were not, it turned out.)

In 2013, a monitoring group sighted another gray whale along the coast of Namibia. It seems improbable that gray whales from the northern Pacific had looped down to the Southern Hemisphere to swim around continents and then into the Atlantic, Alter says. She suspects the whales were feeding along the Arctic coastline as they normally do, and without much ice to block their progress, inadvertently hugged the coast all the way to the Atlantic side.

Should gray whales eventually recolonize the Atlantic, McKeon expects that their new neighbors would notice. Unlike similar whales with baleen plates in their mouths, grays gulp whale-sized mouthfuls of soft sea-bottom gunk to savor its hidden crustaceans. In the course of dining, the whales stir up sediment, scattering clouds of invertebrates that other species eat and leaving behind whale-gouges as habitat. It's impossible to know the impacts, but McKeon speculates on what could happen to the blue crabs that bury themselves in the mud at the mouth of the Chesapeake Bay in winter: "I can't imagine anything much better as a snack for a wintering gray whale than sleepy blue crabs."

Melting may also bring new opportunities to another whale species, the bowheads, which live in the Arctic full time. "They can break ice that's 2 feet thick with their heads," Alter says. The Atlantic and Pacific bowhead populations have shared genes over the last several thousand years, Alter's DNA studies show. And in 2010, biologists tracking both populations by satellite found a whale from each population feeding near each other. After about a week, the whales retreated in opposite directions, but left clear evidence that the melting Arctic permits populations from separate oceans to mix.

Also on McKeon's list of possible vanguards of Arctic crossovers is a northern gannet, a plunge-diving, fish-eating seabird that soars over the Atlantic with a wingspan of about 2 meters. "What every gull dreams of being," he says. In 2011, one of these gannets showed up off the coast of Alaska. Possibly the same bird reached the Farallon Islands along northern California. The most plausible explanation, McKeon says, is that the bird had worked its way through some avian northwest passage with open water for fishing along its flight path.

Open water in the Arctic could also move animals indirectly. As summer sea ice shrinks more and more, shipping could boom along Arctic routes. These ships take on ballast water in one place and release the ballast in another, letting animals (smaller than whales) catch a lift, says Jacqueline Grebmeier of the University of Maryland Center for Environmental Science. The prevailing wisdom has been that stowaways wouldn't survive the harsh Arctic, but as the Arctic climate changes, Grebmeier can imagine circumstances now in which ballast creatures might. Whales and charismatic seabirds may be easier to spot when they switch oceans, but ballast stowaways may turn out to be more common. And as important. ■

Meetups and mix-ups

Unusual sightings of birds and mammals (a selection below) suggest that once-blocked populations of animals might already be moving now that enough Arctic ice is melting to allow it. — *Susan Milius*

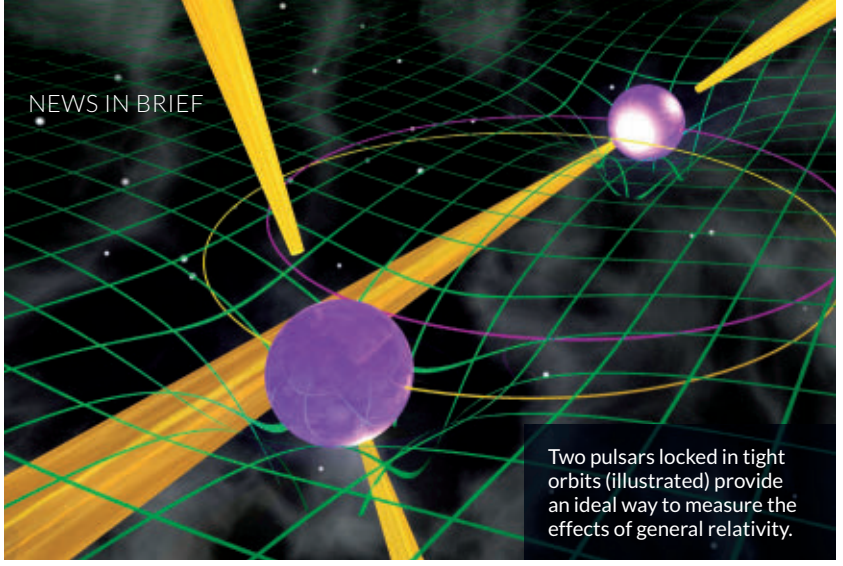
Killer whales Expansion of an Arctic population into Hudson Bay as ice blockades melt allows the whales to prey on beluga whales, narwhals and at least four seal species.

Common eider An Atlantic subspecies was seen in California in 2011; Pacific subspecies were found in Newfoundland and Norway in 2014.

Tufted puffin The North Pacific seabird was seen in England in 2009.

Manx shearwater The North Atlantic seabird may now be breeding in the Pacific.

FROM TOP: ROBERT PITMAN/NOAA; DAVE PARRY/FLICKR (CC BY-NC-SA 2.0); MICHAEL GROSCH/FLICKR (CC BY-NC-SA 2.0); ERNI/SHUTTERSTOCK



Two pulsars locked in tight orbits (illustrated) provide an ideal way to measure the effects of general relativity.

ATOM & COSMOS

Pulsar pair ripples spacetime

GENEVA — A dancing duo of cosmic beacons has provided scientists with the most precise measurement, albeit an indirect one, of ripples in spacetime called gravitational waves.

The measurement comes from analyzing the only known pair of gravitationally bound pulsars, dense cores of dead stars that emit intense beams of radio waves with the regularity of a nearly perfect clock. Michael Kramer, an astrophysicist at the Max Planck Institute for Radio Astronomy in Bonn, Germany, and colleagues precisely tracked the deterioration of the pulsars' orbits, presumably due to loss of energy in the form of gravitational waves. The rate of orbital wane matches perfectly with the predictions of general relativity, Kramer reported December 16 at the Texas Symposium on Relativistic Astrophysics.

The double pulsar system J0737-3039, discovered in 2003, is an astrophysicist's dream. By analyzing the radio beams, researchers can probe the wild things that happen when the small but massive celestial objects circle each other at roughly a million kilometers an hour. Under the rules of general relativity, the pulsars should generate ripples that carry away energy as the pulsars accelerate through spacetime, leading the pulsars to gradually fall toward each other.

Using observations from several telescopes over more than a decade, Kramer and his colleagues determined that the pulsars are approaching each other by 7.152 millimeters a day, give or take a micrometer. That's exactly what theory predicts based on the mass and acceleration of the pulsars.

Though gravitational waves have yet to be detected by observatories on Earth (*SN: 10/17/15, p. 24*), Kramer's work adds to the evidence supporting the waves' existence. The 1993 Nobel Prize in physics went to physicists and who used a binary system with one pulsar to calculate gravitational wave emission. — *Andrew Grant*

ATOM & COSMOS

Equipment failure delays Mars mission

A leaky instrument will push back launch of the Mars InSight lander by at least two years, NASA announced at a news conference December 22. The probe was slated to head to Mars in March 2016 to study the planet's interior and reveal how terrestrial worlds (like Earth) form. InSight beat out other proposed missions, including one to sail a boat on the seas of Saturn's moon Titan.

A faulty seismometer that can't hold its vacuum seal, built by France's national space agency, dashed hopes of an on-time launch. The next launch window is in 2018 due to the position of Earth and Mars in their orbits. — *Andrew Grant*

ATOM & COSMOS

SpaceX rocket sticks its landing

A rocket flying toward the ground is usually a bad sign, but for aerospace company SpaceX, it was a huge success. With engines blazing, the first section of a Falcon 9 rocket returned safely to Earth December 21 after a launch from Cape Canaveral Air Force Station in Florida, landing vertically on a platform just down the road.

The landing is a milestone for the company; earlier attempts to land on a barge at sea didn't go as well. For the latest launch, the rocket stage flew to about 75 kilometers before turning around, leaving the rest of the rocket to deliver a package of satellites into low Earth orbit.

Historically, spent rocket stages have been jettisoned and lost at sea. Reusable stages may greatly reduce costs for future flights. — *Christopher Crockett*

LIFE & EVOLUTION

Farm areas losing their wild bees

Wild bee populations in parts of the United States are declining, largely due to habitat loss in areas with intense farming. That could affect crop pollination and result in higher costs for farmers, researchers report online December 22 in the *Proceedings of the National Academy of Sciences*.

Ecologist Taylor Ricketts of the University of Vermont in Burlington and colleagues found that wild bee populations declined in 23 percent of the contiguous United States from 2008 to 2013. The team also found that 39 percent of farming areas that grow crops such as fruits and nuts that depend on pollinators had low bee abundance. — *Chris Samoray*

Bee map Wild bee abundance in some parts of the United States declined from 2008 to 2013 (relative bee abundance in 2013 shown).

Not getting the sleep you need?
Is your pillow the problem?

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Did you toss and turn all night? Did you wake up with a sore neck, head ache, or was your arm asleep? Do you feel like you need a nap even though you slept for eight hours? Just like you, I would wake up in the morning with all of those problems and I couldn't figure out why. Like many people who have trouble getting a good night's sleep, my lack of sleep was affecting the quality of my life. I wanted to do something about my sleep problems, but nothing that I tried worked.

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Lindell has been featured on numerous talk shows, including *Fox Business News* and *Imus in the Morning*. Lindell and MyPillow have also appeared in feature stories in *The New York Times* and the *Minneapolis Star Tribune*. MyPillow has received the coveted "Q Star Award" for Product Concept of the Year from QVC, and has been selected as the Official Pillow of the National Sleep Foundation.

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HE STRESS, SHE STRESS

Scientists puzzle over why men and women react differently to pressure

By Susan Gaidos

Muscles tighten, the heart pounds and nausea takes hold: In the face of sudden stress, men and women respond alike. But when threats, scares or frustrations continue for days or months, differences between the sexes emerge.

Scientists have long known that women are more likely than men to suffer depression, post-traumatic stress disorder and other anxiety disorders, all of which have been linked to chronic stress, says Temple University psychologist Debra Bangasser. But until recently, studies of people's responses to such stress have focused primarily on men.

Now, a growing number of scientists are studying what happens at the cellular and genetic levels in the brains of stressed-out rodents — male *and* female — to gain insight into the human brain. The studies are beginning to reveal differences between the sexes that may help explain the variability in their reactions and perhaps even provide much-needed insight into why stress-related disorders are more common in women than men.

Recent findings reported at the annual meeting of the Society for Neuroscience, held in Chicago in October, show that a common stress hormone triggers different responses in specific brain cells of male and female animals. The differences make females less able than males to adapt to chronic stress.

Other studies are exploring how exposure to the same hormone influences gene expression in a part of the brain that controls mood and behavior. Still other research suggests that a different hormone, associated with trust, could render females more susceptible than males to depression, anxiety and PTSD.

"Some differences may contribute to disease and some may not," Bangasser says. "But given that it's early days in this understudied area, we're already finding interesting things."

A heightened stress response may bring an evolutionary advantage. An enhanced response to stress hormones could help females — most often caregivers for the young — remain alert and ready to take action in a stressful environment.

The problems occur, Bangasser adds, "when the system is responding when it shouldn't be or when it's responding for a really long time in a way that becomes disruptive."

While no one has managed to tie findings in animals to a specific behavior in people, the studies are an important first step in understanding how sex and hormones contribute to a person's response to stress, she says. Insights from the studies also offer hope for finding ways to better detect and treat stress-related disorders in people of both sexes.

Not the same Stress plays a role in many disorders that occur more often in women than in men, based on studies of U.S. adolescents and adults. SOURCE: D.A. BANGASSER AND R.J. VALENTINO/*FRONT. IN NEUROENDOCRINOL.* 2014

Lifetime prevalence of stress-related disorders, by sex

Disorder	Female (%)	Male (%)
Panic	6.2	3.1
Generalized anxiety	7.1	4.2
Any anxiety disorder	36.4	25.4
PTSD	9.7	3.6
Major depression	20.2	13.2
Any affective disorder	24.4	17.5
Alcohol abuse	7.5	19.6
Drug abuse	4.8	11.6
Migraine	18.2	6.5
Insomnia	12.9	6.2
Irritable bowel syndrome	14.5	7.7

Distress signals

Differences in the male and female nervous system are established early in life. In males, sex hormones are released into the brain before and shortly after birth. Later, at puberty, sex hormones — namely, estrogen and progesterone for females and testosterone for males — exert an influence on the brains of both sexes, signaling cells to turn certain genes on or off.

Fluctuations in sex hormones over a lifetime may influence the body's reaction to stress, for better or worse. To look at that issue, Bangasser's group studies how estrogen, progesterone and testosterone interact with a neuropeptide called corticotropin-releasing factor, or CRF, to influence cell signaling in the brains of stressed-out rodents.

CRF acts as both a hormone and a neurotransmitter. As a hormone, it orchestrates the body's stress response. When rodents — or people, for that matter — feel threatened or experience intense emotion, the brain secretes CRF. CRF molecules then alert the body to a potential threat when they lock on to matching receptor molecules on target cells, initiating a message that travels through the nervous system: Time to pay attention and get all hands on deck.

This arousal response is a normal, instinctive reaction designed to help individuals deal with a threat. But if this system stays on for a long time, it can create a state of constant hyper-readiness (*SN: 3/7/15, p. 18*).

In 2010, while in the laboratory of neurologist Rita Valentino of the University of Pennsylvania, Bangasser and colleagues

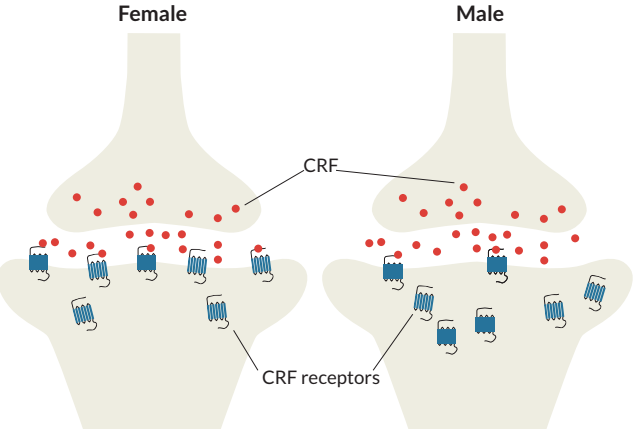
OPPOSITE: CHRIS BUZELLI

found sex differences between CRF receptors in the brains of male and female rodents. The study, published in *Molecular Psychiatry*, showed that after a stressful 15-minute swim, females had more CRF receptors on the surface of target cells, making them very responsive to the stress hormone later on. In male rats exposed to stress, some of the CRF receptors moved from the membrane to the internal part of the nerve cell, or neuron. With fewer CRF receptors on the surface, the male rodents could better cope with similar stress in the future.

Because females don't pull back on the number of exposed CRF receptors following a stressful event, their brains may be more responsive to high levels of CRF, even after repeated exposures to a stressful event, Bangasser says.

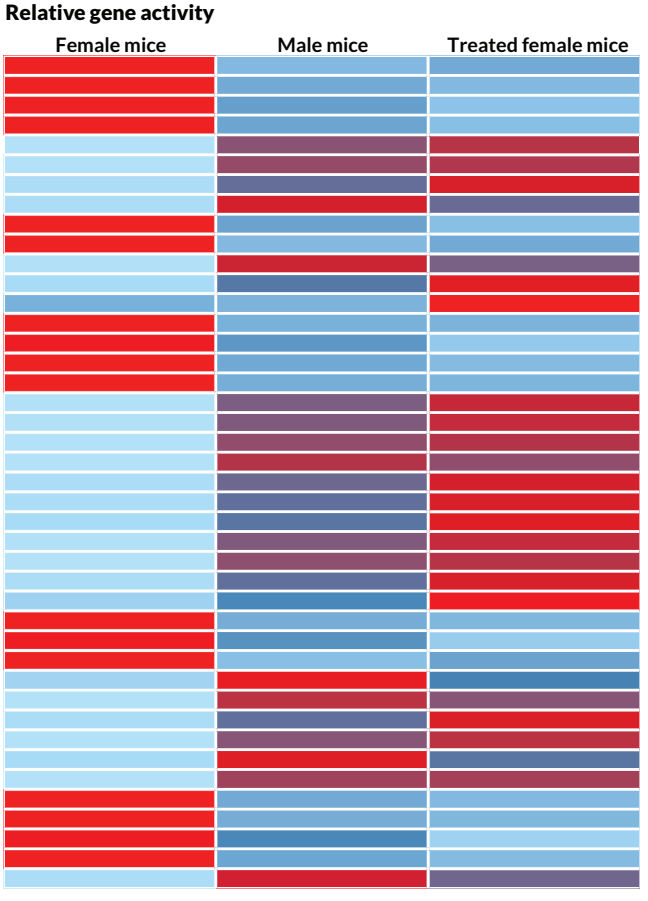
Recently, Bangasser's group found that when administered in high doses, CRF increased anxiety-related grooming in both male and female rats. But female rats groomed longer and more often. Females with the highest levels of estrogen and progesterone groomed obsessively.

Bangasser's group is now mapping the brain circuitry involved. CRF works in several brain regions, including parts of the prefrontal cortex, a brain area linked to attention and planning; the amygdala, an area that controls fear and emotional responses; and the hippocampus, which is essential to forming new memories.



Pulling back After exposure to stress, male rats (right) cut back on the number of receptors on the cell membrane that respond to the stress-related neuropeptide CRF. Female rats do not, and so they don't tamp down their response to CRF. SOURCE: D.A. BANGASSER/*BIOL. SEX DIFFS.* 2013

Brain changes Using a drug to alter epigenetic marks, researchers shifted gene activity in the brains of female mice to more closely resemble male levels. Each bar represents a different gene's activity. Light blue indicates lower relative activity; red is higher activity.



Preliminary findings from her lab suggest that CRF activates these brain networks differently in males and females. Where the female is in her hormonal cycle matters as well. Sex differences in how CRF regulates the brain may explain, in part, why women may be more vulnerable than men to stress-related conditions, Bangasser says.

Environmental influences

Chronic exposure to CRF may also influence gene expression in ways that make women succumb to stress more easily.

When the body's alarm system remains on high alert for long periods, stress hormones can cause modifications to DNA, says neuroscientist Georgia Hodes of the Icahn School of Medicine at Mount Sinai in New York City. These epigenetic modifications can alter gene activity in a way that increases vulnerability to depression and other mood disorders.

Hodes' group found a way to reverse the damaging effects of epigenetic changes in the brains of female rodents. First, Hodes and colleagues transformed a brain structure in a young female rat, giving it malelike attributes, by injecting a drug that altered gene expression. The process, detailed in *Nature Neuroscience* last May, involved drugs that inhibit a family of three enzymes known as DNA methyltransferases, or Dnmts. These enzymes can alter the epigenetic marks on DNA, and thus gene activity, without changing the underlying genetic sequence.

Her team is now investigating how repeated stress alters patterns of DNA methylation — and gene activity — in the nucleus accumbens, located deep in the front part of the brain and involved in mood and behavior. Hodes and her colleagues exposed male and female mice to a variety of scares and frustrations over a period of days. The animals received foot shocks, were restrained in their cages or were briefly

FROM LEFT: B.M. NUGENT *ET AL/NATURE NEUROSCI.* 2015; J. HIRSHFELD

suspended by their tails. Throughout the experiment, researchers looked for behaviors associated with depression.

On day six, the female mice showed depression-like behaviors, which in mice include decreased grooming and fear of eating in a new environment. The mice also lost their taste for rewards such as sugar water and quickly "gave up" when challenged by new frustrations. It took until day 21 before male mice showed depression-like behaviors. The behavioral changes in females corresponded to changes in activity of a specific DNA methyltransferase called Dnmt3a.

The scientists then repeated the experiment, in a mouse genetically engineered to not produce Dnmt3a in the nucleus accumbens. Similar to resilient male mice, stressed females without Dnmt3a engaged in grooming, showed a preference for sugar water and were willing to eat in a novel environment. Findings from the study, published in the Dec. 16 *Journal of Neuroscience*, suggest that the removal of Dnmt3a increased the expression of genes that enabled malelike coping behaviors in the females, Hodes says.

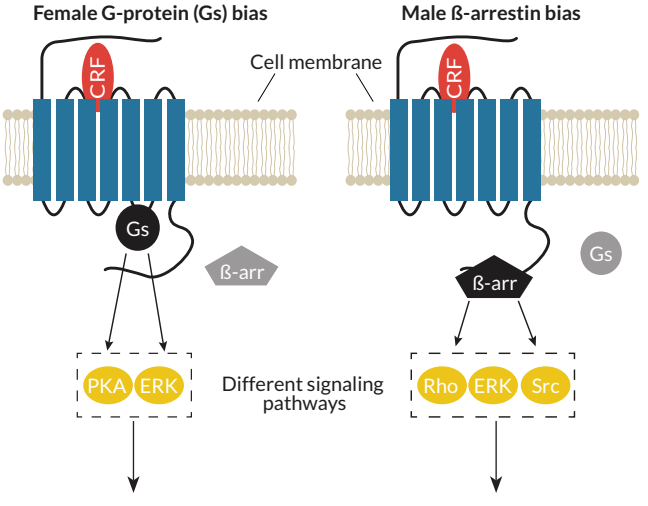
Drugs that inhibit Dnmts are used to treat certain cancers in people, and have shown promise as medications for the treatment of mood disorders. Hodes says the findings suggest that, at least for depression and anxiety, it might be better to develop an inhibitor that just targets Dnmt3a.

"Alternatively, we can now start to examine some of the targets of Dnmt3a such as the CRF pathway and try to focus on developing a therapeutic that would act upon targets within that specific pathway," she says.

A fine line

At the University of California, Davis, psychologist Brian Trainor has found clues to how another hormone contributes to differences in the way males and females handle stress. The results suggest that a hormone important for social bonding may have a dark side.

Sex-biased signaling In females, the CRF stress hormone receptor on the surface of neurons is tightly linked to G proteins, which trigger cellular changes. In males, the CRF receptor responds more readily to a molecule called beta-arrestin, which works like a brake on G-protein activation. This difference makes females sensitive to low levels of CRF. SOURCE: R.J. VALENTINO *ET AL/TRENDS PHARMACOL. SCI.* 2013



J. HIRSHFELD

Oxytocin, known as the warm, fuzzy hormone, has been shown to slow heart rate and promote feelings of well-being. Clinical trials are under way to test the effects of a nose spray containing oxytocin on a variety of conditions, including depression, drug dependence, migraines and pain. But studies in Trainor's lab show that elevated brain levels of oxytocin may stir more anxiety in female mice than in males after stressful experiences.

After being housed with an aggressive mouse for brief periods over three days, male and female mice alike exhibited elevated oxytocin levels in certain brain regions. And for days, both froze in fear when encountering an unfamiliar mouse. Two weeks after clashing with others, males resumed near-normal behavior around unfamiliar mice. But females remained fearful long after the event, avoiding interaction with strangers for 10 weeks. The findings were published online October 19 in *Biological Psychiatry*.

Examinations of brain tissue 10 weeks out show that getting bullied by a stranger increases the total number of both oxytocin-producing neurons and overall oxytocin production in a brain area in females, but not males. This area, the medioventral bed nucleus of the stria terminalis, is a primitive region located near the hypothalamus. Involved in regulating anxiety-like behaviors, this brain area can induce aversion to places or situations linked to stress, Trainor says.

Studies show women with PTSD have elevated oxytocin levels in their blood, Trainor says. "Some have considered this to be a coping mechanism to help them deal with the stress." Not so, he says.

"Our results suggest that an increase in oxytocin-producing neurons in this brain area may be actually contributing to certain behavior changes induced by stress."

In other studies, Trainor's lab is looking at the kappa-opioid cell receptor, which is also activated during stressful encounters. Activated kappa-opioid receptors dampen the body's reactions to stress, but can also depress mood. Compounds that block activity of these receptors have shown promise in humans as treatments for depression, anxiety and other psychiatric conditions, Trainor says, but studies in his lab consistently find differences in the way the sexes respond to these drugs. His group is trying to figure out the mechanisms involved.

To Trainor, the findings all point in the same direction. "It's only a matter of time," he says, before medications for anxiety and depression are formulated differently for men and women to account for biological differences. ■

Explore more

- D. A. Bangasser. "Sex differences in stress-related receptors: 'micro' differences with 'macro' implications for mood and anxiety disorders." *Biology of Sex Differences*. January 21, 2013.

Maternal Input

A mother's weight during pregnancy can shape her child's mental and physical health

By Laura Beil

When Elinor Sullivan was a postdoctoral fellow at Oregon Health & Science University in Portland, she set out to explore the influence of food and exercise habits on obesity. In one experiment, she and her colleagues fed a troop of macaque monkeys regular chow. Other macaques dined American-style, with a hefty 32 percent of calories from fat and ready access to peanut butter treats. Over time, the second group of monkeys grew noticeably fatter.

Then they all had babies.

Sullivan, now at the University of Portland, noticed odd behavior in the plump moms' offspring. At playtime, they often slinked off by themselves. When handled by keepers, the infants tended to vocalize anxiously, and the males became aggressive. They were prone to repetitive habits, like pacing.

In their carefully controlled world, the only difference between those monkeys and others at the facility was their mothers' extra pounds and indulgent diet. The behavior was so striking that Sullivan changed the course of her research.

"It made me start thinking about human children," she says, and the twin epidemics of obesity and behavioral problems such as attention-deficit/hyperactivity disorder. Her research, published in 2010 in the *Journal of Neuroscience*, was one of the first studies to note that the progeny of female monkeys eating a high-fat diet were more likely to experience altered brain development and suffer anxiety. Not long after, researchers worldwide began compiling evidence linking the heaviness of human mothers to mental health in their children. One headline-grabbing study of more than 1,000 births, reported in 2012, found that autism spectrum disorders showed up more often in children of obese mothers than in normal-weight women (*SN: 5/19/12, p. 16*).

Over the course of a generation, obesity rates among U.S. women have soared. Today, 38 percent of females in the population are obese (defined as a body mass index of 30 or higher). Among women of childbearing age, well over half are overweight or obese, with almost 8 percent considered extremely obese (a BMI of 40 or greater). Lucilla Poston, who is head of the division of women's health at King's College London, calls too much weight during pregnancy "the biggest problem in obstetrics at the moment."

Within the body, obesity is not a passive state. Excess weight can inflame the immune system, upset the balance of hormones and even alter the microbial flora tucked inside the intestine. If shared by the fetus, any or all of these changes can affect the baby's development in subtle but important ways. Further complicating matters, the fetus is probably being exposed to the effects of fattening, and perhaps inflammatory, foods.

Only recently have researchers begun to understand what this physiological storm might mean for children. In part, obesity during pregnancy raises the odds that a baby will be born overly large, setting the stage for future health problems (*SN: 5/31/14, p. 22*). But when a mother is excessively overweight, risks persist even for newborns of normal size. One study published in 2013 in the journal *BMJ* analyzed medical records of more than 37,000 people born in Scotland between 1950 and 1976. After accounting for socioeconomic status, gender, weight at birth and many other variables, the researchers found that children born to obese mothers had a 35 percent higher mortality rate from birth to 2012. "Independent of birth weight, a child can grow up with increased blood pressure, obesity and risk of diabetes," Poston says.

The list doesn't stop there. Perhaps most surprisingly, a mom's metabolic state might compromise her child's mental health — the very observation that changed Elinor Sullivan's

ADRIAN825/ISTOCKPHOTO

career. One study published in 2015 even raises the possibility that a child's normal cognitive development might be slightly impaired by mom's high BMI.

If there is a bright spot, it's that unlike many threats during development, this one is preventable. As the risks of obesity during pregnancy emerge, researchers hope more young women on the verge of starting families see the importance of maintaining a healthy life — and that the culture around them will support efforts to do so. "Pregnancy is a good time to talk to people about lifestyle," Poston says, "because they do care deeply about their babies."

More than
1/3
of U.S. women are obese

More than
1/2
of reproductive-age women are obese

More than
8
percent
of reproductive-age women are extremely obese

SOURCE: ACOG

Womb with a clue

Few research questions are easy, but epidemiologists studying maternal obesity face a particularly daunting challenge. They have to separate the effects of a mother's weight from a multitude of other influences on children's health. In the United States, obesity disproportionately affects low income and minority women. Children born in less affluent neighborhoods face obstacles to their well-being: more stress, heightened exposure to pollutants and less access to wholesome foods. Plus, the same food choices and lack of activity that drive a woman's weight gain may also become the lifestyle adopted by her children.

The data become even more difficult to tease apart when examining effects on the mind. Given the correlation of obesity with poverty, children of obese parents also might have educational disadvantages. Case in point: Studies have found that young children in poverty score lower on measures of school readiness, including motor-skill development, emotional health and social knowledge.

That said, the latest studies — many published in recent months — attempt to overcome those biases. And they still find reason for concern. Lisa Bodnar, a nutritional epidemiologist at the University of Pittsburgh, describes a "small but growing literature" suggesting that obesity in a mother is associated with lower cognition and other mental health challenges in children. In 2015 in the *Journal of Nutrition*, Bodnar and her colleagues published a study of women on similar economic footing who were patients at Pittsburgh's Magee Women's Hospital. The majority were unemployed, single mothers. The researchers nonetheless found that children of women who were obese at conception or gained excess weight during pregnancy scored slightly lower on tests of intelligence and executive function, a measure of the ability to plan, organize and adjust to new situations.

Probably the most compelling data link maternal obesity with ADHD, says Sullivan, who continues her primate studies. Whether maternal obesity (or a fattening diet) can actually cause hyperactivity is unclear, but one study of rodents published in *Molecular Psychiatry* in 2012 described results that "point to a direct biological link between in utero exposure to maternal obesity and hyperactivity in the adult offspring." Researchers from England and Sweden fed one group of female mice a high-fat diet that started six months before pregnancy and lasted until weaning, while another group ate regularly. The offspring of the obese mothers scored significantly higher on tests of hyperactivity.

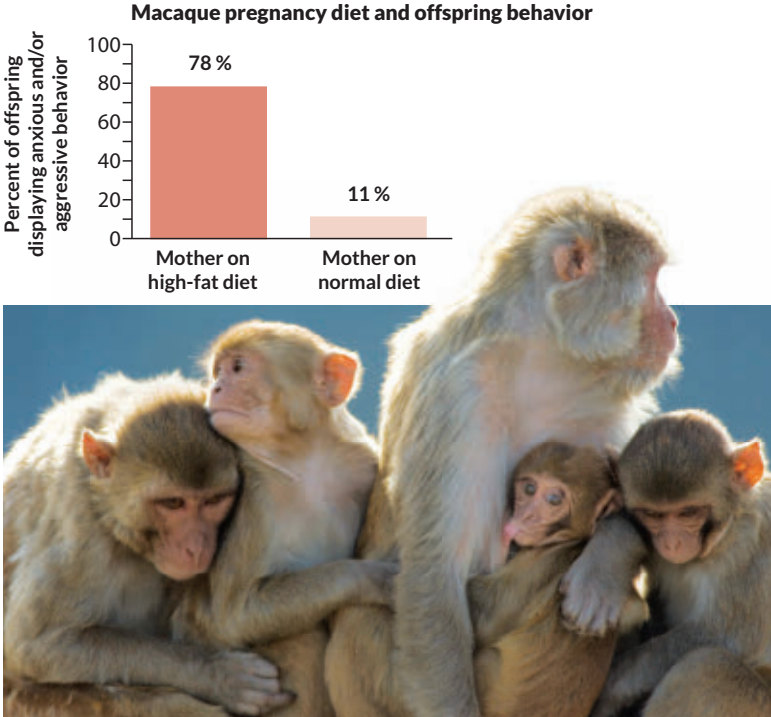
Another animal study, published in 2014 in the *Journal of Neuroinflammation*, found that female offspring of mice fed a high-fat diet had increased anxiety while the males were prone to hyperactivity. The study, from the Mayo Clinic in Rochester, Minn., and Oregon Health & Science University, also opened the door to prevention. When mother rats were given a healthier, less inflammatory diet while nursing, the mental health of the female pups improved, though the males still had issues.

In November 2015, Sullivan and colleagues reviewed the evidence in *Hormones and Behavior*, making the grim prediction that, given persistent rates of obesity and pervasiveness of high-calorie foods, "the prevalence of neurodevelopmental and mental health disorders will continue to rise in future generations." In December, researchers from George Washington University and Mathematica Policy Research announced that 12 percent of U.S. children and adolescents have been diagnosed with ADHD, a 43 percent increase since 2003.

The field is still too new to explain biologically how obesity would impair fetal brain development, but Sullivan

Anxious babes Elinor Sullivan saw behavior differences between macaque infants born to mothers eating a high-fat diet versus those on normal chow. The stark distinctions made her shift her research focus and begin to look at diet and human development.

SOURCE: E.L. SULLIVAN *ET AL/J. NEUROSCI.* 2010



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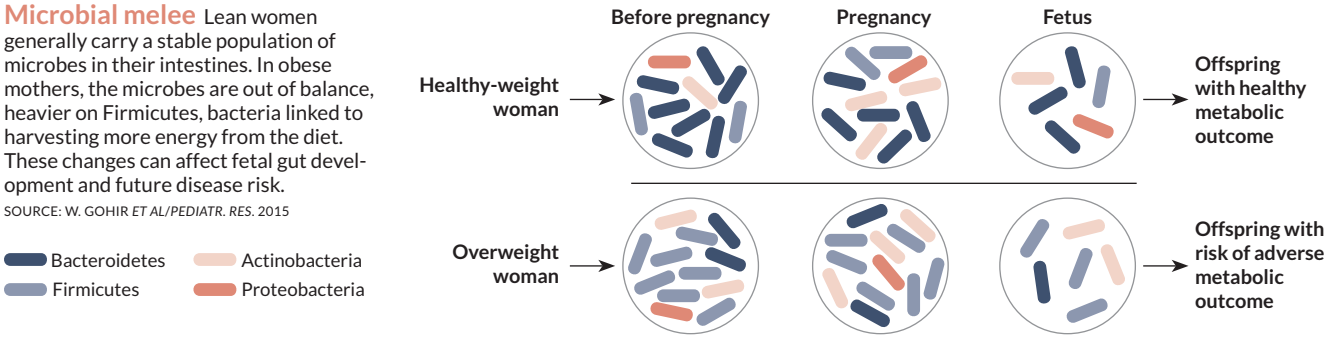


Microbial melee Lean women generally carry a stable population of microbes in their intestines. In obese mothers, the microbes are out of balance, heavier on Firmicutes, bacteria linked to harvesting more energy from the diet. These changes can affect fetal gut development and future disease risk.
SOURCE: W. GOHIR *ET AL/PEDIATR. RES.* 2015

points to theoretical consequences of high glucose or the hormone leptin. Leptin inhibits appetite, but is often elevated in obese individuals and may affect brain development. Most commonly, however, researchers circle back to the effects of an agitated immune system on the brain. "We think of obesity as the state of chronic inflammation," Sullivan says. "Many of the neurotransmitters in the brain are very sensitive [to inflammation] in early development."

Baby buggy

The immune system isn't the only part of body mechanics co-opted by obesity and diet. A compelling line of inquiry has linked the microbiome — specifically the microorganisms inside the digestive system — to body weight. For example, the microbiome of an obese person differs from the microbiome of someone of normal weight. In experiments involving lean mice with no intestinal microbes, transferring the microbiome of an obese person to a thin mouse is enough by itself to make the lean mouse pack on weight.

Since a newborn gets its microbiome from mom, a baby could inherit microbes that want to hoard calories. In both human and animal studies, the microbiomes of offspring born to obese moms are different than in children born to lean moms, says Deborah Sloboda, a fetal physiologist at McMaster University in Hamilton, Ontario. "What we don't know is whether it comes from transfer during pregnancy, transfer during birth or poor developmental environment altering how the gut forms."

The intestine is normally a fortress that does not like microorganisms to escape. Several studies, however, have suggested that when under siege from a fast-food Western diet, the gut lining can become porous (*SN: 5/30/15, p. 18*). Perhaps bacteria slipping into the bloodstream during pregnancy could affect proper formation of the intestine. Other scenarios are also possible: The microbiome transferred during birth could, as it has in animal experiments, predispose a child to a microbiome that extracts more calories from a given amount of food.

In *Pediatric Research* in 2015, Sloboda and colleagues reviewed research on obesity and the maternal microbiome. One theory holds, they noted, that the microbiomes of lean women remain stable during pregnancy; the microbiomes of obese women appear more volatile, experiencing a greater bloom of species associated with obesity. These women's children may then start life with a microbiome inclined toward weight gain.

Provoking problems

Like researchers who study the brain, Sloboda and others suspect that inflammation — which also appears to be a consequence of the microbiome coping with junk food — lies at the heart of many risks conveyed to a developing fetus. "When you consider the spectrum of conditions that have been linked to maternal obesity," says immunologist Ilhem Messaoudi of the University of California, Riverside, "one of the things that links all these diseases is inflammation."

In addition to the irritation that might come from the high-fat, high-sodium, high-calorie fare at the drive-through, adipose tissue itself provokes a mother's immune system. In this state of overactivation, the normal cues for her baby's immune formation might then become lost.

"If you have to develop an immune system in the presence of inflammation, the programming of the immune system is going to change," Messaoudi says. In an experiment published in 2015 in *Pediatric Allergy and Immunology*, she and her colleagues studied 39 pregnant women who were designated as lean, overweight or obese, based on their preconception body mass index, a measurement of body fat. The researchers

A weighty list Although the research is still preliminary, studies are suggesting that a high-fat diet and obesity at conception and during a woman's pregnancy could have lasting influences on her child's mental health. SOURCE: H.M. RIVERA, K.J. CHRISTIANSEN AND E.L. SULLIVAN/*FRONT. NEUROSCI.* 2015

Child's possible mental health risks from mother's obesity

Mom	Child
High prepregnancy BMI	Attention-deficit/hyperactivity disorder
	Autism spectrum disorder
	Anxiety/depression
	Food addiction
	Cognitive impairment
Excessive gestational weight gain	ADHD
	Autism spectrum disorder
Intake of sweets	Food addiction

E. OTWELL

extracted blood samples from the umbilical cords of the women's newborns, and tested the reaction to antigens, molecules that are supposed to trigger an immune reaction.

"The cord blood cells of babies born to obese moms did not respond to bacterial antigens," she says. It was as if the immune system, put to its first real test, was stumped. "If your immune cells don't know how to react, you're going to be sick more often. You may not respond to vaccinations in the way your immune system is supposed to respond."

Those findings may partially explain studies finding that children of obese mothers are more likely to develop disorders that arise from off-kilter immunity. In 2014, researchers who reviewed a dozen studies concluded in the journal *Pediatrics* that babies born to mothers with a high body mass index had a 20 to 30 percent greater risk of asthma and wheezing, though they noted that mechanisms remain unknown.

Rewired appetite

Of all the possible consequences of maternal obesity, the data are most compelling in suggesting that overweight mothers tend to raise children who grow up to be overweight themselves. "It's a very strong effect, and consistent, across all populations," says Bodnar, from Pittsburgh. Chinese researchers writing in 2013 in *PLOS ONE* pooled the analysis of 45 studies examining whether children faced greater odds of being heavy based on mom's size. Although studies have varied and genetics obviously play some role, the scientists concluded that having an obese mother roughly tripled the risk of obesity.

In addition to a woman's weight when she becomes pregnant, excessive weight gain during pregnancy, especially in the first months, is also linked to her child's obesity risk. In one 2012 study comparing more than 6,600 Finnish mothers, those who put on more pounds during the first 20 weeks of gestation (compared with those who gained the least) had children who were 46 percent more likely to be overweight at age 16.

Theories to explain the association are examining how increased glucose and hormonal balance affect fetal development, particularly in the brain. Leptin resistance, which leads to higher secretion of the hormone, can be a consequence of obesity. In the journal *Acta Physiologica* in 2014, Poston and her colleagues from King's College pointed out that many studies have found that the presence of too much leptin can cause collateral damage to the developing hypothalamus, a key interface between the brain and the hormone-producing endocrine system.

Animal studies suggest an altered hypothalamus could mean a child is born with difficulty regulating blood pressure and controlling appetite. "That particular part of the brain may become rewired, and a child may grow up eating more," Poston says.

With little sign that the obesity epidemic is abating, that theory and others are likely to take on increasing importance in medical research. This generation's greatest health threat could leave an unexpected legacy. Scientists working in this field often worry that their research will be seen as solely finding fault with mothers. "I think it's unfair to blame this on women," Bodnar says. Obesity is a global problem. One starting point, she says, is for more doctors to speak with their patients about the importance of weight. Since half of all pregnancies are unplanned, those conversations should happen before a woman gets pregnant. Yet in a U.S. study published in 2014, overweight women of child-bearing age received diet and exercise advice during preventive medicine exams only 36 percent of the time. The number was even lower among pregnant women who were overweight.

At the same time, Bodnar says, this is not going to be fixed in doctors' offices. Women every day are offered cheap, calorie-dense food, pushed by companies with fat marketing budgets (McDonald's alone spends about $900 million a year on advertising). "It's not easy, in this environment, to lose weight," Bodnar says. "We have to agree as a society that this matters." ■

The other half

Let's not forget the father, whose size can alter sperm, perhaps in ways that affect a child's risk of obesity, according to recent studies.

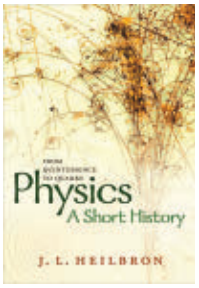
In a study published online in December in *Cell Metabolism*, researchers compared sperm samples from 13 lean and 10 obese Danish men. Scientists from the University of Copenhagen looked for epigenetic differences — the chemical attachment of methyl groups to DNA that affects which genes are turned off or on. The researchers found significant differences depending on the men's size. The obese men had more methylation in genes involved in metabolism and appetite control.

Six of the obese men then underwent gastric bypass surgery and lost weight. A year later, their sperm had lost many of the epigenetic changes linked to obesity and appetite. The researchers caution, however, that the extent to which epigenetic changes affect a child's appetite isn't known.

Other studies also suggest that overweight dads can harm a baby's development. In September, a team of Australian researchers reported on a mouse experiment that found the offspring of two obese parents fared worse than if either parent alone was obese. The scientists found lower weights in the placenta and fetus, as well as cellular differences (such as impaired mitochondrial function) in the offspring of two obese mice. That study appeared in the *American Journal of Physiology — Endocrinology and Metabolism*. — *Laura Beil*

Explore more

- Elinor L. Sullivan *et al*. "Maternal high-fat diet programming of the neuroendocrine system and behavior." *Hormones and Behavior*. November 2015.



Physics
J.L. Heilbron
OXFORD UNIV., $18.95

BOOKSHELF

A brief history of the evolution of physics

Modern physicists like to compare themselves to the ancient Greeks — searchers for knowledge about the ultimate foundations of reality. But science historian John Heilbron argues in his latest book, *Physics*, that modern physics is not much like the Greeks' contemplation of nature.

"In antiquity, physics was philosophy, a liberal art, the pursuit of a free man wealthy enough to do what he wished," Heilbron writes. In Greek philosophy, "physics ... inquired into the principles regulating the physical world from the high heavens to the Earth's center, and from the human soul to the life of the least of living creatures." It was about defining man's place in nature, for the purpose of identifying "the ethical consequences of ... the way the world began and persists."

Few modern physicists would conceive of their quest in quite that way. And the Greeks did not pursue their quest with the methods that modern physicists employ, bothering little with experiments and only occasionally with math.

So Heilbron refers to premodern physicists as *physici* who practiced *physica*, and proceeds to tell the story of how the *physica* of the ancients became modern physics. In an engaging 200 pages, he documents the step-by-step transformation of the philosophy of the past into the science of the present.

Heilbron's deep insight into the workings of scientific minds and the mechanisms of history informs every sentence of this concise but rich volume. Apart from a slight confusion on whether the modern idea of quintessence refers to dark matter or dark energy, it's also a model of scientific as well as historiographic rigor.

His story begins with Greek science, which was initially multifaceted but ended up dominated by Aristotle, whose science was revitalized by Arabic translators after the ascent of Islam. Islamic scientists went on to develop science of their own that, along with Arabic translations from Greek, invigorated the intellectual revival in Western Europe during the Middle Ages. A new institution, the university, provided impetus for exploring the natural world more deeply — mostly by theologians seeking insight into religious issues. Ultimately modern science emerged from the works and writings of Copernicus, Francis Bacon and Galileo, leading to the triumph of Newton's laws of nature and his principles of natural philosophy.

But even then, modern physics had not yet fully formed. In the 18th century, the modern approach began to congeal around studies of electricity. By the end of the 19th century, the resulting classical physics had matured, only to be deposed in the 20th by the dual revolutions of relativity and quantum mechanics. And then came the consortium of university, government and military/industrial endeavors that emerged from 20th century physics, shaping a present-day physics much different from the Greeks' *physica*. Nevertheless, Heilbron notes, physicists today are "pursuing modern versions of Greek speculations." — *Tom Siegfried*

TO DO

Human Evolution gallery
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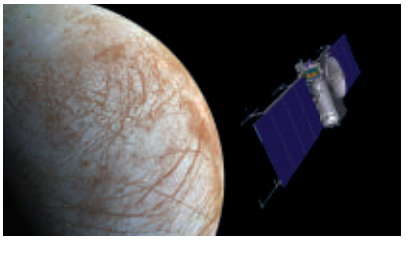
This new, permanent display marches through 7 million years of hominid history; highlights include a 3.5-million-year-old tooth from Tanzania, a Neandertal skull and the world's oldest known wooden spear.
NATURAL HISTORY MUSEUM IN LONDON

Stratospheric Balloons Over Antarctica
FEBRUARY 2
In this free public lecture, a physicist will explain how he uses giant helium-filled balloons to hunt for cosmic rays.
ST. LOUIS ZOO

The von Kármán Lecture Series: The Europa Mission
FEBRUARY 11 AND 12
Two NASA scientists will discuss a planned mission to Jupiter's moon Europa (right) that will investigate whether the icy orb's subterranean ocean could host life (*SN: 5/17/14, p. 20*).
JET PROPULSION LABORATORY, PASADENA, CALIF.; PASADENA CITY COLLEGE

Family Science Days
FEBRUARY 13 AND 14
Meet an astronaut, play with hands-on exhibits and see a quiz show at this free event.
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE ANNUAL MEETING, WASHINGTON, D.C.

Animals: Machines in Motion
OPENS FEBRUARY 14
This interactive exhibit explores a range of organisms' adaptations and looks at how engineers mine the natural world for inspiration.
MUSEUM OF SCIENCE IN BOSTON



FROM LEFT: © THE TRUSTEES OF THE NATURAL HISTORY MUSEUM, LONDON; JPL-CALTECH/NASA

Origins: The Scientific Story of Creation
Jim Baggott
OXFORD UNIV., $34.95

BOOKSHELF

Origins offers science-based account of creation

Throughout history, every culture has woven its own tale of creation, addressing deeply philosophical questions ranging from what the universe is made of to where humans came from. Now, by tapping into the latest findings from quantum physics, biochemistry, evolutionary biology and other fields, science writer Jim Baggott has compiled a science-based Genesis for the 21st century.

It's an ambitious task to chronicle everything from the Big Bang to the evolution of human consciousness in one small book. But Baggott delivers a wonderfully detailed yet eminently readable account in *Origins*.

Creation, of course, is a tale best told in chronological order. The book's first six chapters are packed with cosmology, from the dawn of the universe some 13.8 billion years ago to the birth of our solar system. The universe's "let there be light" moment arrived an estimated 380,000 years after the Big Bang. That's when the light-blocking fog of charged subatomic particles generated in the universe's first few moments finally cooled enough for neutral hydrogen and helium atoms to form, thus rendering the universe transparent to photons long trapped in limbo.

Later chapters detail the evolution of Earth and life on it, from the development of primitive cells by at least 3.8 billion years ago to the subsequent appearance of multicellular blobs that, given hundreds of millions of years, yielded creatures intelligent enough to ponder their own existence and seek answers dispassionately about the world around them.

Baggott clearly lays out areas where scientists still haven't come up with solid answers — including what the conditions were like during the first one-trillionth of a second after the Big Bang and how prebiotic chemicals on the ancient Earth gave rise to living cells. Despite these gaps, which researchers strive to fill using the scientific tools at their disposal, *Origins* is a compelling tale of creation. — *Sid Perkins*

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75 years of young scientists

In March 2016, the Society will celebrate the 75th anniversary of the Science Talent Search. Alumni of this prestigious competition have achieved many accomplishments, including a few profiled below:

BEN MOTTELSON
1944 FINALIST

After becoming a finalist at STS 1944 (then sponsored by Westinghouse), Ben Mottelson went on to win the 1975 Nobel Prize in physics for his work on the shape and structure of atomic nuclei. He is one of a dozen STS alumni who have been honored with the Nobel Prize.

CECILIA LO
1971 FINALIST

For Cecilia Lo, STS 1971 was just the beginning of a successful career in science. She went on to study at MIT and Rockefeller University. In 2009, she joined the University of Pittsburgh School of Medicine as the F. Sargent Cheever Chair. Her research focus is on heart and kidney diseases.

CHETAN NAYAK
1988 FINALIST

Chetan Nayak won the top prize at STS 1988 for his analysis of gravitational and electromagnetic fields. With degrees from Harvard and Princeton universities, he became a professor at the University of California, Santa Barbara. His research focus is condensed matter physics, particularly the organization of electrons.

NOAH GOLOWICH
2015 FINALIST

After STS 2015, Noah Golowich was awarded a $50,000 Davidson Fellows Scholarship for developing a proof in Ramsey theory, a field of mathematics based on finding patterns in large and complex systems. He now attends Harvard University and plans to study mathematics or computer science.

Read more about our alumni on our *Doing Science* blog at **student.societyforscience.org/doing-science**

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NOVEMBER 14, 2015

NOVEMBER 28, 2015

SOCIAL MEDIA

Hood head

A breathing hood helped test whether clothes protected an engineer's skin from absorbing phthalates from the air, as described in **Janet Raloff's** story "Skin soaks up toxic air pollutants" (*SN: 11/14/15, p. 10*). But the apparatus triggered a cloud of jokes and alternate captions on Facebook.

Dispatches from the ultrasecret underground labs at Head & Shoulders.
Rob Faulkner

When hypochondriacs relax in front of the computer.
Terry Shannon

Nose itches, but phthalates will kill me. Decisions.
Casey Larsen

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Molecule mystery

*The Rosetta spacecraft discovered oxygen leaking from comet 67P, **Christopher Crockett** reported in "Oxygen in comet surprises scientists" (SN: 11/28/15, p. 6). The molecules' presence supports a long-held belief that comets are pristine relics of the solar system's birth.*

Reader **R. Powell** questioned that assumption. The story notes "that the pristine oxygen is released from the [comet's] water-ice when the sun's heat sublimes the ice," he wrote in an e-mail. "How is it known that the oxygen was not created by [ultraviolet] light breaking down the water into oxygen and hydrogen?" If the latter is true, Powell said, the oxygen may not be primordial.

The researchers spent a lot of time on this very question, **Crockett** says. Water can generate oxygen in a couple of ways: either through exposure to UV light or bombardment with electrons and ions. Comet 67P spent billions of years in the Kuiper belt beyond Neptune, where a rain of charged particles could have created oxygen. But such rain only penetrates a few meters below a comet's surface, the researchers say, and a comet loses several meters of its surface after every close encounter with the sun. So any oxygen that 67P built up while hanging out in the Kuiper belt is long gone.

Solar wind can also break apart water molecules, but it can't keep up with the rate at which a comet sheds its skin. If wind was the primary source of 67P's oxygen, the ratio between oxygen and water on the comet's surface would decrease as the comet approached the sun. But the ratio has stayed relatively constant, **Crockett** says. That relative stability over a period of several months suggests that the oxygen is coming from a deep reservoir within the comet, which would have been buried 4.6 billion years ago.

Boring billions

*About 1.8 billion years ago, Earth's planetary processes seemingly stalled during a low-oxygen period, **Thomas Sumner** wrote in "Earth's (not so boring) boring billion" (SN: 11/14/15, p. 18). But new chemical clues hint that the planet's midlife was anything but monotonous.*

Reader **Steve Schlosser** wanted to know what caused oxygen levels to take such a roller coaster ride after the stagnant boring billion. "If the burst of oxygen levels to well above today's levels occurred after this period, what caused the levels to drop to those we know today?" he asked in an e-mail.

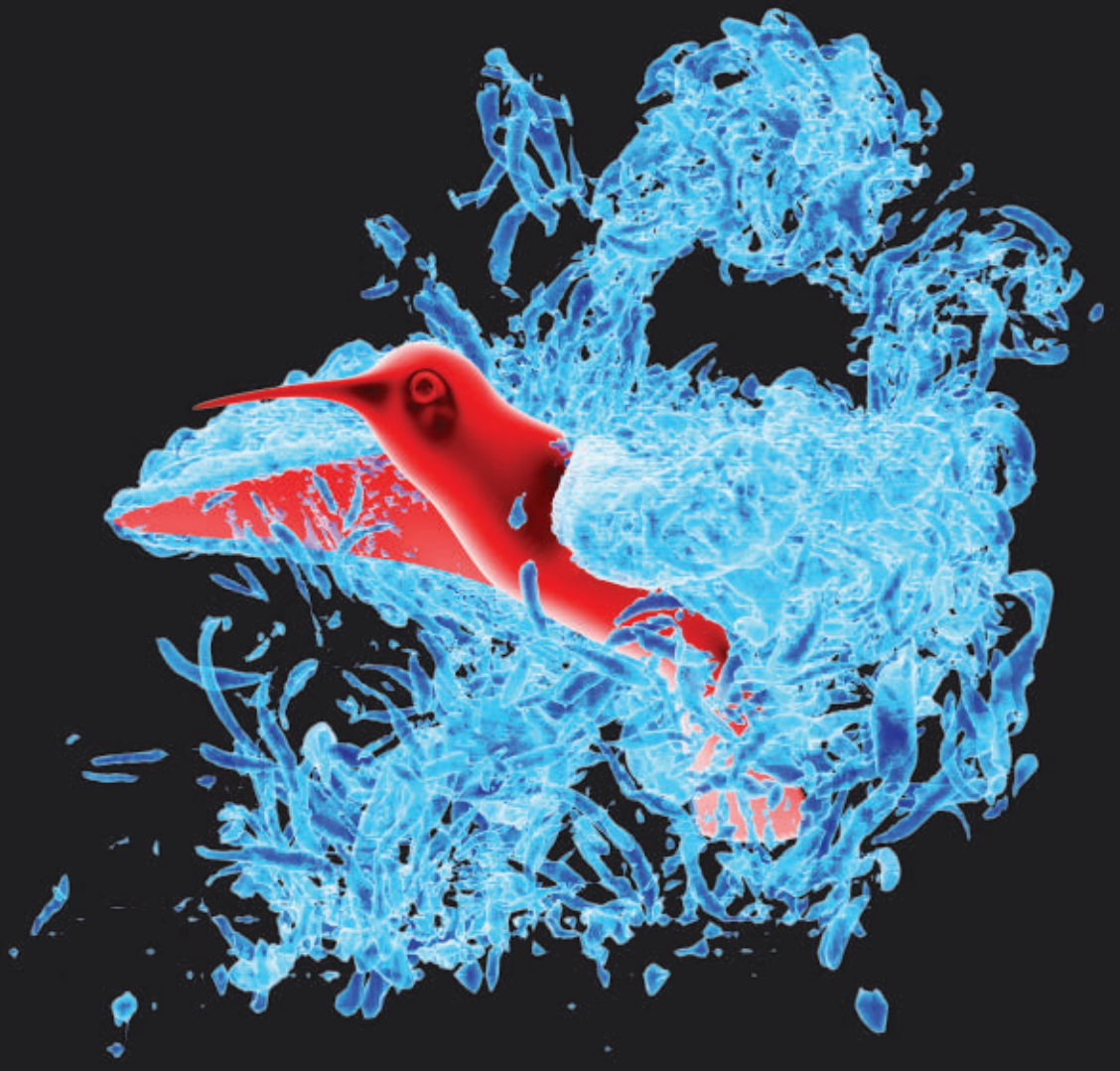
Oxygen levels are largely controlled by photosynthesis but they are also influenced by decomposition, **Sumner** says. Generally, the more plants and photosynthesizing microbes, the more oxygen there is. A few hundred million years ago, for example, Earth was a lot warmer than today with an abundance of oxygen-producing plants. When these plants died, much of that organic matter ended up buried in swamps, stalling decay that would have actually drawn down oxygen. So oxygen levels rose until the climate cooled. But, **Sumner** notes, these more recent ups and downs in oxygen concentration are pretty minor compared with the large-scale changes earlier in Earth's history. For comparison, during the boring billion oxygen levels were less than a hundredth of what they are now.

As for the greater mystery of oxygen stagnation during the boring billion, no one actually knows why the levels stayed low and stable for so long, **Sumner** says. Scientists have kicked around a few ideas, but none have gained wide acceptance yet. The new excitement and focus on that era will hopefully lead to an answer, he says.

Correction

Reader **Ann Harmer** enlightened us about a recent cover image, which we described as a "plasticized" brain (*SN: 11/14/15, p. 1*). "The process by which the beautiful vascular specimen of the human brain was produced is plastination," she wrote in an e-mail. "Therefore, the brain was plastinated, not plasticized (a common error). The process was invented by Dr. Gunther von Hagens and patented in 1978."

G.C. MORRISON *ET AL/JOURNAL OF EXPOSURE SCIENCE AND ENVIRONMENTAL EPIDEMIOLOGY* 2015



YAN REN, HAIBO DONG, XINYAN DENG, B. TOBALSKE (CC BY-NC 4.0)

Capturing the wonders of hummingbird flight

Hummingbirds are extreme athletes, deftly hovering and darting between flowers. Now a combination of high-speed filming and computer simulations reveals how the birds' wings manipulate the surrounding air to aid in flight. The images seen here come from a video of simulated flight that won an American Physical Society Gallery of Fluid Motion award in November.

Above, small pockets of air swirl in tornado-like vortices as a hummingbird turns to its right. Researchers have known that the bird's wings induce lift by generating what are called leading-edge vortices (represented as thick blue layers around the wing edges). But the air movement is even more complex, the simulations reveal. The sequence of images at right, which display only the largest vortices, shows how a bird in flight spawns an array of helpful swirls near different parts of the wings. Blue pockets of air are circulating in the opposite direction of red pockets.

These vivid depictions of hummingbird flight incorporate data from the lab of University of Montana biologist Bret Tobalske, who films the birds with cameras shooting at 1,000 frames a second. The simulations help Tobalske dissect how the birds use leading-edge vortices in flight, a tactic that has also been mastered by insects and the seed capsules of trees. Other researchers hope to create flying robots that mimic this approach. *—Andrew Grant*

Watch the video at **bit.ly/SN_fluidmotion**

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