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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
JULY 21, 2018

Lack of Sleep Linked to Alzheimer's

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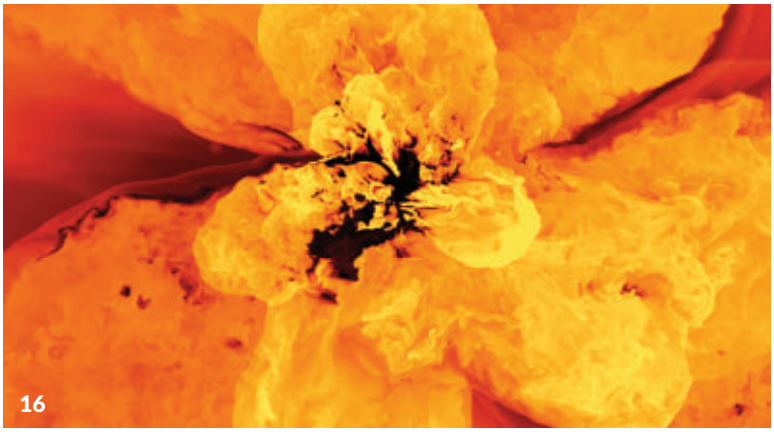
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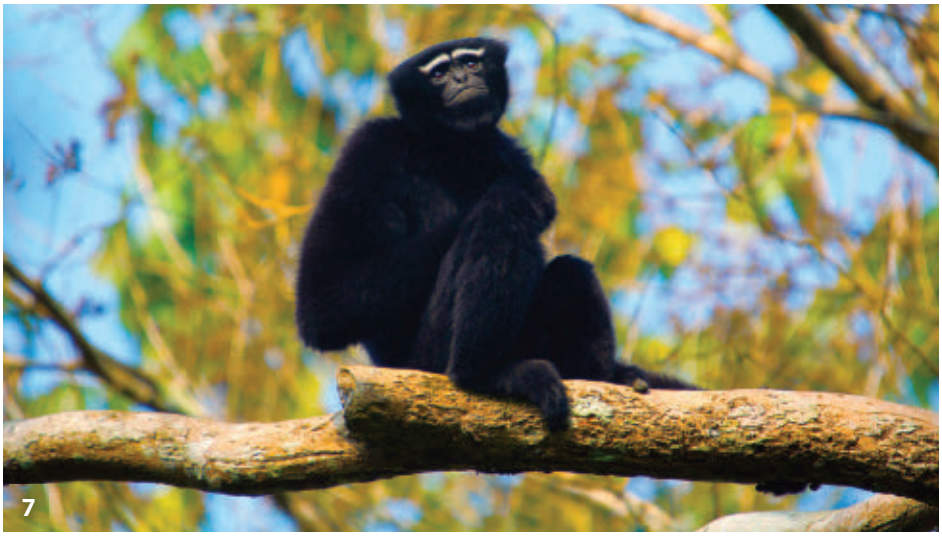
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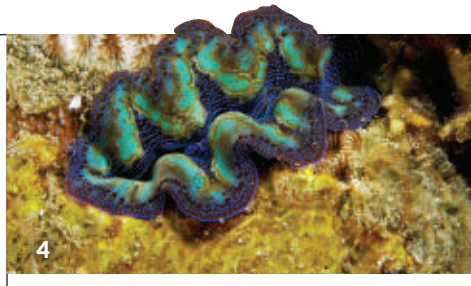
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SOCIETY UPDATE
The latest headlines from *Science News for Students*

COVER Gas flows out from M82, the Cigar galaxy, to its invisible circumgalactic medium in this Hubble image. *NASA, ESA, Hubble Heritage Team*

FROM TOP: M.S. PEEPLES ET AL/FOGGIE PROJECT; NHOBGOOD/WIKIMEDIA COMMONS (CC BY-SA 3.0); REALITYIMAGES/SHUTTERSTOCK

In research, detours are a key part of discovery

For more than a century, scientists have known that abnormal clumps and tangles in the brain are the hallmarks of Alzheimer's disease. But identifying the cause of that devastating damage has proven elusive, hampering efforts to come up with a cure for an affliction that robs memory from millions of people worldwide.

But what if those clumps and tangles accumulated because the brain's garbage disposal went on the fritz? And what if a lack of sleep played some role in the breakdown of the trash-removal process?

Over the last decade, neuroscientists have been testing this provocative thesis, largely in mice. In this issue (see Page 22), contributor Laura Beil explains the thinking behind this theory, and why the idea that Alzheimer's is a problem in the brain's cleanup system is drawing such interest.

Testing the idea in humans, not surprisingly, is a lot more complicated. Answers don't come easily. Some studies have shown more amyloid-beta plaques in the brains of people who sleep badly, while other studies have shown no such association.

And it's hardly the only theory being tested on the cause of Alzheimer's. In another story in this issue, our intern Leah Rosenbaum explains how other researchers stumbled upon a correlation between herpesvirus infection and Alzheimer's disease while searching for treatment targets. Perhaps, as we report on Page 10, amyloid-beta forms plaques to trap pathogens like herpesvirus, in an effort to protect the brain.

That's all very interesting, but plenty of questions about Alzheimer's disease remain unanswered, including a couple of chicken-and-egg doozies: Does the lack of sleep cause the brain damage, or does the brain damage cause the lack of sleep? Does herpesvirus boost Alzheimer's risk or does Alzheimer's somehow reactivate herpesvirus, which can sit quiet in the body for years after an infection? And since most adults have been exposed to herpesvirus, why would only some people get Alzheimer's?

The new findings, false leads and dead ends inherent in scientific research can lead the public to get annoyed with scientists, and with science journalists. Why, readers wonder, do you people keep changing your minds? But stories of these contradictory findings and the tantalizing possibilities they raise just remind us how the process of scientific discovery works — and how science journalism lets us dive into the midst of it.

And sometimes the digressions of the scientific process can be delightful, as in life sciences writer Susan Milius' report on the evolving explanations for a giant clam's ability to bore its way into a coral reef (Page 4). It turns out the clam's skill set hasn't changed; it's science's approach to investigating the clam's "boring organ" that has. And yes, it's really called that.

With Alzheimer's, odds are that the solution won't turn out to be as simple as getting a good night's rest or avoiding a ubiquitous virus. But wouldn't it be wonderful if sleep turned out to be a balm of hurt minds in more ways than we have so far imagined. — *Nancy Shute, Editor in Chief*

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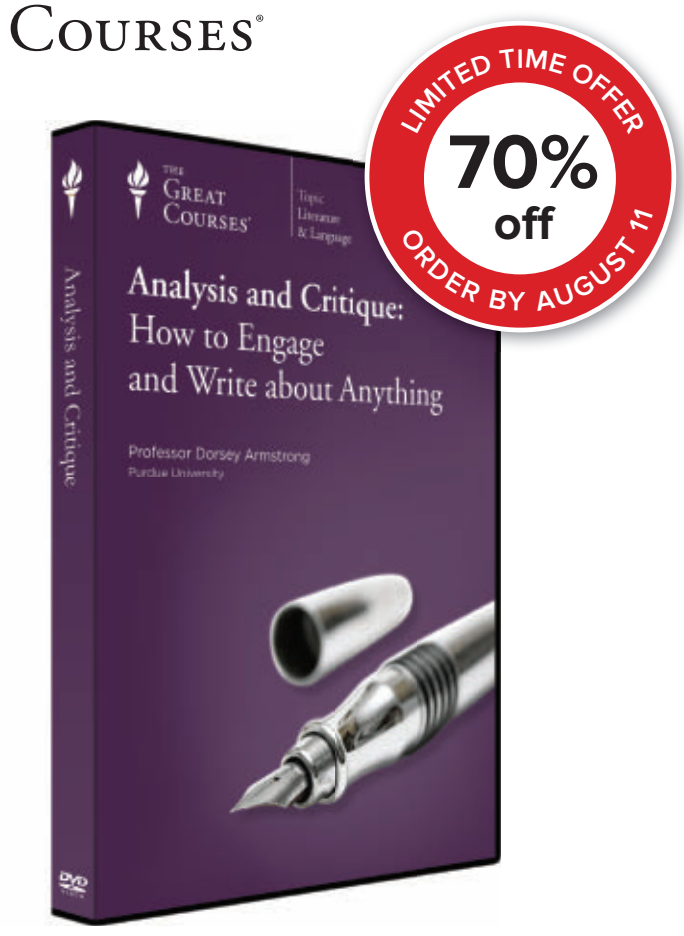

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Excerpt from the July 20, 1968 issue of *Science News*

50 YEARS AGO

Tracking the neutrino

The definite detection of nonterrestrial neutrinos, whether from the sun or from beyond the solar system, will yield a far deeper understanding of stellar interiors and, therefore, of how today's universe came to be.

UPDATE: In May 1968, researchers reported that a particle detector in South Dakota spotted ghostly subatomic particles called neutrinos from the sun, but only about a third as many as theories predicted. The shortage vexed physicists for decades, until the 2001 discovery that many of the sun's electron neutrinos — the only kind the South Dakota detector was designed to find — switch flavors on their way to Earth, becoming muon and tau neutrinos (*SN: 6/23/01, p. 388*). That switch accounted for the sun's missing neutrinos. Detectors have also glimpsed neutrinos spawned by supernova 1987A (*SN: 3/7/87, p. 148*) and maybe even supermassive black holes (*SN: 2/17/18, p. 8*).

Showy blue-and-green frills are the only visible parts of a giant clam that traps itself for life inside the rocky mass of a reef, using chemistry to make room.

IT'S ALIVE

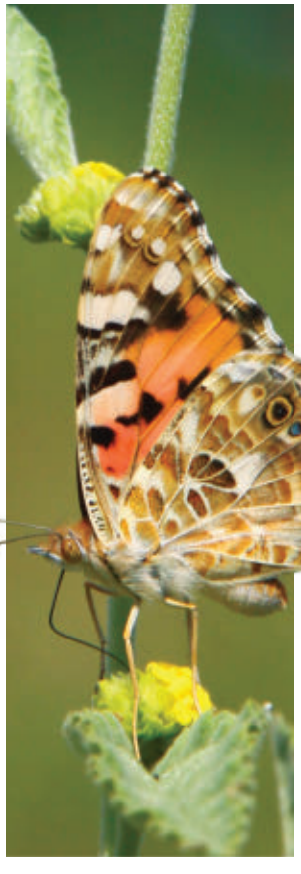
How a squishy clam conquers a rock

Burrowing giant clams have perfected the ship-in-a-bottle trick, and the one big thing that scientists convinced themselves couldn't explain it, actually can.

Tridacna crocea, the smallest of the 10 or so giant clam species, grows a shell that eventually reaches the size of a large fist. Starting as youngsters in tiny shells, the burrowers bore into the stony mass of an Indo-Pacific coral reef, trapping themselves behind a too-skinny exit for their decades-long lives.

Only the extravagantly colored upper edges of the clam's body can peek out of the thin slit in the reef. These protruding frills teem with algae related to those in corals. Basking in sunlight, the algae pay rent in the form of a substantial portion of a giant clam's nourishment.

The clams "actually have eyes in this



THE –EST

Painted ladies go the distance

Move over, monarchs. The painted lady butterfly (*Vanessa cardui*) now boasts the farthest known butterfly migration.

Though found across the world, the orange-and-brown beauties that live in Southern Europe migrate into Africa each fall, crossing the Sahara on their journey (*SN Online: 10/12/16*). But what happened after was a mystery. Researchers hypothesized that the insects either remained in Africa or made a round trip, but there was no evidence either way.

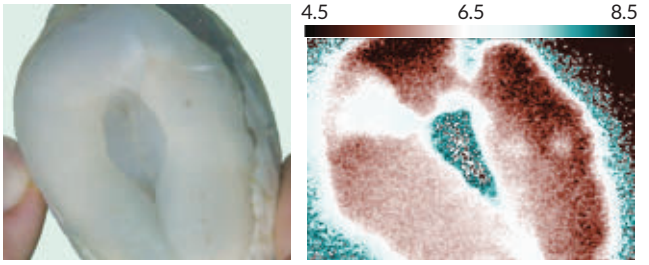
A new chemical analysis of butterfly wings suggests that the butterflies head back to Europe in the spring. The round trip, which usually plays out over several generations, is an annual journey of about 12,000 kilometers. That's 2,000 kilometers or so farther than successive generations of monarchs are known to travel in a year (*SN: 4/14/18, p. 22*).

Researchers were surprised when they detected chemical markers from Africa on some European painted ladies' wings. Those markers indicated where an individual had eaten when it was still a caterpillar. The results, reported in the June *Biology Letters*, provide evidence that the butterflies return from Africa each year. Some tenacious individuals even make the return trip in a single lifetime. — *Leah Rosenbaum*

tissue," says environmental physiologist Richard Hill of Michigan State University in East Lansing. At the slightest shadow — a predator, perhaps — the mollusk yanks in those vulnerable parts through the very narrow crack. "It's as if the clam vanished," he says.

The colors the clam creates on this extendable tissue approach the psychedelic and can bewitch aquarium hobbyists into paying three-figure sums. "The ones that get the big money are turquoise," Hill says, but he's seen indigo blue as well as yellow, crimson and even a boring brown.

The opposite rim of the clam body, hidden deep inside the coral crevice, looks anything but colorful. Through a hole near the shell hinge, a soft cream-colored mass called (quite unfairly) the "boring organ," emerges. This tissue spreads upward, surrounding the outside of the shell. The embrace puts the tissue in touch with the cave wall that the clam must erode as it grows.



Acid kiss
A giant clam's soft, pale boring organ (shown at left) uses acid to carve its cave in coral. A flat pH indicator picked up the lip-shaped acid signature (red zones at right).

A leading mollusk biologist of the 20th century, Sir Charles Maurice Yonge, proposed that boring organs gradually dissolve the rock by secreting acid. Yet he shot down his own theory (and fretted about it through the rest of his life) by adding a pH indicator to the clam's seawater. There was no sign of a surge in acidity.

Hill decided to reexamine the mystery. After some epic bouts of Googling the options for testing pH in a liquid, he suddenly wondered if direct clam contact mattered. He found a device measuring pH at lots of points across a flat piece of foil that a clam, he hoped, could be persuaded to press its boring organ against.

The project required a trip to Japan plus world-class mollusk management to coax clams to touch organs to foil in the desired way. When they did, the detector revealed red blotches of acidity, like lipstick smudges on a napkin.

The clams may not be able to bring down the pH of alkaline seawater, but they can acidify a surface, Hill and his colleagues report in the June *Biology Letters*. Turns out that this organ is boring in the very best sense of the word. — *Susan Milius*

FOR DAILY USE

Don't get burned by these plants

Another warning to add to the summertime list: Check for ticks, go inside during lightning ... and hands off the giant hogweed. Getting the plant's sap on the skin, along with exposure to sunlight, can lead to severe burns.

All good advice, but the invasive plant (*Heracleum mantegazzianum*), which looks like Queen Anne's lace on steroids and was recently spotted for the first time in Virginia, isn't the only vegetation that contains the burn-causing chemical compounds.

Furocoumarins can be found in the fruit and vegetable bins of most refrigerators. Lime, lemon, parsnip, fennel and dill are some of the other plants that have the chemicals. Furocoumarins make the skin more prone to sunburn. It takes 30 to 120 minutes for the skin to absorb the chemicals from a plant's juice or sap. With sun exposure, ultraviolet A radiation activates the furocoumarins, which then bind to and damage DNA. Cells with the damaged DNA die, leaving behind a burn. The condition is called phytophotodermatitis. (The popular summertime combo of Mexican beer with lime has led to another moniker: Mexican beer dermatitis.)

Pediatric dermatologist Robin Gehris of the Children's Hospital of Pittsburgh sees phytophotodermatitis "at least once a week" in her practice during the summer, most commonly from limes and lemons, she says. The reaction happens only where juice or sap touches the skin; a dribble of juice will leave a streaky mark. A hand covered in lime juice could leave its likeness on a leg. "Often, the pattern is one of the things that keys us in" to a diagnosis, Gehris says. How bad the burn is depends on how much juice or sap and how much sun; a lot could lead to blistering. The best prevention? Rinse juice-covered hands and plant-touching explorers. — *Aimee Cunningham*

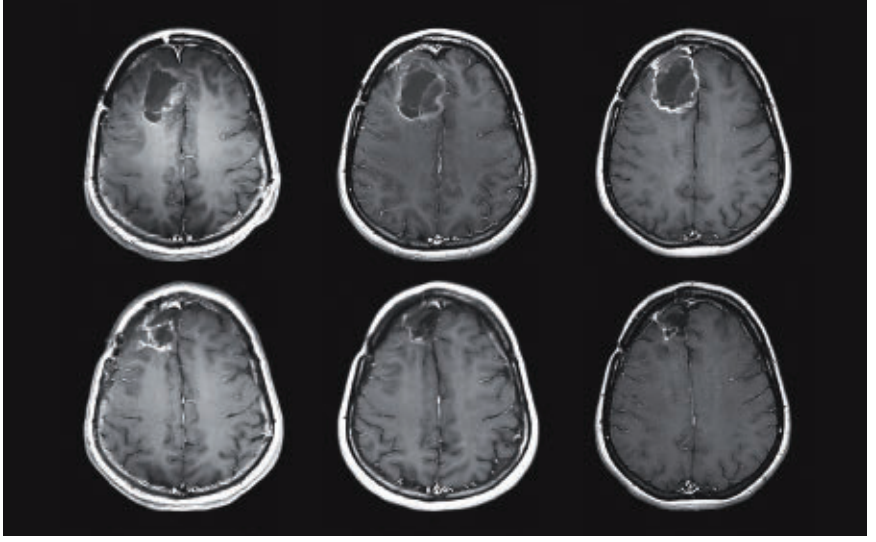
Giant hogweed (top) is one of many plants that contain chemical compounds that can burn skin when activated by sunlight. The thigh of a 13-year-old girl who had been squeezing lemons into her family's drinks at the beach reveals burns corresponding to the shape of her hand.

FROM TOP: R. HILL *ET AL/BIOLOGY LETTERS* 2018; SALICYNA/WIKIMEDIA COMMONS (CC BY-SA 4.0); J.F. MOREAU, J.C. ENGLISH III AND R.P. GEHRIS/*JOURNAL OF PEDIATRIC AND ADOLESCENT GYNECOLOGY* 2014

BODY & BRAIN

Poliovirus helps fight brain cancer

Treatment increased survival in some glioblastoma patients



A patient's glioblastoma tumor (upper left on MRI scans) shrank after a dose with a modified poliovirus. The bottom right image shows the tumor nearly five years after treatment.

BY AIMEE CUNNINGHAM

Few treatment options are available for people facing a second battle with a particularly fatal type of brain tumor called glioblastoma. But dosing the tumor with a genetically modified poliovirus — one that doesn't cause the eponymous, devastating disease — may give these patients more time, a small clinical study suggests.

Of 61 people with recurring glioblastoma who were treated with the modified virus, 21 percent were alive after three years. In a "historical" comparison group of 104 patients who would have been eligible for the treatment but died before it was available, 4 percent lived as long, researchers report online June 26 in the *New England Journal of Medicine*.

Two patients who received the altered virus are still alive six years after treatment. "They've been able to lead largely normal lives, and we almost never see that with these brain tumors," says neuro-oncologist Darell Bigner of Duke University Medical Center.

Standard treatment for glioblastoma is surgery, radiation and chemotherapy, Bigner says. Usually patients do not survive longer than 20 months after being diagnosed; those with a recurrence typically live less than a year.

Poliovirus, which can cause paralysis and death, infects nerve cells by connecting with a cell surface protein that also appears on tumor cells. In previous work, the Duke research team swapped out the genetic machinery that lets the virus commandeer and destroy nerve cells with a piece of a virus that causes the common cold. This change didn't prevent the poliovirus from killing tumor cells. And the treatment triggered the immune system to target the cancer.

In the new study, the team delivered the virus directly into patients' tumors via a tube traversing the skull. None of the patients developed polio symptoms.

Both people who have survived for six years developed glioblastoma again, but were successfully treated a second time. "There doesn't seem to be any resistance to re-treatment," Bigner says.

Bigner's group plans to study the effects of combining the poliovirus treatment with drugs that may further boost the immune response against the cancer.

"We must be optimistic, but with caution," says neurosurgical oncologist E. Antonio Chiocca of Brigham and Women's Hospital in Boston. "The history of glioblastoma treatments is littered with lots of early clinical trials that appear to show very promising and encouraging results," but don't prove to be useful in later trials. ■

BODY & BRAIN

Sex among U.S. teens is on the decline

But fewer sexually active high school kids are using condoms

BY AIMEE CUNNINGHAM

Fewer teens are having sex than at any point since 1991, a survey of U.S. high school students finds. Among those students who are sexually active, fewer are using condoms, raising the risk of contracting sexually transmitted infections.

About 40 percent of teens surveyed in 2017 reported having ever had sex. That's down from about 54 percent in 1991, the first year the survey was conducted. Of the roughly 29 percent of students who are currently sexually active — defined as having had sexual intercourse in the three months before the survey — nearly 54 percent reported that either they or their partner used a condom the last time they had sex. Ten years ago, about 62 percent of teens reported condom use.

Cora Breuner, a pediatrician at Seattle Children's Hospital, says doctors have been doing a better job educating teens about sex. "The more kids know about it, the less mystique there is about it," she says, and "the more they want to wait."

Breuner sees two reasons for the drop in condom use: less fear of HIV with the advent of antiretroviral drugs and wider availability of long-acting contraceptives. "We are not doing a good job informing kids about protecting themselves from getting sick with infections that can last the rest of their lives and have significant negative outcomes," she says.

The new analysis, released June 14 by the U.S. Centers for Disease Control and Prevention, relied on nearly 15,000 surveys from teenagers at 144 high schools. ■

A. DESJARDINS *ET AL*/*NEJM* 2018

Fossil ape discovered in Chinese tomb

Humans probably played a role in ancient gibbon's extinction

BY BRUCE BOWER

A royal crypt from China's past has issued a conservation alert for apes currently eking out an existence in East Asia.

The partial remains of a gibbon were discovered in 2004 in an excavation of a 2,200- to 2,300-year-old tomb in central China's Shaanxi Province. Now, detailed comparisons of the animal's face and teeth with those of living gibbons show that the buried ape is from a previously unknown and now-extinct genus and species. In the June 22 *Science*, conservation biologist Samuel Turvey and colleagues name the creature *Junzi imperialis*.

There's no way to know precisely when *J. imperialis* died out. But hunting and the loss of forests due to expanding human populations probably played big roles in the ape's demise, the researchers say.

"Until the discovery of *J. imperialis,* it was thought that the worrying global decline of apes was a modern-day phenomenon," says Turvey, of the Zoological Society of London's Institute of Zoology. "We're now realizing that there may have been numerous human-caused extinctions of apes and other primates in the past."

Climate was relatively stable several thousand years ago, and no vertebrate extinctions have been definitively linked to natural climate shifts over the last 10,000 years. So "it is reasonable to conclude that *Junzi* became extinct as a result of human impacts," says study coauthor Alejandra Ortiz, a paleoanthropologist at Arizona State University in Tempe.

Historical records indicate that gibbons with features similar to those of *J. imperialis,* as well as some other distinctive-looking gibbon populations no longer seen in the wild, inhabited central and southern China up to around 300 years ago, the researchers say. Most gibbons today live in Southeast Asia.

The tomb is thought to have belonged to the grandmother of China's first emperor, Qin Shihuang, who ordered the building of the Great Wall of China and the famous terra-cotta warriors (*SN: 9/16/17, p. 19*). Twelve pits with animal remains, including those of the gibbon, were found in the crypt. During Qin's reign and throughout much of Chinese history, gibbons were thought to have noble traits, and royals often acquired gibbons as high-status pets.

This partial skull found in an ancient Chinese crypt belonged to *Junzi imperialis*, a newly identified gibbon species that is now extinct.

Ancient Chinese art includes many depictions of gibbons, too.

Turvey's group compared a 3-D digital reconstruction of the gibbon's skull, based on its skeletal remains, with 477 skulls from nearly all living species of gibbons and siamangs, a closely related ape. Digital images of the recovered gibbon's upper and lower molar teeth were compared with 789 molars from 279 gibbon and siamang individuals.

"The science in this paper is strong, but its message for the future of apes and all animals and plants on Earth today is dismal," says biological anthropologist Brenda Benefit of New Mexico State University in Las Cruces. All species of gibbons living today remain imperiled, as do most other primates, due to habitat loss, hunting and the international trade in exotic pets (*SN: 3/17/18, p. 10*).

The report highlights long-standing human threats to gibbons' survival, agrees biological anthropologist Terry Harrison of New York University. But the ancient gibbon remains may not represent a new genus, he says. A partial skull from a captive ape of unknown geographic origin leaves crucial questions unanswered, including what the creature's lower body looked like, says Harrison. Relatively complete skeletons of wild gibbons from Chinese sites dating to the last 10,000 years are needed to check the Shaanxi ape's evolutionary ID, he contends. ■

People may have driven a distinctive line of gibbons to extinction sometime within the last 2,000 years. Human activities continue to threaten modern gibbons (*Hoolock hoolock*, shown).

FROM TOP: S. TURVEY/ZSL; REALITYIMAGES/SHUTTERSTOCK

MATH & TECHNOLOGY

This robot can 'read' your mind

People can direct the machine via brain waves, hand gestures

BY MARIA TEMMING

Getting robots to do what we want would be a lot easier if they could read our minds.

That sci-fi dream might not be so far off. With a new robot control system, a human can stop a bot from making a mistake and get the machine back on track using brain waves and simple hand gestures. People who oversee robots in factories, homes or hospitals could someday use this setup, presented June 28 at the Robotics: Science and Systems conference in Pittsburgh, to ensure bots operate safely and efficiently.

Electrodes worn on the head and forearm allow a person to control the robot. The head-worn electrodes detect electrical signals called error-related potentials, which people's brains naturally generate when they see someone goof up, and send an alert to the robot. When the robot receives an error signal, it stops what it is doing. The person can then make hand gestures, detected by arm-worn electrodes that monitor electrical muscle signals, to show the bot what it should do instead.

MIT roboticist Daniela Rus and colleagues tested the system with seven volunteers. Each user supervised a robot that moved a drill toward one of three possible targets, each marked by an LED bulb, on a mock airplane fuselage. Whenever the robot zeroed in on the wrong target, the user's mental error alert halted the bot. And when the user flicked his or her wrist left or right to redirect the robot, the machine moved toward the proper target. In more than 1,000 trials, the robot initially aimed for the correct target about 70 percent of the time, and with human intervention chose the right target more than 97 percent of the time.

The team plans to build a version that recognizes a wider variety of user movements. That way, "you can gesture how the robot should move, and your motion can be more fluidly interpreted," says project member Joseph DelPreto, also a roboticist at MIT.

Robots that are sensitive to brain and muscle signals from a humans, like this drill-wielding bot with a human controller, could make for better assistants in factories or homes.

Issuing commands via brain and muscle activity could work especially well in noisy or poorly lit places like factories or outdoors. In such areas, other hands-off means of directing robots, such as visual cues or verbal instructions, may not work as well, says Alexandre Barachant, a brain-computer interface researcher at CTRL-Labs in New York City. This technique could also be used to direct robots that assist people who can't speak or

EARTH & ENVIRONMENT

Fiber-optic cables can detect quakes

Seafloor network could help scientists sense seismic activity

BY MARIA TEMMING

The global network of seafloor cables may be good for more than ferrying digital communication between continents. These fiber-optic cables could also serve as earthquake detectors, researchers report online June 14 in *Science*.

"It's a very exciting proposition," says seismologist Barbara Romanowicz of the University of California, Berkeley and the Collège de France in Paris. Almost all of the world's seismic stations are land-based, leaving many oceanic earthquakes undetected. Harnessing the million-plus kilometers of underwater fiber-optic cables to monitor seafloor quakes would be "a great step forward" for studying Earth's interior, Romanowicz says.

Quake-detecting cables could also bolster tsunami alert systems. "The more [seismic] stations feeding into a tsunami warning system, the faster it can give a warning," says study coauthor Richard Luckett, a seismologist at the British Geological Survey in Edinburgh.

The global network of submarine fiber-optic cables that deliver e-mails and cat videos to computers around the world could double as undersea earthquake detectors. Existing cables are shown in purple; planned cables are in blue.

To use a telecommunication cable as a seismic sensor, researchers inject light from a laser into one end of the optical fiber and monitor the light that exits the other end. When a seismic wave rattles the cable, it distorts the laser light travelling through the cable. By comparing the original laser signal with the light that exits the cable, researchers determine how much the beam was distorted — and therefore the strength of the seismic wave that strummed the cable.

Combining measurements from multiple fiber-optic cables can triangulate the quake's point of origin, explains study coauthor Giuseppe Marra, a frequency metrology researcher at the National Physical Laboratory in Teddington, England. Knowing the strength of a

FROM TOP: CSAIL/MIT; G. MARRA *ET AL*/*SCIENCE* 2018

can hardly move, such as patients with amyotrophic lateral sclerosis, or ALS (*SN: 11/16/13, p. 22*).

What's more, the system can correct robot errors almost instantly. Error-related potentials in the brain are discernible a few hundred milliseconds after a person notices a mistake, and electrical muscle signals can be detected before actual movement, Barachant says. This feature could be useful in situations where quick reaction time is key for the safety of the bot and others — as with self-driving cars or manufacturing machines.

For this system to enter widespread use, though, the equipment that tracks users' brain activity would need to be more broadly accessible than it is now, Barachant says. This mind-monitoring device can cost thousands of dollars, and electrode caps are hardly the most comfortable headwear. But if researchers could measure brain waves with cheaper, more comfortable headsets, the system could provide a relatively quick, easy way for average users to make a robot do their bidding. ■

seismic wave when it passed through a cable and where the wave started, scientists can estimate quake magnitude.

Marra, Luckett and colleagues tested their technique on both land-based and submarine fiber-optic cables. A 79-kilometer-long land cable in England sensed vibrations from two quakes originating in New Zealand and Japan that seismometers put at magnitude 7.9 and 6.9. An underwater cable that runs 96 kilometers from Sicily to Malta detected a magnitude 3.4 tremor emanating from the Mediterranean Sea last September.

Fiber-optic cables that identify quakes far from land could provide new insight into geologic goings-on under the sea. Better views of seafloor movements could help reveal how volcanism at mid-ocean ridges creates new oceanic crust, Luckett says. Monitoring seafloor seismic activity could also help scientists study mantle plumes, upwellings of hot, buoyant rock in Earth's mantle, Romanowicz says. ■

ATOM & COSMOS

Magnetism may prop up stellar nursery

New data explain why the Pillars of Creation haven't crumbled

BY EMILY CONOVER

The Pillars of Creation may keep standing tall due to the magnetic field within the star-forming region.

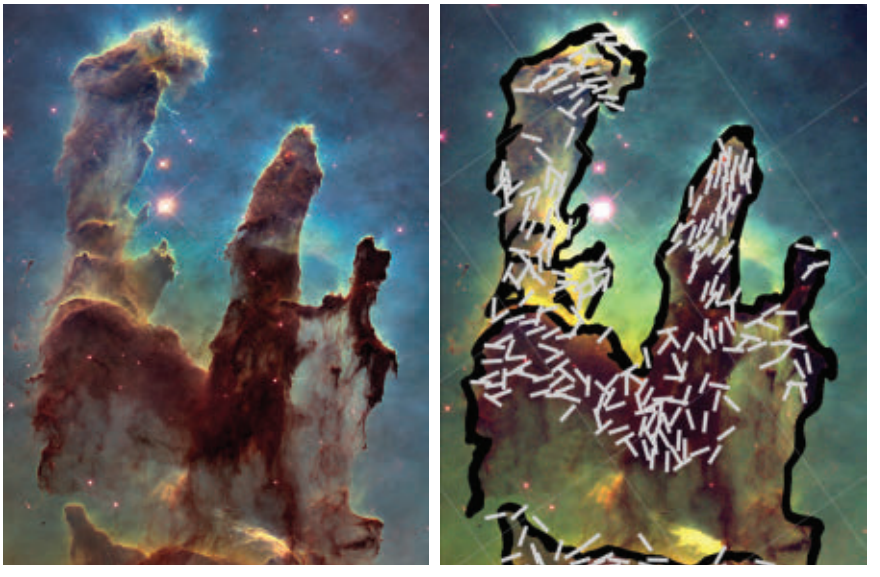
For the first time, scientists have made a detailed map of the magnetic field inside the pillars, made famous by an iconic 1995 Hubble Space Telescope image (*SN Online: 1/6/15*). The data reveal that the field runs along the length of each pillar, perpendicular to the magnetic field outside. This configuration may be slowing the destruction of the columns of gas and dust, astronomer Kate Pattle and colleagues suggest in the June 10 *Astrophysical Journal Letters*.

Hot ionized gas called plasma surrounds the pillars, located within the Eagle Nebula about 7,000 light-years from Earth. The pressure from that plasma could cause the pillars to pinch in at the middle like an hourglass before breaking up. However, the researchers suggest that the organization of the magnetic field within the pillars could be providing an outward force that resists the plasma's onslaught, preventing the columns from disintegrating.

The team studied light emitted from the pillars, measuring its polarization — the direction of the wiggling of the light's electromagnetic waves — using the James Clerk Maxwell Telescope in Hawaii. Dust grains within the pillars are aligned with each other due to the magnetic field. These aligned particles emit polarized light, allowing the researchers to trace the direction of the magnetic field at various spots.

"There are few clear measurements of the magnetic fields in objects like pillars," says Koji Sugitani of Nagoya City University in Japan. To fully understand the formation of such objects, more observations are needed, he says.

Studying objects where stars are born, such as the pillars, could help scientists get a handle on the role that magnetic fields may play in star formation (*SN: 6/9/18, p. 12*). "This is really one of the big unanswered questions," says Pattle, of National Tsing Hua University in Hsinchu, Taiwan. "We just don't have a very good idea of whether magnetic fields are important and, if they are, what they are doing." ■



Columns of cosmic gas and dust dubbed the Pillars of Creation (left) may be held up by an internal magnetic field. A map (right) reveals that the orientation of the magnetic field runs roughly parallel to each skinny column. White bars indicate the field's orientation in that location.

FROM LEFT: NASA, ESA, HUBBLE HERITAGE TEAM/STSCI AND AURA; K. PATTLE *ET AL*/*ASTROPHYSICAL JOURNAL LETTERS* 2018

BODY & BRAIN

Herpesvirus linked to Alzheimer's

Plaque buildup could be the brain's way of protecting itself

BY LEAH ROSENBAUM

While searching for vulnerabilities to exploit in creating an Alzheimer's disease treatment, Joel Dudley and his colleagues stumbled across a surprising association. Many of the hundreds of brains in datasets the team examined had signs of herpesvirus infection, but brains from people with Alzheimer's had much higher levels of viral DNA than those from healthy people.

In particular, the researchers found high levels of HHV-6 and HHV-7, two herpesvirus strains that cause the common childhood illness roseola, the team reports June 21 in *Neuron*.

"We had no intention of looking at viruses," says Dudley, a biomedical informatics researcher at the Icahn School of Medicine at Mount Sinai in New York City, who has given a talk jokingly titled, "I went looking for drugs and all I found were these stupid viruses."

It is unclear whether the herpesviruses contribute to the development of Alzheimer's, or if Alzheimer's patients are just more susceptible to reactivation of these viruses, which can remain latent in the body long after exposure. Genetic factors also influence a person's risk of developing Alzheimer's. The researchers did find that the viruses interacted with genes linked with Alzheimer's disease, though the implications are still murky.

Dudley has now found himself in the middle of a long-standing debate about whether there's a link between pathogens and the degenerative brain disease. One reason for the controversy, says neurologist James Leverenz of the Cleveland Clinic, is that herpesviruses "are so ubiquitous, and so many people carry them." For decades, many researchers have thought it unlikely that a common virus could contribute to the devastating disease.

Traditional research into Alzheimer's, which affects 5.7 million Americans, has focused on two primary characteristics of the disease: amyloid-beta plaques that collect between nerve cells in the brain, and tau tangles, twisted protein fibers that accumulate in those nerve cells, or neurons (*SN: 12/24/16, p. 27*). But recent research suggests that A-beta, rather than junk that clogs up spaces between brain cells, may actually function to trap pathogens.

A second new study, done in mice and published July 11 in *Neuron*, suggests that A-beta in Alzheimer's patients could become overactivated by infections such as herpes and form plaques in an effort to protect the brain. This hypothesis suggests that herpesviruses trigger the A-beta buildup, which in turn triggers Alzheimer's disease (see Page 22 for more on another factor that may play a role in the disease).

Among mice engineered to develop an Alzheimer's-like disease, animals injected with HSV-1, a common herpesvirus, formed A-beta plaques more quickly, neurologist Rudolph Tanzi of Massachusetts General Hospital in Boston and colleagues found. Compared with normal mice, these mice also had less herpes-caused brain inflammation, suggesting that A-beta plays a role in the immune system. Though herpesvirus is most commonly linked to Alzheimer's, other pathogens, including bacteria and fungi, could theoretically trigger plaques, Tanzi says.

With mounting evidence of a potential link, other Alzheimer's researchers might be more receptive to these findings than in the past, says Leverenz, who was not involved in either study. "Between the immune system [research] and the recognition that Alzheimer's is very complex," he says, "there's probably a little more openness to examine this idea."

More work is needed to understand if there is a connection between herpesvirus and Alzheimer's. It's also unclear how a person's genetics come into play, says neuroscientist Keith Fargo of the Alzheimer's Association in Chicago.

One thing is clear, Dudley says: You can't catch Alzheimer's from someone experiencing dementia symptoms. Even if herpesviruses play a role, many other factors contribute to Alzheimer's. ■

COURTESY OF FABIAN SINZINGER/KTH ROYAL INSTITUTE OF TECHNOLOGY, STOCKHOLM

LIFE & EVOLUTION

Domestication changed rabbits' brains

Domestic rabbits have smaller brains relative to their body size than wild rabbits do, a new study shows. And that's not the only change domestication wrought on bunny brains.

Two "fear centers" are the most altered brain regions. Compared with wild rabbits, domestic rabbits have smaller amygdalae (yellow in the brains above), emotion-processing centers that play a role in the fight-or-flight response, and larger medial prefrontal cortices (light blue), thought to be involved in social behavior. An international research group describes the differences June 25 in the *Proceedings of the National Academy of Sciences*. — *Tina Hesman Saey*

BODY & BRAIN

Narcolepsy molecule tied to addiction

Opioids boost a brain chemical that regulates wakefulness

BY LAUREL HAMERS

Using opioids gives some brain cells a call to action.

Opioid addicts' brains, examined after death, contained about 50 percent more nerve cells that release a molecule called hypocretin compared with brains of people who didn't use the drugs, a study finds. Giving morphine to mice induced similar changes in their brains. Once-dormant nerve cells, or neurons, appear to rev up their hypocretin machinery in response to the drugs, researchers report in the June 27 *Science Translational Medicine*.

The findings fit with a growing body of research suggesting that hypocretin — a brain chemical that regulates wakefulness and arousal and has been linked to narcolepsy — may be involved in addiction.

"There is extensive evidence now that shows that the hypocretin neurons are supporting motivated behavior in general," and addiction falls under that umbrella, says Rodrigo España, a neurobiologist at Drexel University in Philadelphia who wasn't involved in the study. His lab recently showed that rats with a weaker brain response to hypocretin showed less motivation to seek out cocaine rewards.

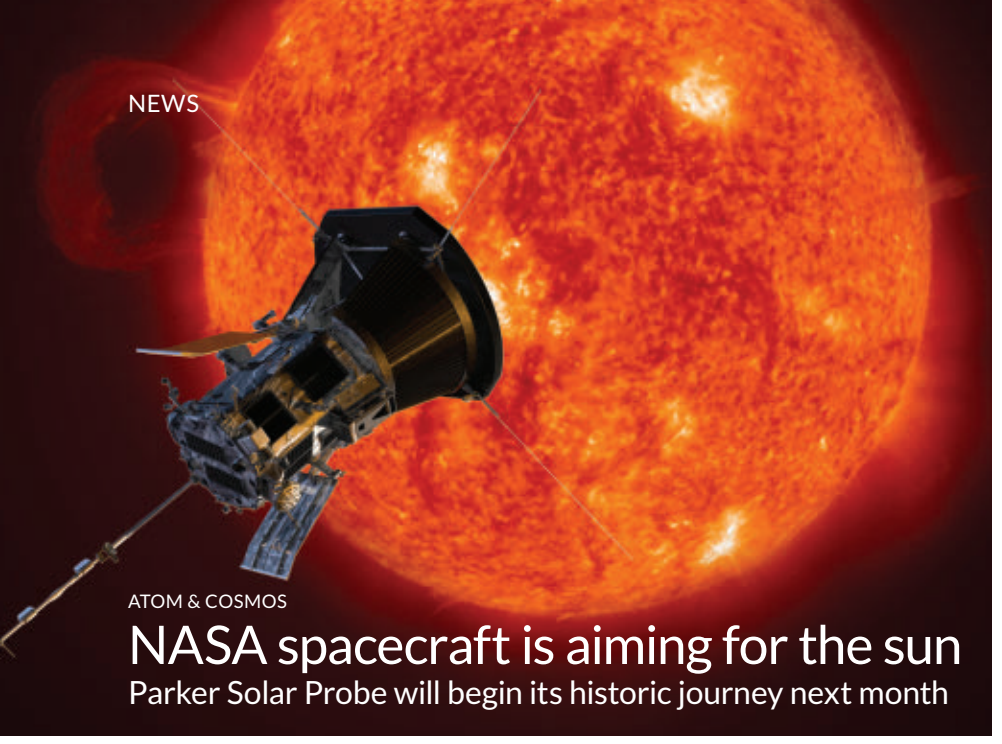
The new study comes from the opposite angle, showing changes in hypocretin neurons in response to drug use. "It does suggest the possibility that part of the reason it's so hard to get off drugs is there's this massive change in the brain," says UCLA neuroscientist Jerome Siegel.

Siegel and colleagues discovered hypocretin's potential link to addiction while investigating narcolepsy. People with the sleep disorder have about 90 percent fewer hypocretin-producing neurons than normal. While examining brains as part of a narcolepsy study, Siegel's group got a surprise: a supposedly healthy brain with an unexpectedly large number of hypocretin neurons. That person had been a heroin addict.

Now, an analysis of four more brains from people addicted to heroin or other opioids suggests that the elevated number of hypocretin neurons in the first brain was not a fluke.

Addicts' brains had 54 percent more hypocretin-producing neurons, on average, than healthy brains, the team found. In experiments, two weeks of receiving morphine increased the number of active hypocretin-producing neurons in mice's brains. Narcoleptic mice's muscle weakness, a symptom of the disorder, even reversed with morphine injections.

With proper dosing and monitoring, opioids might be an effective treatment for narcolepsy, Siegel says. Further testing is needed to determine whether opioids are more effective than other, less addictive drugs for the sleep disorder. ■



The Parker Solar Probe (illustrated), set to launch in early August, will get closer to the sun than any previous spacecraft.

ATOM & COSMOS

NASA spacecraft is aiming for the sun

Parker Solar Probe will begin its historic journey next month

BY MARIA TEMMING

NASA's Parker Solar Probe is about to embark on one daredevil stunt of a space mission.

Slated to launch August 4, the probe will be the first spacecraft to swoop through the sun's outer atmosphere, or corona, a roiling inferno of plasma heated to several million degrees Celsius.

Parker will whip around the sun two dozen times over the next seven years, skirting within about 6 million kilometers of the star's surface — more than seven times as close as any previous spacecraft. At its nearest approach, Parker will hurtle through the corona at about 700,000 kilometers per hour, making the craft the fastest human-made object in the solar system. The probe would need only about a second to zip from Philadelphia to Washington, D.C.

Parker's closeup observations of the corona and the solar wind, the torrent of charged particles that the sun spews into space, could help resolve long-standing mysteries about the inner workings of the sun's atmosphere. And the new data may improve forecasts for space weather that endangers spacecraft, astronauts and technology on the ground.

The trove of new data gathered by this probe "is going to answer a lot of questions that we couldn't answer in any other way," says Craig DeForest, a heliophysicist at the Southwest Research Institute in Boulder, Colo., who is not involved in the mission. "There's been a tremendous amount of anticipation."

Scientists have had a probe like Parker on their mission wish lists for nearly 60 years. In 1958, the year that NASA was created, the National Academies' Space Studies Board recommended that the new agency send a spacecraft inside the orbit of Mercury to investigate the environment surrounding the sun.

Over the years, several research groups have floated solar probe mission ideas, but none could get as close to the sun as astronomers wanted. "It's only been recently that the technology of heat shields and everything else has converged well enough that we could make this a reality," DeForest says.

About the size of a small car, the Parker Solar Probe will pack instruments to take 3-D images, measure electric and magnetic fields and catalog high-energy particles. Although the corona sizzles at millions of degrees, the atmosphere is so diffuse that most of the heat that will imperil Parker's instruments comes from radiation emanating directly from the sun's surface. This lethally intense sunlight can heat the face of the spacecraft to about 1370°.

To guard Parker's instruments against that radiation, the probe is armed with a heat shield composed of a layer of carbon foam sandwiched between panes of another carbon-based material similar to the graphite epoxy used to make golf clubs and tennis rackets. As Parker swings around the sun, this heat shield will continuously face the star to keep the instruments tucked behind it safe from radiation up to about 475 times as intense as what Earth-orbiting spacecraft endure.

Parker will dive into the sun's corona for the first time just three months after launch, sending its first batch of data back to Earth in early December. For scientists, that's pretty quick gratification: For spacecraft such as New Horizons (*SN Online: 6/15/15*) that have rendezvoused with more distant solar system objects, the intermission between launch and arrival can span years.

The probe will circle the sun 24 times, using Venus' gravitational pull to gradually shrink the craft's orbit. On its first go-round, Parker will fly to about 24 million kilometers from the sun's surface; on its final few loops in 2024 and 2025, the probe will get within about 6 million kilometers.

The probe may have some fuel left over to keep cruising around the sun after completing its mission-mandated 24 orbits, says Nicola Fox, project scientist for the mission. But eventually, Parker won't be able to fire the thrusters that it needs to keep its heat shield aimed at the sun. The probe "will start to turn, and bits of the spacecraft that are totally not designed to see the sun will be in full illumination," says Fox, a heliophysicist at the Johns Hopkins Applied Physics Laboratory in Laurel, Md. "The spacecraft will break up into kind of large chunks at first, and then they'll get smaller and smaller." Eventually, Parker will be nothing more than a smattering of dust scattered across the corona.

The spacecraft's legacy, however, will live on. Parker's observations are expected to help answer questions about the corona and solar wind that researchers have puzzled over for decades.

For instance, Parker data could explain

JHU-APL

the strange temperature difference between the surface of the sun, which is a toasty 5500°, and the several-million-degree corona. This spike may be due to vibrating magnetic field lines heating up material in the corona, or jets of material from the sun's surface that inject energy into its atmosphere (*SN Online: 8/20/17*). Parker could also help explain where solar wind particles get the energy to speed up as they escape the sun's immense gravitational pull (*SN Online: 8/18/17*).

The enigmatic coronal heat and acceleration of the solar wind probably have a common cause, says David McComas, a space plasma physicist at Princeton University. McComas is the principal investigator for one of the probe's instruments, the Integrated Science Investigation of the Sun. There are many competing theories to explain these two problems, but Parker's views of the sun should help winnow down the list of possible explanations.

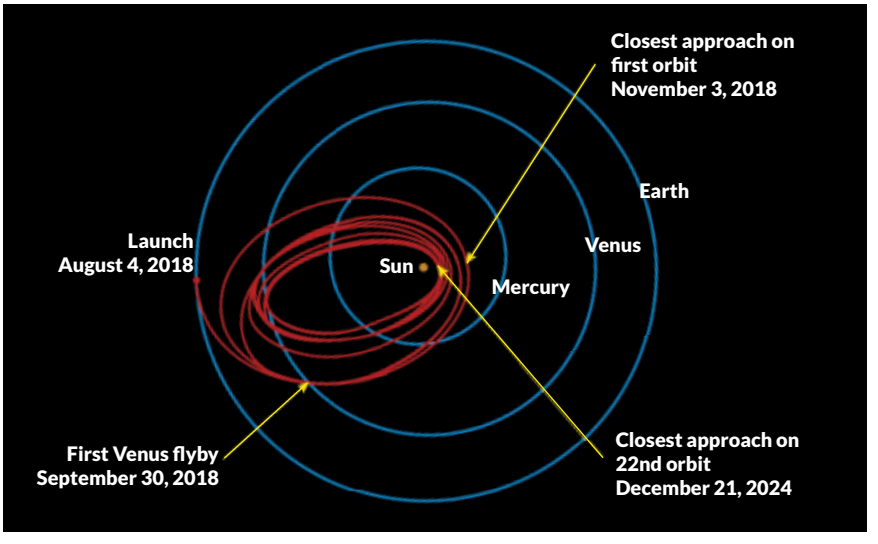
Parker's observations should also give new insight into the origins of those highly energetic particles that escape the sun into the solar wind, McComas says. The solar wind washes over Earth at hundreds of kilometers per second, and disturbances in this cosmic breeze can mess with satellites, spacecraft and power grids (*SN: 8/19/06, p. 120*). A better understanding of the sun's tumultuous atmosphere and solar wind could lead to better forecasts for potentially dangerous space weather events.

On top of all that, Parker's zoomed-in view of the sun will undoubtedly raise new mysteries about our home star, McComas says. The data haul from "one mission [often] just whets our appetites for even more observations down the road," he says.

Fortunately, another spacecraft bound for the sun is launching right on the heels of the Parker probe. The European Space Agency's Solar Orbiter, set to take flight in 2020, will provide the first direct images of the sun's poles. Paired with Parker's observations closer to the sun's midriff, Solar Orbiter data may reveal how the solar wind varies at different latitudes.

These missions aren't just about getting to know our own solar system. "Once you know about how our star works, you're going to know a lot more about ... other stars," Fox says.

Whatever scientific discoveries come from the mission, it's difficult not to get excited for the sheer "wow" factor of the probe's impending expedition. "This is really freaking cool," DeForest says. "We're launching a probe and flying it through [several-] million-degree plasma on the periphery of a star. I mean, how cool is that?" ■



NASA'S SCIENTIFIC VISUALIZATION STUDIO

Round and round The Parker Solar Probe will circle the sun 24 times over the next seven years, using the gravitational tug of Venus to gradually shrink its own orbit. On its final few loops, beginning in 2024, the probe will skirt within about 6 million kilometers of the sun's surface.

ATOM & COSMOS

Mars got its crust before Earth did

Red Planet's exterior hardened by 4.547 billion years ago

BY CAROLYN GRAMLING

Mars was a fully formed planet — crust and all — within 20 million years of the solar system's birth. That rapid formation means the Red Planet probably got a 100-million-year jump on Earth in terms of habitability, new research suggests.

Geochemical analyses of zircon crystals extracted from Martian meteorites reveal that Mars had formed its earliest crust by 4.547 billion years ago, planetary scientist Laura Bouvier of the University of Copenhagen and colleagues report in the June 28 *Nature*.

The emergence of an outer shell, or crust, is the final stage in the formation of rocky planets. The process begins with the accretion of particles from the disk of gas and dust that surrounds an infant star. Eventually, those particles form molten material that makes up a magma ocean. As the magma ocean cools and crystallizes, it forms a dense metallic core, and then an outer crust. Simulations suggest that the whole process usually occurs on timescales of 30 million to as long as 100 million years.

"Having Mars cool so quickly puts limits on how massive its atmosphere could have been," says planetary scientist Linda Elkins-Tanton of Arizona State University in Tempe. Going by how quickly a planet cools and how quickly the sun can strip away its atmosphere, researchers can estimate how much water and carbon dioxide might have been released by the magma. In Mars' case, that atmosphere would have been pretty thin to allow for such rapid heat loss, Elkins-Tanton says.

Around the time Mars solidified, Earth was almost certainly molten, possibly thanks to a giant whack that formed the moon and remelted the entire planet (*SN: 4/15/17, p. 18*), Elkins-Tanton says. Earth had to wait another 100 million years to fully harden. ■

GENES & CELLS

Turning on genes requires teamwork

Flipping genetic switches isn't a job for solo proteins, studies find

BY TINA HESMAN SAEY

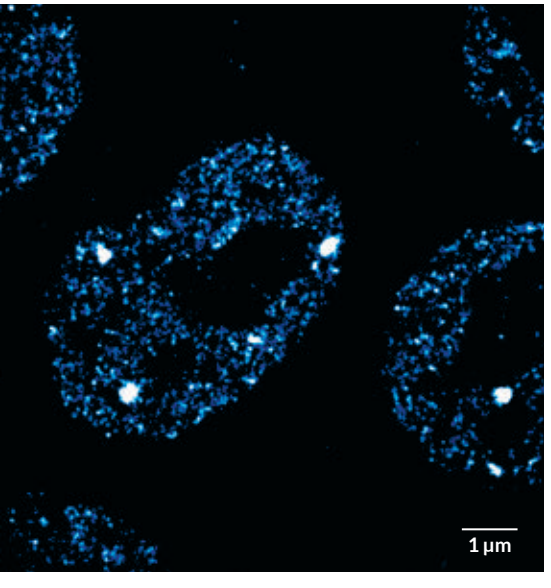
Turning on genes may work like forming a flash mob.

Inside a cell's nucleus, fast-moving groups of floppy proteins crowd together around genetic switches and coalesce into droplets to turn on genes, biological physicist Ibrahim Cissé of MIT and colleagues report online June 21 in two papers in *Science*.

Researchers have previously demonstrated that proteins form such droplets in the cytoplasm, the cell's jellylike guts. Some scientists, including Cissé's MIT colleagues Richard Young and Phillip Sharp, have proposed that this process — called phase separation — could also happen in the nucleus when cellular machinery turns genes on, which involves copying DNA instructions into RNA messages.

If confirmed, the discovery challenges earlier ideas that gene activity is controlled by single molecules of stable protein complexes that remain stuck to DNA for long periods.

Cissé and colleagues used super-resolution microscopy to view single protein molecules in live mouse embryonic stem cells. In particular, the team was interested in RNA polymerase II, the enzyme that copies DNA into RNA, and parts of the Mediator complex, a group of proteins that helps kick-start that copying process, called transcription. The researchers tagged the proteins with a fluorescent protein and watched what happened.



In this microscope image of mouse embryonic stem cells, molecules of the enzyme that copies DNA instructions into RNA messages cluster (white and blue spots) within nuclei.

RNA polymerase II and Mediator proteins both formed large clusters, each with about 200 to 400 molecules. Those clusters had properties of phase-separated droplets: The clusters formed distinct dots when viewed through the microscope. Those dots could fuse together, like oil droplets merging in water. And the droplets could be dispersed with alcohol. That's convincing evidence that Cissé's group sees phase-separated condensates, says Anthony Hyman, a biologist at the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden, Germany.

While these clusters seem stable, individual polymerase or Mediator proteins were constantly darting in or out of the cluster. About 90 percent of polymerase molecules and 60 percent of Mediator molecules spent only about 10 seconds in the clusters, the team found.

That's in contrast to previous studies suggesting that RNA polymerase II stays at a gene for minutes to hours, says single-cell biochemist Robert Tjian, a Howard Hughes Medical Institute investigator at the University of California, Berkeley. "The biggest surprise is how fast these things are happening," he says. In a study also reported online June 21 in *Science*, he and colleagues found that these proteins interact only briefly, most for just five to 20 seconds.

These protein mobs are drawn together by their floppy bits, called low complexity or intrinsically disordered regions, Tjian's team found. Floppy, intrinsically disordered proteins are needed for a wide variety of cellular processes (*SN: 2/9/13, p. 26*).

In Cissé's studies, Mediator proteins clustered with groups of genetic switches called super-enhancers. Typically, super-enhancers are located far from the genes they regulate and may control several genes, sometimes simultaneously. Droplets containing Mediator proteins and super-enhancers may interact with droplets containing RNA polymerase II to spur transcription, the findings suggest.

Sudden coalescence of proteins into droplets could help explain why genes turn on in a flash, Hyman says. Bubbles of enhancers might interact with multiple bubbles of RNA polymerase II to turn on several genes at once, something that could be hard to explain if single protein molecules were responsible.

Tjian doesn't call what he sees phase separation, even though his results are similar to Cissé's. It's not necessary to concentrate proteins so densely that they will form droplets to get transcription started, he says. Instead, proteins clustered in hubs can spur transcription at a range of concentrations, he found.

Julie Forman-Kay, a biophysical chemist at the Hospital for Sick Children in Toronto, contends that Tjian is making a semantic argument. "What he calls a hub is, in my book, evidence for phase separation," she says. All of the studies show the same thing, she says: Clusters of floppy proteins concentrate in particular locations to turn on genes.

But the association between phase separation and transcription hasn't been proven yet, says Danny Reinberg, a biochemist at New York University Langone Health. He agrees with Tjian's findings that weak interactions between proteins can add up to a strong push to do something, in this case to copy DNA into RNA. But he needs more evidence that transcription is spurred by phase separation into droplets, as Cissé and colleagues describe. "I'm not saying it's not happening," Reinberg says. "I'm saying it can happen, it might be happening, but there's no proof of that in these two papers." ■

W.-K. CHO *ET AL*/*SCIENCE* 2018

GENES & CELLS

Zika gets an extreme close-up

Researchers have gotten the closest look yet at the Zika virus and may have discovered some chinks in its armor.

Using cryo-electron microscopy, structural biologist Madhumati Sevvana and colleagues mapped Zika's structure at a resolution of 3.1 angstrom, which is equivalent to the size of two atoms. That closeup view, reported online June 26 in *Structure*, is the most zoomed-in image that scientists have gotten of any flavivirus, the family of viruses that includes Zika, dengue, yellow fever, West Nile and Japanese encephalitis.

Comparing Zika's structure with that of some other flaviviruses revealed a few differences that might account for different symptoms produced by the various viruses, says Sevvana, of Purdue University in West Lafayette, Ind. The researchers identified some pockets where drugs may be able to dock and disrupt Zika, Sevvana says. — *Tina Hesman Saey*

GENES & CELLS

Coffee may help protect the heart by fueling cells' power plants

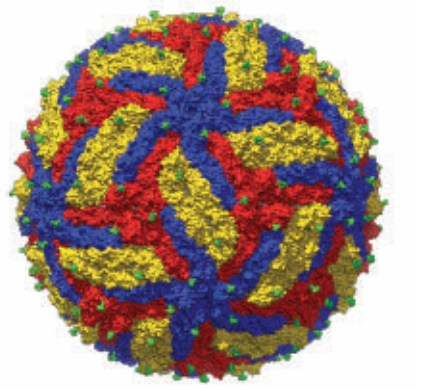
Coffee revs up cells' energy factories and helps hearts recover from heart attacks, a study of mice suggests.

Researchers gave mice the equivalent of four cups of coffee a day for 10 days and then induced heart attacks. Heart cells in mice that got caffeine repaired damage better than cells in mice that didn't get coffee, researchers report June 21 in *PLOS Biology*. Caffeine in the coffee helps move a protein called p27 into mitochondria, the organelles that produce energy for cells. Increasing p27 in mitochondria upped the organelle's energy production, which helped heart cells recover from damage.

Humans and other animals also have p27, raising the possibility that caffeine could help heal people's hearts, too. Normally, p27 is found in the cell nucleus, where it helps control when cells divide. Its energy-boosting role in mitochondria, outside the nucleus, wasn't known before.

Coffee seems to protect against heart disease, diabetes and some other ailments (*SN: 10/3/15, p. 16*). The new discovery in mice may help explain why, says study coauthor Judith Haendeler, a biochemist at Heinrich Heine University Düsseldorf in Germany.

Haendeler cautions that just upping coffee consumption without doing other heart-friendly activities, such as exercising and eating right, probably won't do people much good. She also warns that drinking too much coffee or green tea may drive too much p27 into mitochondria and destroy them, causing health problems. — *Tina Hesman Saey*



M. SEVVANA *ET AL*

A high-resolution model of the Zika virus shows that its envelope protein, which helps the virus get into cells, makes three distinct shapes (yellow, red and blue) that fit together.

ATOM & COSMOS

Solar system intruder may not be an asteroid after all

The solar system's first known interstellar visitor may not be what we thought.

Evidence is growing that 'Oumuamua, which careened into the solar system from parts unknown before veering off, is a comet, not an asteroid.

Unlike asteroids, comets are icy and tend to be surrounded by a halo of gas and dust. Astronomers saw no signs of a halo around the roughly 400-meter-long 'Oumuamua. So the interloper, discovered in October 2017, was dubbed an asteroid (*SN: 11/25/17, p. 14*). But some scientists questioned that conclusion: The object has a reddish surface, suggestive of a comet with an outer crust shielding an icy heart (*SN Online: 12/18/17*).

Now, a team of researchers reports online June 27 in *Nature* that the path 'Oumuamua took on its whirlwind tour of the solar system can't be explained just by the gravitational tugs from the sun and other celestial bodies. Some other force must also have been acting on the object. That force could be a result of spewing gas propelling 'Oumuamua, the scientists say, strengthening the case for a comet. — *Emily Conover*

ATOM & COSMOS

Einstein's general relativity reigns supreme, even on a galactic scale

Chalk up another win for Einstein's seemingly invincible theory of gravity. A new study shows that the theory of general relativity holds true even over vast distances.

General relativity prevailed within a region spanning a galactic distance of about 6,500 light-years, scientists report in the June 22 *Science*. The new test is the most precise one yet across such great distances. Previously, researchers had precisely tested the theory by studying its effects on the solar system (*SN Online: 8/15/17*).

According to general relativity, the force of gravity is the result of matter warping spacetime (*SN: 10/17/15, p. 16*). The team looked at how light from a faraway galaxy was bent by that warping as the light passed by an intervening galaxy while traveling toward Earth. The closer galaxy, known as ESO 325-G004 and located about 450 million light-years from Earth, distorted the image of the distant galaxy into a ring, like a cosmic version of a fun house mirror (*SN: 10/17/15, p. 24*).

Using the observations of distorted light, a team of international researchers estimated ESO 325-G004's mass. Then they compared that measurement with a second mass estimate based on how stars in the galaxy zipped around and hence how much mass was tugging on them. The two measurements agreed, validating Einstein's theory.

The result challenges certain proposed tweaks to general relativity, which predict that the masses won't match up. For physicists, such tweaks are appealing because they might eliminate the need for dark energy, a mysterious pressure thought to be behind the universe's accelerating expansion. But so far, Einstein still reigns supreme. — *Emily Conover*

A GALAXY'S ECOSYSTEM

The circumgalactic medium is an invisible cloak that controls how galaxies live and die

By Lisa Grossman

Whirls of cold and hot gas billow in this simulation of a circumgalactic medium surrounding a galaxy. With new tools and simulations, researchers have learned that the CGM helps a galaxy recycle its materials.

M.S. PEEPLES *ET AL*/FOGGIE PROJECT

There's more to a galaxy than meets the eye. Galaxies' bright stars seem to spiral serenely against the dark backdrop of space. But a more careful look reveals a whole lot of mayhem.

"Galaxies are just like you and me," Jessica Werk, an astronomer at the University of Washington in Seattle, said in January at a meeting of the American Astronomical Society. "They live their lives in a constant state of turmoil."

Much of that turmoil takes place in a huge, complicated setting called the circumgalactic medium, or CGM. This vast, roiling cloud of dust and gas is a galaxy's fuel source, waste dump and recycling center all in one. Astronomers think the answers to some of the most pressing galactic mysteries — how galaxies keep forming new stars for billions of years, why star formation abruptly stops — are hidden in a galaxy's enveloping CGM.

"To understand the galaxies, you have to understand the ecosystem that they're in," says astronomer Molly Peeples of the Space Telescope Science Institute in Baltimore.

Yet this galactic atmosphere is so diffuse that it's invisible — a liter of CGM contains just a single atom. It has taken almost 60 years and an upgrade to the Hubble Space Telescope just to begin probing distant CGMs and figuring out how their constant churning can make or break galaxies.

"Only recently have we been able to really, truly, observationally characterize the relationship between this gaseous cycle and the properties of the galaxy itself," Werk says.

Armed with the first extragalactic census,

astronomers are now piecing together how a CGM controls its galaxy's life and death. And new theoretical studies hint that galaxies' stars would be arranged very differently without a medium's frenetic flows. Plus, new observations show that some CGMs are surprisingly lumpy. A better understanding of CGMs, enabled by new telescopes and computer simulations, could change how scientists think about everything from galaxy collisions to the origins of our own atoms.

"The CGM is the part of the iceberg that's under the water," says astrophysicist Kevin Schawinski of ETH Zurich, who studies the more conventional parts of galaxies. "We now have good measurements where we're sure it's important."

Waiting for Hubble

That 2009 Hubble telescope upgrade, which made the CGM census possible, almost didn't happen.

In a cosmic coincidence, the Hubble telescope's chief champions were also the first astronomers to figure out how to observe a galaxy's CGM. Lyman Spitzer of Princeton University and John Bahcall of the Institute for Advanced Study in Princeton, N.J., and other astronomers noticed something strange after the 1963 discovery of quasars (*SN Online: 3/21/14*), bright beacons now known to be white-hot disks surrounding supermassive black holes in the centers of distant galaxies.

Everywhere astronomers looked, quasars' spectra — the rainbow created when their light is spread out over all wavelengths — were notched with dark holes. Some wavelengths of light weren't getting through.

In 1969, Spitzer and Bahcall realized what was going on: The missing light was absorbed by gas at the edges of galaxies, the same stuff that would later be called the CGM. Astronomers had been peering at quasars shining through CGMs like headlights through a fog.

Not much more could be done at the time, though. Earth's atmosphere also absorbs light in those same wavelengths, making it difficult to tell which light-blocking atoms were in a galaxy's CGM and which came from closer to home. Knowing that a CGM was there was one thing; taking its measurements would require something extra.

Spitzer and Bahcall knew what they needed: a space telescope that could observe from outside Earth's atmosphere. The pair were two of the most vocal and consistent champions of the Hubble Space Telescope, which launched in 1990. Spitzer's colleagues called him Hubble's "intellectual and political father."

Bahcall never stopped advocating for Hubble. In February 2005, six months before his death at age 70 from a rare blood disorder, he cowrote an article in the *Los Angeles Times* urging Congress to restore funding for a mission to fix some aging Hubble instruments, which NASA had canceled after the 2003 *Columbia* space shuttle disaster.

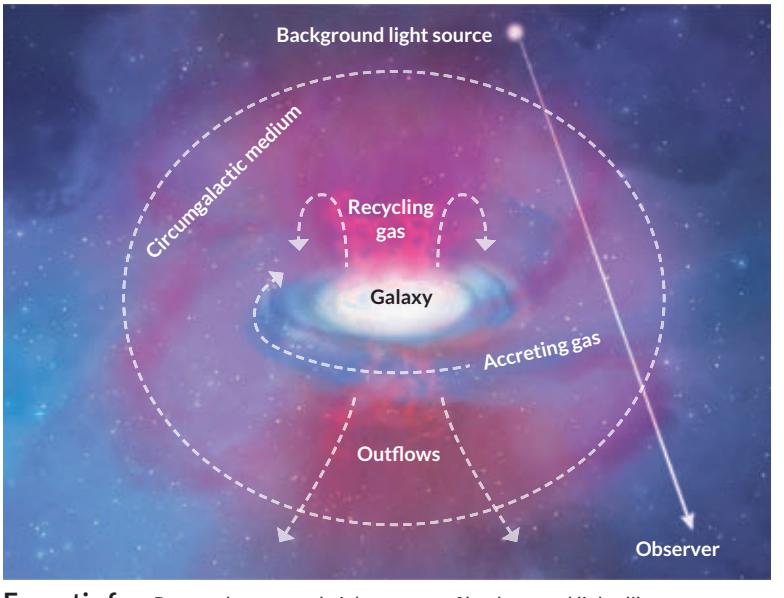
"What is at stake is not only a piece of stellar technology but our commitment to the most fundamental human quest: understanding the cosmos," Bahcall and colleagues wrote. "Hubble's most important discoveries could be in the future."

His plea was answered: The space shuttle *Atlantis* brought astronauts to repair Hubble for the last time in May 2009 (*SN Online: 5/19/09*). During the repair, the astronauts installed the Cosmic Origins Spectrograph, which could pick up diffuse CGM gas with 30 times the sensitivity of any previous instrument. Although earlier spectrographs on Hubble had picked out CGMs a few quasar-beams at a time, the new device let astronomers search around dozens of galaxies, using the light of even dimmer quasars.

"It blew the field wide open," Werk says.

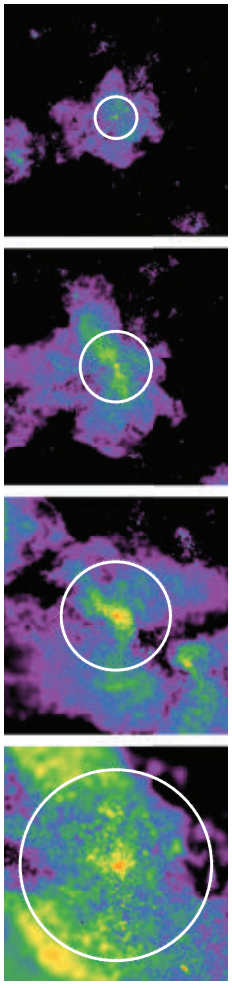
The circumgalactic census

A team led by Jason Tumlinson of Baltimore's Space Telescope Science Institute, Hubble's academic home, made a catalog of 44 galaxies with a quasar sitting behind them from Hubble's perspective. In a 2011 paper in *Science*, the researchers



Frenetic fog Researchers use a bright source of background light, like a quasar, to learn about a galaxy's circumgalactic medium, a diffuse cloud of gas and metals (pink in the illustration) surrounding a galaxy. Gas is recycled between the galaxy and the CGM. SOURCES: J. TUMLINSON, M.S. PEEPLES AND J.K. WERK/*ANNUAL REVIEW OF ASTRONOMY AND ASTROPHYSICS* 2017; M.S. PEEPLES/*NATURE* 2015

C. CHANG



This EAGLE simulation shows that, over time, metals (colors) move away from the center of a galaxy to the circumgalactic medium.

reported that every time they looked within 490,000 light-years of a galaxy, they saw spectra dappled with blank spots from atoms absorbing light. That meant that CGMs weren't odd cloaks worn by just a few galaxies. They were everywhere.

Tumlinson's team spent the first few years after Hubble's upgrade like 19th century naturalists describing new species. The group measured the mass and the chemical makeup of the galaxies' CGMs and found they were huge cisterns of heavy elements. CGMs contain 10 million times the mass of the sun in oxygen alone. In many cases, the mass of a CGM is comparable to the mass of the entire visible part of its galaxy.

The finding offers an answer to a long-standing cosmic mystery: How do galaxies have enough star-forming fuel to keep going for billions of years? Galaxies build stars from collapsing clouds of cool gas at a constant rate; the Milky Way, for example, makes one to two solar masses' worth of stars every year. But there isn't enough cool gas within the visible part of a galaxy, the disk containing its stars, to support observed rates of star formation.

"We think that gas probably comes from the CGM," Werk says. "But exactly how that gas is getting into galaxies, where it gets in, the timescale on which it gets in, are there things that prevent it from getting in? Those are big questions that keep us all awake at night."

Werk and Peeples realized that all that mass could help solve two other cosmic bookkeeping problems. All elements heavier than helium (which astronomers lump together as "metals") are forged by nuclear fusion in the hearts of stars. When stars use up their fuel and explode as supernovas, they scatter those metals around to be folded into the next generation of stars.

But if you add up all the metals in the stars, gas and dust in a given galaxy's disk, it's not enough to account for all the metals the galaxy has ever made. The mismatch gets even worse if you include the hydrogen, helium, electrons and protons — basically all the ordinary matter that should have collected in the galaxy since the Big Bang. Astronomers call all those bits baryons. Galaxies seem to be missing 70 to 95 percent of that stuff.

So Peeples and Werk led a comprehensive effort to tally all the ordinary matter in about 40 galaxies observed with Hubble's new spectrometer. The researchers published the results in two 2014 papers in the *Astrophysical Journal*.

At the time, Werk reported that at least half of galaxies' missing ordinary matter can be accounted for in their CGMs. In a 2017 update, Werk and colleagues found that the mass of baryons just in the form of cool gas in a galaxy's CGM could be nearly 90 billion solar masses. "Obviously, this mass could resolve the galactic missing baryons problem," the team wrote.

"It's a classic science story," Schawinski says. The researchers had a hypothesis about where the missing material should be and made predictions. The group made observations to test those predictions and found what it sought.

In a separate study, Peeples showed that although metals are born in galaxies' starry disks, those metals don't stay there. Only 20 to 25 percent of the metals a galaxy has ever produced remains in the stars, gas and dust in the disk, where the metals can be incorporated into new stars and planets. The rest probably ends up in the CGM.

"If you look at all the metals the galaxies ever produced in their whole lifetime, more of them are outside the galaxy than are still inside the galaxy," Tumlinson says, "which was a huge shock."

Recycling centers

So how did the metals get into the CGM? Quasars' spectra couldn't help with that question. Their light shows only a slice through a single galaxy at a single moment in time. But astronomers can track galaxies' growth and development with computer simulations based on physical rules for how stars and gas behave.

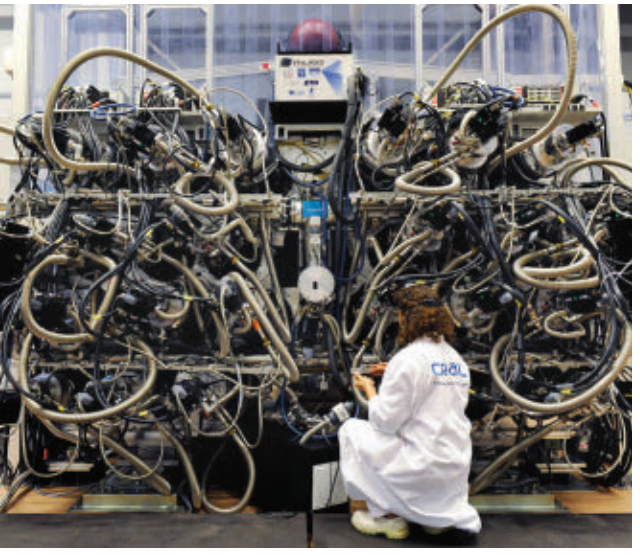
This strategy revealed the churning, ever-changing nature of gas in galaxies' CGMs. Simulations such as EAGLE, or Evolution and Assembly of GaLaxies and their Environments, which is run out of Leiden University in the Netherlands, showed that metals can reach CGMs through stars' violent lives: in powerful winds of radiation blowing away from massive young stars, and in the death throes of supernovas spraying metals far and wide.

Once the metals are in the CGM, though, they don't always stay put. In simulations, galaxies seem to use the same gas over and over again.

"It's basically just gravity," Peeples says. "Throw a baseball up, and it'll come back to the ground." The same goes for gas flowing out of galaxies: Unless the gas travels fast enough to escape the galaxy's gravity altogether, those atoms will eventually fall back into the disk — and form new stars.

Some simulations show discrete gas parcels making the trip from a galaxy's disk out into the CGM and back again several times. Together, CGMs and their galaxies are giant recycling devices.

J. TUMLINSON, M.S. PEEPLES AND J.K. WERK/*ANNUAL REVIEW OF ASTRONOMY AND ASTROPHYSICS* 2017



The European Southern Observatory's Medusa-like MUSE instrument was installed on the Very Large Telescope in Chile in 2014 to take spectra across a full galaxy.

That means that the atoms that make up planets, plants and people may have taken several trips to circumgalactic space before becoming part of us. Over hundreds of millions of years, the atoms that eventually became part of you traveled hundreds of thousands of light-years.

"This is my favorite thing," Tumlinson says. "At some point, your carbon, your oxygen, your nitrogen, your iron was out in intergalactic space."

How galaxies die

But not all galaxies get their CGM gas back. Losing the gas could shut off star formation in a galaxy for good. No one knows how star formation shuts off, or quenches. But the answer is probably in the CGM.

Galaxies come in two main forms: young spiral galaxies that are making stars and old blobby galaxies where star formation is quenched (*SN Online: 4/23/18*).

"How galaxies quench and why they stay that way is one of the most important questions in galaxy formation generally," Tumlinson says. "It just has to have something to do with the gas supply."

One possibility, suggested in a paper posted online February 20 at arXiv.org, is that sprays of supernova-heated gas could get stripped from galaxies. Physicist Chad Bustard of the University of Wisconsin–Madison and colleagues simulated the Large Magellanic Cloud, a satellite galaxy of the Milky Way, and found that the small galaxy's outflowing gas was swept away by the slight pressure of the galaxy's movement around the Milky Way.

Alternatively, a dead galaxy's CGM gas could be too hot to sink into the galaxy and form stars. If so, star-forming galaxies should have CGMs full of cold gas, and dead galaxies should be shrouded in hot gas. Hot gas would stay floating above the galactic disk like a hot air balloon, too buoyant to sink in and form stars.

But Hubble saw the opposite. Star-forming galaxies had CGMs chock-full of oxygen-VI — meaning that the gas was so hot (a million degrees Celsius or more) that oxygen atoms lost five of their original electrons. Dead galaxies had surprisingly little oxygen-VI.

"That was puzzling," Tumlinson says. "If theory told us anything, it should have gone the other way."

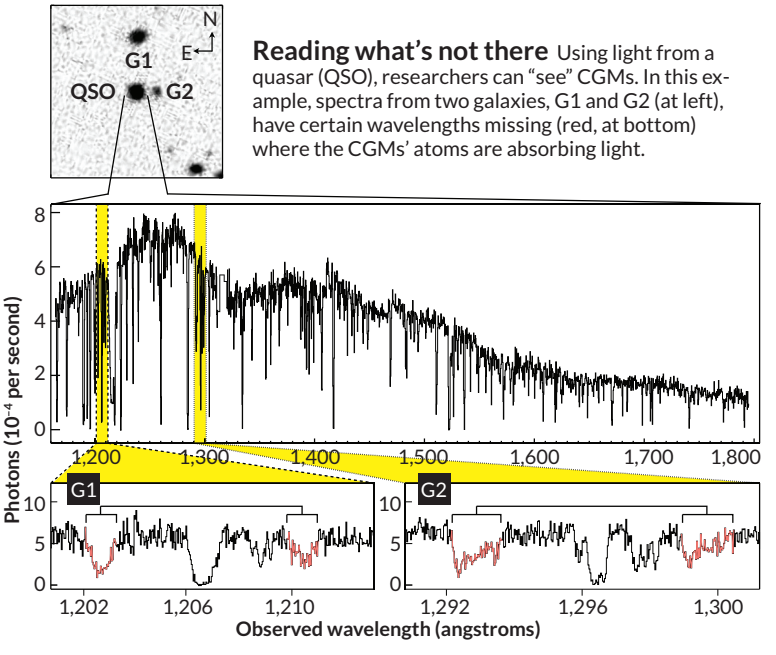
In 2016, Benjamin Oppenheimer, a computational astrophysicist at the University of Colorado Boulder, suggested a solution: The "dead" galaxies didn't lack oxygen at all. The gas was just too hot for Hubble to observe. "In fact, there is even more oxygen around those passive galaxies," Oppenheimer says.

All that hot gas could potentially explain why those galaxies died — except that these galaxies were full of star-forming cold gas, too.

"The dead galaxies have plenty of fuel left in the tank," Tumlinson says. "We don't know why they're not using it. Everybody's chasing that problem."

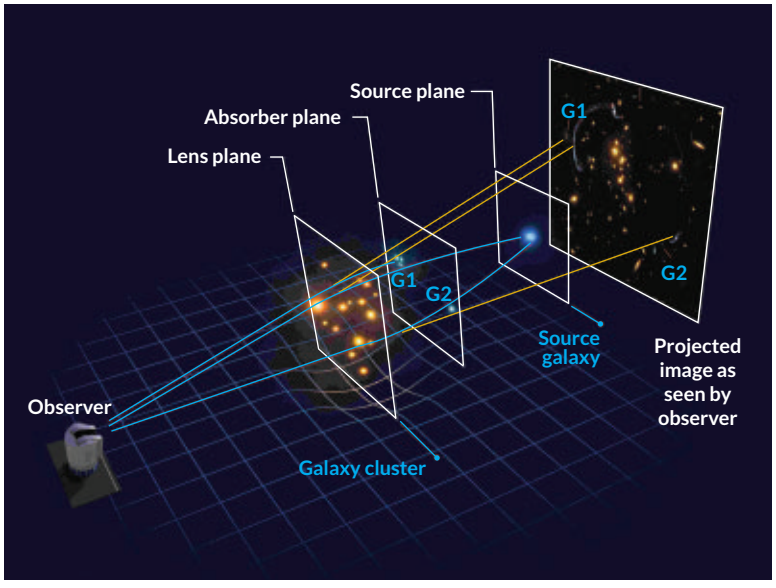
Grabbing at the elephant

The chase comes at a good time. Until recently, observers had no way to map a single galaxy's CGM. Researchers have had to add up dozens of

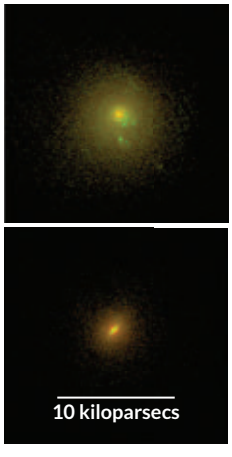


Reading what's not there Using light from a quasar (QSO), researchers can "see" CGMs. In this example, spectra from two galaxies, G1 and G2 (at left), have certain wavelengths missing (red, at bottom) where the CGMs' atoms are absorbing light.

FROM TOP: ERIC LE ROUX/SERVICE COMMUNICATION/UCBL/MUSE/ESO; J. TUMLINSON *ET AL*/*SCIENCE* 2011



MUSE makes a mark Light from a source galaxy is deflected and magnified by an intervening galaxy cluster to form the bright arc seen in the projected image at far right. Unlike a quasar's narrow beam of light, the extensive arc lights up a large area of galaxy G1's CGM, showing it is surprisingly lumpy.



FOGGIE computer simulations improve CGM resolution. In these renderings of the same galaxy, the bottom shows FOGGIE at work. The galaxy's shape and size change dramatically.

quasar beams to understand the composition of CGMs on average.

"We've been like the three blind people grabbing at the elephant," says John O'Meara, an observational astronomer at Saint Michael's College in Colchester, Vt.

Teams using two new spectrographs — KCWI, the Keck Cosmic Web Imager on the Keck telescope in Hawaii, and MUSE, the Multi Unit Spectroscopic Explorer on the Very Large Telescope in Chile — are racing to change that. These instruments, called integral field spectrographs, can read spectra across a full galaxy all at once. Given enough background light, astronomers can now examine a single galaxy's entire CGM. Finally, astronomers have a way to test theories of how gas circulates into and out of a galaxy.

A Chilean team, led by astronomer Sebastian Lopez of the University of Chile in Santiago and colleagues, used MUSE to observe a small dim galaxy that happens to be sandwiched between a bright, distant galaxy and a massive galaxy cluster closer to Earth. The cluster acts as a gravitational lens, distorting the image of the distant galaxy into a long bright arc (*SN: 3/10/12, p. 4*). The light from that arc filtered through the CGM of the sandwiched galaxy, which the team called G1, at 56 different points.

Surprisingly, G1's CGM was lumpy, not smooth as expected, the team reported in the Feb. 22 *Nature*. "The assumption has been that that gas is distributed homogeneously around every system," Lopez says. "This is not the case."

O'Meara is leading a group that is hot on Lopez's trail. Last year, while KCWI was being installed, O'Meara got an hour of observing time and was able to see hydrogen — which is associated with cool, star-forming gas — in the CGM of another galaxy backlit by a bright lensed arc. He's not ready to discuss the results in detail yet, but the team is submitting a paper to *Science*.

Meanwhile, Peeples' team is revisiting how computers render CGMs. "The resolution of the circumgalactic medium in simulations is, um, bad," she says. Existing simulations are good at matching the visible properties of galaxies — their stars, the gas between the stars, and the overall shapes and sizes. But they "utterly fail at reproducing the properties of the circumgalactic medium," she says.

So she's running a new set of simulations called FOGGIE, which focus on CGMs for the first time. "We're finding that it changes everything," she says: The shape, star formation history and even the orientation of the galaxy in space look different.

Together, the new observations and simulations suggest that the CGM's function in the life cycle of a galaxy has been underestimated. Theorists like Peeples and observers like O'Meara are working together to make new predictions about how the CGM should look. Then the researchers will check real galaxies to see if they match.

"Molly will post a really amazing new render of a simulation on Slack, and I'll go, 'Holy crap, that looks weird!'" O'Meara says. "I'll go scampering off to find a similar example in the data, and we get into this positive feedback loop of going 'Holy crap! Holy crap!'"

While future circumgalactic studies will focus on gathering spectra from full CGMs, Tumlinson is hoping to squeeze more information out of Hubble while he still can. Hubble made CGM studies possible, but the telescope is 28 years old, and probably has less than a decade left. Hubble's spectrograph is still the best at observing certain atoms in CGMs to help reveal the gaseous halos' secrets. "It's something we definitely want to do," he says, "before Hubble ends up in the ocean." ■

Explore more

■ Jason Tumlinson, Molly S. Peeples and Jessica K. Werk. "The Circumgalactic Medium." *Annual Review of Astronomy and Astrophysics.* August 2017.

FROM TOP: CARLOS POLANCO, ESO; M.S. PEEPLES *ET AL*/FOGGIE PROJECT

The clean cycle

MICHAEL MORGENSTERN

The body may use sleep as a time to wash away the waste that can cause Alzheimer's disease

By Laura Beil

Neuroscientist Barbara Bendlin studies the brain as Alzheimer's disease develops. When she goes home, she tries to leave her work in the lab. But one recent research project has crossed into her personal life: She now takes sleep much more seriously.

Bendlin works at the University of Wisconsin–Madison, home to the Wisconsin Registry for Alzheimer's Prevention, a study of more than 1,500 people who were ages 40 to 65 when they signed up. Members of the registry did not have symptoms of dementia when they volunteered, but more than 70 percent had a family history of Alzheimer's disease.

Since 2001, participants have been tested regularly for memory loss and other signs of the

disease, such as the presence of amyloid-beta, a protein fragment that can clump into sticky plaques in the brain. Those plaques are a hallmark of Alzheimer's, the most common form of dementia.

Each person also fills out lengthy questionnaires about their lives in the hopes that one day the information will offer clues to the disease. Among the inquiries: How tired are you?

Some answers to the sleep questions have been eye-opening. Bendlin and her colleagues identified 98 people from the registry who recorded their sleep quality and had brain scans. Those who slept badly — measured by such things as being tired during the day — tended to have more A-beta plaques visible on brain imaging, the researchers reported in 2015 in *Neurobiology of Aging*.

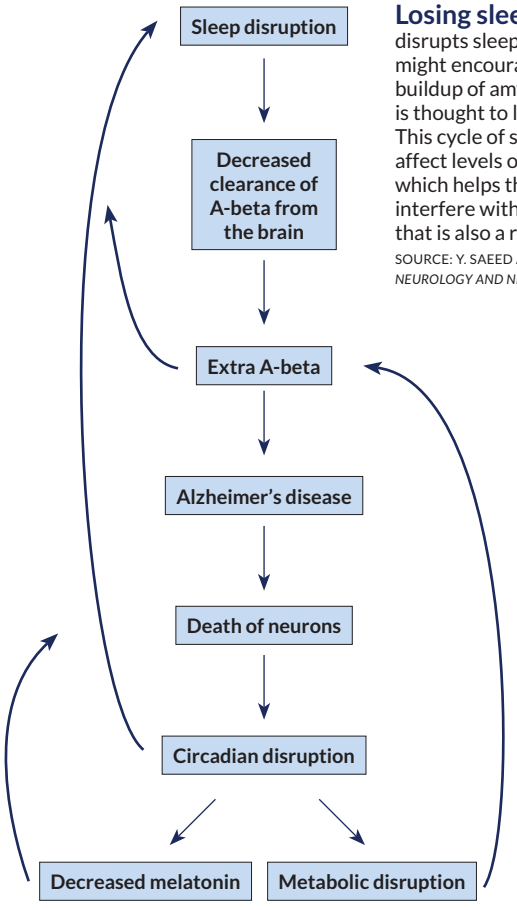
In a different subgroup of 101 people willing to have a spinal tap, poor sleep was associated with biological markers of Alzheimer's in the spinal fluid, Bendlin's team reported last year in *Neurology*. The markers included some related to A-beta plaques, as well as inflammation and the protein tau, which appears in higher levels in the brains of people with Alzheimer's.

Bendlin's studies are part of a modest but growing body of research suggesting that a sleep-deprived brain might be more vulnerable to Alzheimer's disease. In animal studies, levels of plaque-forming A-beta plummet during sleep. Other research suggests that a snoozing brain runs the "clean cycle" to remove the day's metabolic debris — notably A-beta — an action that might protect against the disease. Even one sleepless night appears to leave behind an excess of the troublesome protein fragment (*SN Online: 7/10/17*).

But while the new research is compelling, plenty of gaps remain. There's not enough evidence yet to know the degree to which sleep might make a difference in the disease, and study results are not consistent.

A 2017 analysis combined results of 27 studies that looked at the relationship between sleep and cognitive problems, including Alzheimer's. Overall, poor sleepers appeared to have about a 68 percent higher risk of these disorders than those who were rested, researchers reported last year in *Sleep*. That said, most studies have a chicken-and-egg problem. Alzheimer's is known to cause difficulty sleeping. If Alzheimer's both affects sleep and is affected by it, which comes first?

For now, the direction and the strength of the cause-and-effect arrow remain unclear. But approximately one-third of U.S. adults are considered sleep deprived (getting less than seven hours of sleep a night) and Alzheimer's is expected to strike almost 14 million U.S. adults by 2050 (5.7 million have the disease today). The research has the potential to make a big difference.



Losing sleep Alzheimer's disease disrupts sleep. And disrupted sleep itself might encourage Alzheimer's by allowing buildup of amyloid-beta, or A-beta, which is thought to lead to the death of neurons. This cycle of sleep deprivation can also affect levels of the hormone melatonin, which helps the body to sleep, and can interfere with metabolism, a disruption that is also a risk factor for Alzheimer's.

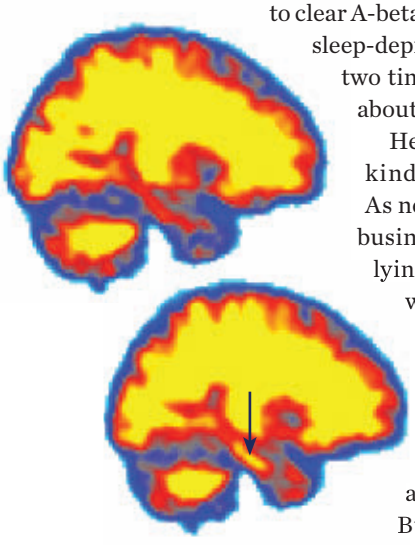
SOURCE: Y. SAEED AND S.M. ABBOTT/*CURRENT NEUROLOGY AND NEUROSCIENCE REPORTS* 2017

Dream weavers

It would be easier to understand sleep deprivation if scientists had a better handle on sleep itself. The brain appears to use sleep to consolidate and process memories (*SN: 6/11/16, p. 15*) and to catalog thoughts from the day. But that can't be all. Even the simplest animals need to sleep. Flies and worms sleep.

But mammals appear to be particularly dependent on sleep — even if some, like elephants and giraffes, hardly nod off at all (*SN: 4/1/17, p. 10*). If rats are forced to stay awake, they die in about a month, sometimes within days.

And the bodies and brains of mice change when they are kept awake, says neurologist David Holtzman of Washington University School of Medicine in St. Louis. In one landmark experiment, Holtzman toyed with mice's sleep right



Hard day's night
Scientists measured accumulation of amyloid-beta in people who were rested (top) and then again after 31 hours without sleep (bottom). In this PET scan of one volunteer's brain, levels of A-beta, which is linked to Alzheimer's, rose in the hippocampus (yellow at arrow) after sleep deprivation.

when the animals' brain would normally begin to clear A-beta. Compared with well-rested mice, sleep-deprived animals developed more than two times as many amyloid plaques over about a month, Holtzman says.

He thinks Alzheimer's disease is a kind of garbage collection problem. As nerve cells, or neurons, take care of business, they tend to leave their trash lying around. They throw away A-beta, which is a leftover remnant of a larger protein that is thought to form connections between neurons in the developing brain, but whose role in adults is still being studied. The body usually clears away A-beta.

But sometimes, especially when cheated on sleep, the brain doesn't get the chance to mop up all the A-beta that the neurons produce, according to a developing consensus. A-beta starts to collect in the small seams between cells of the brain, like litter in the gutter. If A-beta piles up too much, it can accumulate into plaques that are thought to eventually lead to other problems such as inflammation and the buildup of tau, which appears to destroy neurons and lead to Alzheimer's disease.

About a decade ago, Holtzman wanted to know if levels of A-beta in the fluid that bathes neurons fluctuated as mice ate, exercised, slept and otherwise did what mice do. It seemed like a run-of-the-mill question. To Holtzman's surprise, time of day mattered — a lot. A-beta levels were highest when the animals were awake but fell when the mice were sleeping (*SN: 10/24/09, p. 11*).

"We just stumbled across this," Holtzman says. Still, it wasn't clear whether the difference was related to the hour, or to sleep itself. So Holtzman and colleagues designed an experiment in which they used a drug to force mice to stay awake or fall asleep. Sure enough, the A-beta levels in the brain-bathing fluid rose and fell with sleep, regardless of the time on the clock.

A-beta levels in deeply sleeping versus wide-awake mice differed by about 25 percent. That may not sound like a dramatic drop, but over the long term, "it definitely will influence the probability [that A-beta] will aggregate to form amyloid plaques," Holtzman says.

The study turned conventional thinking on its head: Perhaps Alzheimer's doesn't just make it hard to sleep. Perhaps interrupted sleep drives the development of Alzheimer's itself.

Published in *Science* in 2009, the paper triggered a flood of research into sleep and Alzheimer's. While the initial experiment found that the condition worsens the longer animals are awake, research since then has found that the reverse is true, too, at least in flies and mice.

Using fruit flies genetically programmed to mimic the neurological damage of Alzheimer's disease, a team led by researchers at Washington University School of Medicine reversed the cognitive problems of the disease by simply forcing the flies to sleep (*SN: 5/16/15, p. 13*).

Researchers from Germany and Israel reported in 2015 in *Nature Neuroscience* that slow-wave sleep — the deep sleep that occupies the brain most during a long snooze and is thought to be involved in memory storage — was disrupted in mice that had A-beta deposits in their brains. When the mice were given low doses of a sleep-inducing drug, the animals slept more soundly and improved their memory and ability to navigate a water maze.

Gray matters

Even with these studies in lab animals indicating that loss of sleep accelerates Alzheimer's, researchers still hesitate to say the same is true in people. There's too little data. Human studies are harder and more complicated to do. One big hurdle: The brain changes in humans that lead to Alzheimer's build up over decades. And you can't do a controlled experiment in people that forces half of the study's volunteers to endure years of sleep deprivation.

Plus the nagging chicken-and-egg problem is hard to get around, although a study published in June in *JAMA Neurology* tried. Researchers from the Mayo Clinic in Rochester, Minn., examined the medical records of 283 people older than 70. None had dementia when they enrolled in the Mayo Clinic Study of Aging. At the study's start, participants answered questions about their sleep quality and received brain scans looking for plaque deposits.

People who reported excessive daytime sleepiness — a telltale sign of fitful sleep — had more plaques in their brains to start with. When checked again about two years later, those same people showed a more rapid accumulation than people who slept soundly.

Other scientists have used brain scans to measure what happens to A-beta in people's brains after a sleepless night. Researchers from the National Institutes of Health and colleagues

E. SHOKRI-KOJORI/NIH

completed a study involving 20 healthy people who had a brain scan while rested and then again after they were forced to stay awake for 31 hours.

Nora Volkow, head of the National Institute on Drug Abuse in Bethesda, Md., led the study. She is interested in sleep's potential connections to dementia because people with drug addiction have massive disruptions of sleep. For the study, the researchers injected people with a compound that latches onto A-beta and makes it visible under a PET scanner.

The sleep-deprived brains showed an increase in A-beta accumulation that was about 5 percent higher in two areas of the brain that are often damaged early in Alzheimer's: the thalamus and hippocampus. Other regions had lesser buildup.

"I was surprised that it was actually so large," says study coauthor Ehsan Shokri-Kojori, now at the National Institute on Alcohol Abuse and Alcoholism. "Five percent from one night of sleep deprivation is far from trivial." And while the brain can likely recover with a good night's sleep, the question is: What happens when sleep deprivation is a pattern night after night, year after year?

"It does highlight that sleep is indispensable for proper brain function," Volkow says. "What we have to question is what happens when you are consistently sleep deprived." The study was published April 24 in the *Proceedings of the National Academy of Sciences*.

As tantalizing as studies like this may seem, there are still inconsistencies that scientists are trying to resolve. Consider a study published in May in *Sleep* from a team of Swedish and British researchers. They set out to measure levels of A-beta in cerebrospinal fluid and markers of neuron injury in 13 volunteers, sleep deprived and not.

The first measurements took place after five nights of sound sleep. Then participants were cut back to four hours of sleep a night, for five nights. Four participants even lasted eight days with only four hours of nightly sleep. After good sleep versus very little, the measurements did not show the expected differences.

"That was surprising," says Henrik Zetterberg of the University Gothenburg in Sweden. Given the previous studies, including his own, "I would have expected a change."

He notes, however, that the study participants were all healthy people in their 20s and 30s. Their youthful brains might cope with sleep deprivation more readily than those in middle age and older. But that's just a hypothesis. "It shows why we have to do further research," he says.

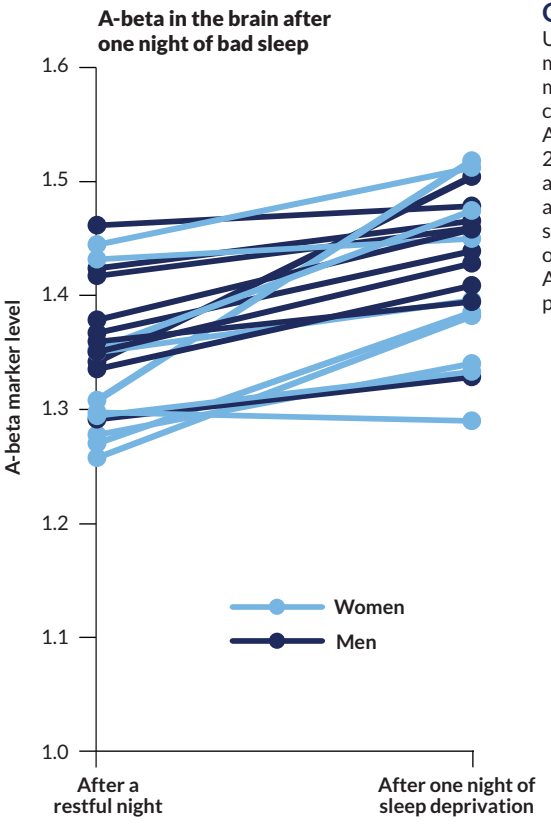
Rinse cycle

Questions could be better answered if scientists could find a mechanism to explain how sleepless nights might exacerbate Alzheimer's. In 2013, scientists revealed an important clue.

The lymphatic system flows through the body's tissues to pick up waste and carry it away. All lymphatic vessels run to the liver, the body's recycling plant for used proteins from each organ's operation. But the lymphatic system doesn't reach the brain.

"I found it weird because the brain is our most precious organ — why should it be the only organ that recycles its own proteins?" asks Maiken Nedergaard, a neuroscientist at the University of Rochester in New York. Maybe, she thought, the brain has "a hidden lymphatic system."

Nedergaard and colleagues decided to measure cerebrospinal fluid throughout the brain. When mice were awake, there appeared to be little circulation of fluid in the brain. Then the team examined sleeping mice. "You take mice and train them to be quiet under a microscope," Nedergaard says. "The mice after a couple of days feel very



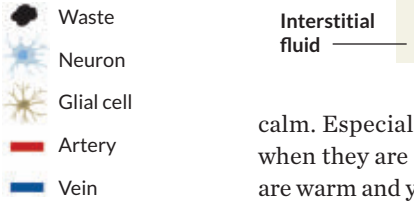
One bad night
Using PET scans to measure amyloid-beta markers, researchers compared levels of A-beta in the brains of 20 healthy volunteers after one restful night and after one night of sleep deprivation. Levels of the plaque-forming A-beta rose in most people tested.

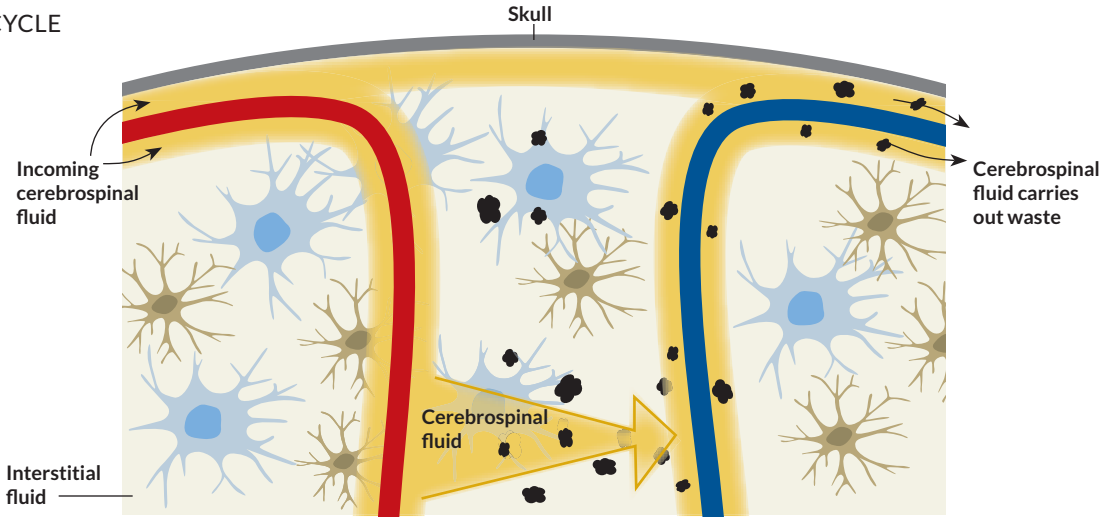
E. SHOKRI-KOJORI ET AL/ PNAS 2018

Go with the flow

One way the brain might clear out waste, including amyloid-beta, is via circulation of cerebrospinal and interstitial fluids. Fluid flows through the spaces in the brain, bathing neurons and eventually carrying debris out of the brain toward the liver. Studies suggest that this "glymphatic" circulation increases during sleep.

SOURCE: M. NEDERGAARD/*SCIENCE* 2013





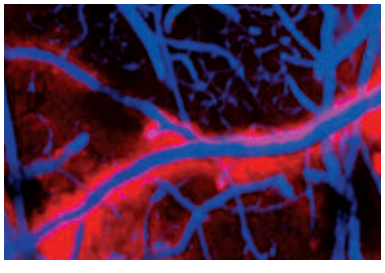
calm. Especially if you do it during the daytime when they are supposed to be sleeping, and they are warm and you give them sugar water. They're not afraid."

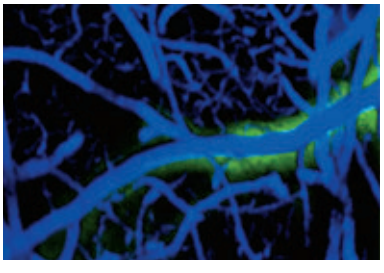
The day of the experiment, the scientists made a hole in the mice's skulls, placed a cover over it and injected a dye to measure cerebrospinal fluid in the brain. During sleep, the spaces between the brain cells widened by about 60 percent and allowed more fluid to wash through, taking the metabolic debris, including A-beta, with it.

"It's like the dishwasher turned on," Nedergaard says. She named this phenomenon the "glymphatic system" because it appears to be controlled by glial cells, brain cells that help insulate neurons and perform much of the brain's routine maintenance work (*SN: 8/22/15, p. 18*).

Similar observations of cerebrospinal fluid circulation have been carried out in people, but with less invasive ways of measuring. In one, researchers from Oslo University Hospital, Rikshospitalet compared 15 patients who had a condition called normal pressure hydrocephalus, a kind of dementia caused by buildup of cerebrospinal fluid in the cavities of the brain, with eight people who didn't have the condition.

The researchers used a tracer for cerebrospinal fluid and magnetic resonance imaging to measure the flow over 24 hours. Immediately after a night's sleep, cerebrospinal fluid had drained in healthy people but lingered in the patients with dementia, the researchers reported in *Brain* in 2017.





Flow of cerebrospinal fluid in a mouse's brain is much higher during sleep (left, red) than when the animal is awake (right, green).

FROM TOP: E. OTWELL; M. NEDERGAARD

Don't snooze, you lose?

The central question — the one that doctors really want to answer — is whether better sleep could treat or even prevent Alzheimer's. To try to figure this out, Bendlin and her Wisconsin colleagues are now studying people with sleep apnea. People with that condition stop breathing during the night, which wakes them up and makes for a lousy night's sleep. A machine called a CPAP, short for continuous positive airway pressure, treats the condition.

"Once people start treatment, what might we see in the brain? Is there a beneficial effect of CPAP on markers of Alzheimer's?" Bendlin wonders. "I think that's a big question because the implications are so large."

A study reported in *Neurology* in 2015 offers a reason to think CPAP might help. Using data from almost 2,500 people in the Alzheimer's Disease Neuroimaging Initiative, researchers at the New York University School of Medicine found that people with sleep disorders like obstructive sleep apnea showed signs of mild cognitive problems and Alzheimer's disease at younger ages than those who did not. But for those who used CPAP, onset of mild cognitive problems was delayed.

"If we find out that sleep problems contribute to brain amyloid — what that really says is there may be a window to intervene," Bendlin says. And the solution — more attention to sleep — is one prescription with no side effects. ■

Explore more

■ Yumna Saeed and Sabra M. Abbott. "Circadian disruption associated with Alzheimer's Disease." *Current Neurology and Neuroscience Reports*. April 2017.

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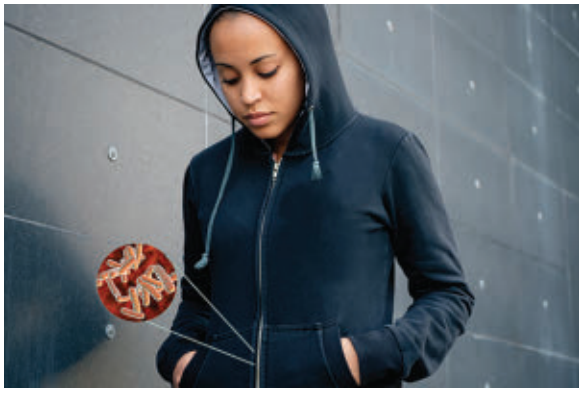


Belly bacteria can shape mood and behavior

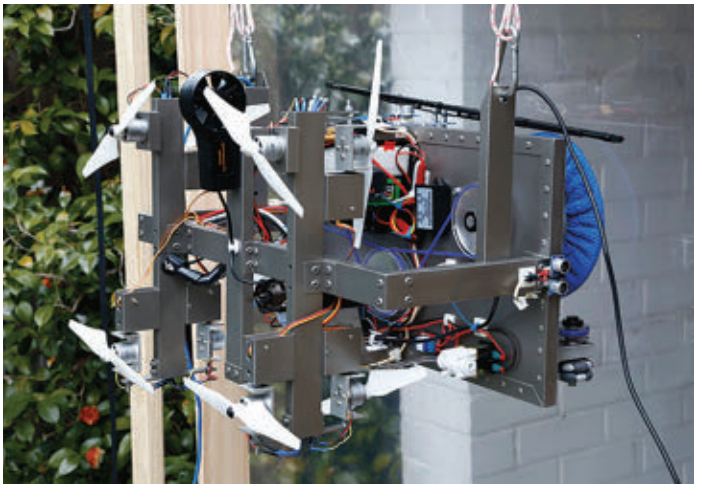
When Margaret Morris goes to the grocery store, she fills her cart with french fries, cheesecakes, meat pies and other tasty treats. People often ask if she's throwing a party. And she is, but her guests are lab rats. The animals are helping her study how a junk food diet affects the nonstop chemical "chatter" between the brain, the gut and all of the many microbes living in the gut. By eavesdropping on what those microbial freeloaders "tell" the brain, Morris and other scientists are revealing the extent to which foods can influence our feelings and behavior. — *Bethany Brookshire*

Read more: **www.sciencenewsforstudents.org/belly**

Surprise! Fire can help some forests keep more of their water

In forests, abundant trees are good and fire is bad, right? Actually, the reverse can be true — especially in some dry parts of California, a new study concludes. Trees release some of the water they absorb into the air through pores in their leaves. Periodic tree loss due to wildfires clears out many of the young trees, leaving fewer plants to pull water from the soil. With less competition from other plants, the larger trees can grow and remain healthy. Not suppressing wildfires in the 5,310-square-kilometer American River basin could save an estimated 773 billion liters of water per year that's not being lost to the air, the study finds. — *Michelle Donahue*

Read more: **www.sciencenewsforstudents.org/forest-fire**



This robot can wash a skyscraper's windows

Washing windows on a high-rise can be a dangerous job, notes Oliver Nicholls. So the Australian teen created a robot to do it. About the size of a medium-sized picnic cooler, the robot withstands winds of up to 45 kilometers per hour. The economically competitive, computer-controlled device sprays a window, then scrubs away dirt and leftover water. Next, propellers push the device off the glass so cables can bring the bot to the next window. This nifty invention earned Nicholls, age 19, $75,000 and the top prize at the Intel International Science and Engineering Fair in May. — *Sid Perkins*

Read more: **www.sciencenewsforstudents.org/window-washer**

FROM TOP: TOMMASO79; DR_MICROBE/ISTOCKPHOTO. ADAPTED BY L. STEENBLIK HWANG; G. DICKMAN/NSF; O. NICHOLLS

Buzz: The Nature and Necessity of Bees
Thor Hanson
BASIC BOOKS, $27

INTERVIEW

People, and Big Macs, depend on bees

When you hear the word *bee*, the image that pops to mind is probably a honeybee. Maybe a bumblebee. But for conservation biologist Thor Hanson, author of the new book *Buzz*, the world is abuzz with thousands of kinds of bees, each as beautiful and intriguing as the flowers on which they land.

Speaking from his "raccoon shack" on San Juan Island in Washington — a backyard shed converted to an office and bee-watching space, and named for its previous inhabitants — Hanson shares what he's learned about how bees helped drive human evolution, the amazing birds that lead people to honey, and what a Big Mac would look like without bees. The following conversation has been edited for length and clarity. — *Erika Engelhaupt*

This bee book is unusual — it isn't mainly about honeybees. Why did you write about lesser-known bees?
I made a deliberate decision because I thought the celebrity bees, the honeybees, would steal the show. It was high time to turn a stage light onto these 20,000 other species of bees, which have habits that are less familiar but just as fascinating. For example, most people think of hives when they think of bees, but actually most bees are solitary.

You write that this book is an "exploration of how the very nature of bees makes them so utterly necessary." So let's cut to the chase: Why are bees necessary?
First is the deep connection between bees and flowering plants. They've had a partnership from an early stage; each spurs the other in terms of diversity. It's an incredible role that bees have played in shaping the natural world. They're also important to our lifestyle, first for their role in the human diet. It's often said that one of every three bites of food depends on bees.

But there are all these other connections that we don't think about: Bees have provided light from beeswax candles and sweetness from honey. Early industrial uses of wax included making bronze sculptures with wax molds, batiks in Indonesia and wax tablets to write on.

You can trace our relationship with bees back not hundreds, but *hundreds of thousands* of years. The role of honey in the human diet goes back into prehistory. That source of sugar may have even helped fuel the expansion of our brain size. It may have helped us become who we are.

One of the most astonishing examples of our relationship with bees has to do with a bird called the honeyguide. Tell me about that.
Hunter-gatherers in Africa follow this bird to bees' nests, and have for generations (*SN: 8/20/16, p. 10*). The honeyguide is very good at locating a hive. But on its own, it can't access the nest. So once it locates one, the next thing it does is look for people. It hops around on branches and makes a piercing cry to get attention, then leads a person to the honey. People climb the tree or dig out the nest, and honeyguides feed on the remains.

Thor Hanson, shown here catching bees for identification, wants people to appreciate the diversity and importance of bees.

NOAH HANSON

What's funny is how long it took biologists to figure out this relationship. The original explanation was that the honeyguide coevolved with the honey badger, which also raids nests for honey. Then a biologist pointed out that badgers are nocturnal, and the birds aren't. Also, no one has ever seen a honeyguide leading a badger. It makes more sense that the relationship evolved on the savannah with people out looking for honey every day.

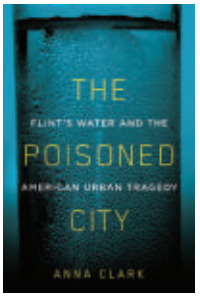
One of the book's most hilariously geeky moments is when you go to McDonald's and pick apart a Big Mac. Why did you do that?
I wanted to look for the significance of bees in an unexpected place. And you don't think of bees when you go into McDonald's — you just don't! I didn't care how much people stared. I sat there with my tweezers, pulling all the seeds off the bun. I ended up with one pile you could have without bees [meat and bun] and one you couldn't [including not only the veggies, but also the cheese and special sauce]. We could still eat, but it would be pretty dull.

You're worried about bees. Why?
It's the four p's: pesticides, pathogens, parasites and poor nutrition. Poor nutrition is one that people don't think of. We ship honeybees all over the place, and they get force-fed almond blossoms for three weeks, then they're packed onto trucks and shipped off to pollinate apples. It's not a healthy lifestyle, and not a varied diet.

You say that bees are one of the few insects that inspire fondness instead of fear. Why do you think that is?
Bees have been with us from the beginning. Our primordial sweet tooth led us to follow these creatures, then we domesticated bees very early on, setting out hives and reusing good sites in baobab trees. I think we have a very deep connection to these creatures. ■

BOOKSHELF

Flint's water tragedy laid bare



The Poisoned City
Anna Clark
METROPOLITAN BOOKS, $30

America is built on lead. Networks of aging pipes made from the bluish-gray metal bring water into millions of U.S. homes. But when lead, a poison to the nervous system, gets into drinking water — as happened in Flint, Mich. — the heavy metal can cause irreparable harm (*SN: 3/19/16, p. 8*). In *The Poisoned City,* journalist Anna Clark provides a thorough, nuanced account of the public health disaster in Flint — one that, she argues, was magnified by government malfeasance and decades of systemic racism.

Trouble first began in April 2014. To save the cash-strapped city some money, Flint's emergency manager switched the city's source of water from Detroit's water system, which drew from Lake Huron, to one that tapped the Flint River. But the city's water treatment program didn't include corrosion control, which the Michigan Department of Environmental Quality said wasn't necessary — a violation of federal law. The result: Corroded pipes leached lead into drinking water.

Residents, forced to use the brown, smelly tap water, developed rashes and lost clumps of hair. Twelve people died from *Legionella* bacteria, which the corrosive water dislodged from pipes, and dozens more were sickened. Despite residents' complaints, as well as an independent analysis that found higher-than-allowable lead levels, state officials insisted that the water was safe, even when their own internal records showed it was not. "Anyone who is concerned about lead in the drinking water in Flint can relax," said one spokesperson for the Michigan Department of Environmental Quality.

That's when one of the book's heroes, pediatrician Mona Hanna-Attisha, enters Clark's story. About 18 months after Flint switched to its new water source, the percentage of children under age 5 with high blood-lead levels nearly doubled from 2.1 to 4 percent, Hanna-Attisha discovered after taking a close look at Flint kids' medical records. (Hanna-Attisha's own account of her experiences, *What the Eyes Don't See*, was published in June.)

Faced with mounting evidence that became hard to ignore, Gov. Rick Snyder negotiated a switch back to Detroit's water system in October 2015, declaring a state of emergency a few months later. Meanwhile, taps in Flint were retrofitted with filters as the long, slow process of replacing pipes began. The Michigan National Guard trucked in bottled water.

Readers who followed this crisis as it unfolded will still learn plenty in *The Poisoned City*. Clark goes into exquisite detail explaining not only what happened, but also *why* it happened. A history of racist housing, education and hiring practices precipitated the city's "debt, dysfunctional urban policy, disappearing investment, disintegrating infrastructure, and a compromised democratic process," she writes. The evidence linking these factors to the water crisis is compelling. Anyone wanting to dig deeper can refer to the book's exhaustive bibliography.

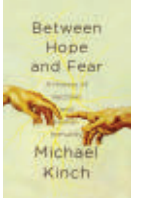
Overall, Clark does a masterful job weaving together history, science and rigorous reporting to tell Flint's story, which served as a "wake-up call" for cities around the country. A 2016 investigation by the Natural Resources Defense Council found that more than 5,300 water systems across the United States were in violation of federal lead rules. And it's not just cities that are affected, Clark notes. Rural America is vulnerable, too. But replacing America's lead pipes is an expensive proposition. By some estimates, removing lead service lines alone would cost somewhere between $30 billion and $1 trillion.

Four years after Flint's water crisis began, residents are still grappling with lingering effects: potentially lifelong health problems, ruined pipes that will take years to fix and zero trust in government. In April, Michigan declared Flint's water safe. But people who live in the city are not convinced. And Hanna-Attisha has urged the state to continue Flint's bottled water program until all of the lead service lines are replaced. — *Cassie Martin*

BOOKSHELF

Troublesome Science
Rob DeSalle and Ian Tattersall
Armed with genetic evidence, two researchers argue that there's no biological basis for classifying humans into races. *Columbia Univ., $35*

Unnatural Selection
Katrina van Grouw
With more than 400 illustrations, this coffee table book documents how selective breeding has transformed dogs, pigeons and other domestic animals. *Princeton Univ., $45*



Between Hope and Fear
Michael Kinch
A medical researcher introduces readers to immunology and chronicles the history of vaccine science and antivaxxers. *Pegasus Books, $27.95*

Blossoms
Maxine F. Singer
This primer on flower genetics looks at how genes and environmental cues work together to influence the color, scent and timing of blooms. *Oxford Univ., $22.95*

JUNE 9, 2018

Pressure gauge

The pressure inside a proton is the highest of any known substance, ***Emily Conover*** *reported in "Protons break the record for pressure"* (SN: 6/9/18, p. 10).

"I don't think it's valid to think of pressure on a quantum level the same way we do classically," Reddit user **phazer6** wrote. Pressure relates to collections of particles, but "here we're dealing with a single particle.... How can we possibly speak of pressure the same way in such different contexts?" **phazer6** asked.

Although the proton can be thought of as a single particle, it is made up of other particles called quarks and gluons that interact with one another. The way we normally think of pressure in a gas is based on molecules' motions and how molecules bounce off walls of the container that confines them. "In an ideal gas, the molecules do not interact with each other," says theoretical particle physicist **Peter Schweitzer** of the University of Connecticut in Storrs. Pressure can also be defined for liquids and solids, in which internal forces allow molecules to interact. The difference for a proton is that the interaction is extremely strong, so that it is impossible for a lone quark to escape. There's no direct way to measure a proton's internal pressure, "but one can infer information about the pressure... from high energy experiments," **Schweitzer** says.

Wearable worries

Casual daywear may someday contain serious tech, ***Maria Temming*** *and* ***Mariah Quintanilla*** *reported in "Fashion forward"* (SN: 6/9/18, p. 18).

Online reader **Mizuki Mochizuki** wondered about the harm that electronics in clothing may pose to wearers.

Most clothing-embedded electronics would run on very low current — like today's wearable devices — and couldn't give users an electric shock, says wearable technology researcher **Lucy Dunne** of the University of Minnesota campus in St. Paul. The battery used to power the electronics is another question. If a high-capacity battery were used, it would have the same risks as a mobile phone, she says. The battery could overheat and catch fire if shorted or crushed. "Durability would have to be a manufacturer concern, just as it is with mobile phones," **Dunne** says.

Out of range

If global warming exceeds 1.5 degrees Celsius, the geographic ranges of many land-based species may shrink, ***Carolyn Gramling*** *reported in "A little less warming could save species"* (SN: 6/9/18, p. 6).

Online reader **Mark S.** thought that insect ranges would expand.

That's a common assumption, but insect species, like the plants and vertebrates in the study, each have their preferred climatic niches: not too hot or cold, not too wet or dry, **Gramling** says. "The researchers looked broadly at how the distribution of preferred niches is projected to change as the planet warms," she says. "But they did not consider how well specific species might be able to adapt to a changing climate, which is a focus of very active research."

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X-rays help hidden faces see the light

With the aid of a particle accelerator, scientists are bringing back ghosts from the past, revealing portraits hidden underneath the tarnished surface of two roughly 150-year-old silver photographic plates.

Researchers used an accelerator called a synchrotron to produce strong, nondamaging X-rays to scan the photographs, called daguerreotypes, and map their chemical composition. This allowed Madalena Kozachuk, a chemist at Western University in London, Canada, and colleagues to trace mercury deposits in the plates and create digital copies of the hidden images, the team reports June 22 in *Scientific Reports*. One image revealed a woman (top); the other, a man who had been completely obscured by tarnish (left).

An early form of photography, daguerreotypes were popular from the 1840s through the 1860s. Photographers crafted the images by making a silver-coated copper plate and treating it with iodine vapor to generate a light-sensitive surface. Subjects sat still for the several minutes required to expose the plate and create an image. Then the plate was treated with heated mercury vapor and a gold solution to develop the image, creating tiny silver-mercury-gold particles where light struck the plate during the exposure process. These particles make up the image, reflecting white light. Lighter parts of an image, such as the woman's hands and collar, have a higher density of these particles.

The researchers used mercury to map the contours of the original images because that metal remains fixed in place under years of cloudy tarnish. The scans revealed where the original particles were, letting researchers reconstruct the image. Scanning the roughly 8-by-7-centimeter daguerreotypes, provided by the National Gallery of Canada, was time-consuming, taking about eight hours per square centimeter.

Synchrotrons had never been used to image daguerreotypes before, so Kozachuk didn't know what to expect. "When the image became apparent, it was jaw-dropping," she says. The machines are expensive, and getting time to work on them can be difficult. But she hopes her research will help museums to reveal more of these faded faces.

— Katherine Bourzac

UNPROCESSED IMAGES: NATIONAL GALLERY OF CANADA; PROCESSED: M.S. KOZACHUK *ET AL/SCIENTIFIC REPORTS* 2018

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