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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
NOVEMBER 24, 2018

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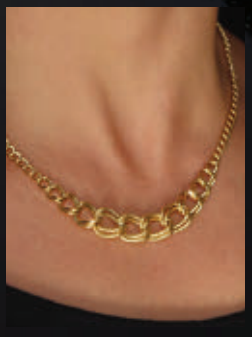

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SOCIETY UPDATE
Recent articles from *Science News for Students*

COVER The Columbian mammoth, which stood about 4 meters tall at the shoulder, went extinct about 11,000 years ago. *Sergio de la Rosa*

FROM TOP: KOKOROYUKI/ISTOCK.COM; COLDCREATION/WIKIMEDIA COMMONS; K.C. CATANIA/*BRAIN, BEHAVIOR AND EVOLUTION* 2018

Do you know how your drinking water is treated?

Disinfection of public drinking water is one of the great public health success stories of the 20th century. In 1900, outbreaks of cholera and typhoid, both caused by waterborne bacteria, were common in American cities. In 1908, Jersey City, N.J., became the first U.S. city to routinely disinfect community water. Other cities and towns quickly followed, and by 1920, the typhoid rate in the United States had dropped by 66 percent.

But that battle isn't over. Around the world, more than 2 billion people lack reliable access to safe water (*SN: 8/18/18, p. 14*), and half a million people die each year from diarrhea caused by contaminated water, according to the World Health Organization.

And in the United States, challenges remain. The management failures that caused the 2014 lead contamination crisis in Flint, Mich., were a wake-up call (*SN: 3/19/16, p. 8*), but Flint is hardly alone. Systems in other big cities are also falling short. In October, officials in Newark, N.J., scrambled to hand out home water filters after it became clear that efforts to prevent lead from leaching into drinking water were not getting the job done. In the first six months of 2017, more than 22 percent of water samples in that city exceeded federal limits for lead, according to news reports.

If big cities are struggling, small towns with skimpy budgets as well as the many people who get their water from private wells often have it harder, lacking access to the infrastructure or technology to make water reliably safe. But science can help.

In this issue, *Science News* staff writer Laurel Hamers digs into the latest research on water treatment technology and finds a focus on efforts to invent affordable, scalable solutions (Page 18). There's a lot of engineering and chemistry involved, not surprisingly, and also physics — it's hard to move water efficiently through a filter while also catching the bad stuff. Her story is a testament to researcher ingenuity, and a helpful primer on how a typical municipal water treatment plant works.

As I read Hamers' story, I realized that I didn't know how our water is treated here in Washington, D.C., even though I live barely a mile from one of the city's two treatment plants. (I at least get credit for knowing the water comes from the Potomac River.) So I Googled it and found a description of how that process works. Plus I found data on potential contaminants such as *Giardia* and *Cryptosporidium*, as well as information on how residents can get their water tested for lead, which can leach from pipes or fixtures.

I also learned that each spring, the Washington Aqueduct briefly switches disinfectants from chloramine to chlorine while the agency cleans the water pipes. That might explain the short-lived swimming pool smell in the tap water.

For me, this became a double win; I learned a lot about advances in water treatment technology from Hamers' reporting, and I was motivated to seek out information about my local water supply.

If other readers feel inspired by our work to learn more, count me as a happy journalist. — *Nancy Shute, Editor in Chief*

Science News
1719 N Street NW, Washington, DC 20036
(202) 785-2255

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Excerpt from the November 23, 1968 issue of *Science News*

50 YEARS AGO

Screwworm fly upsurge

Screwworms, the first pest to be eliminated on a large scale by the use of the sterile male technique, have shown an alarming increase, according to U.S. and Mexican officials.... The screwworm fly lays its eggs in open wounds on cattle. The maggots live on the flesh of their host, causing damage and death, and economic losses of many millions of dollars.

UPDATE: Though eradicated in the United States in 1966, screwworms reemerged two years later, probably coming up from Mexico. Outbreaks in southern U.S. states in 1972 and in Florida in 2016 were both handled with the sterile male technique, considered one of the most successful approaches for pest control. Males are sterilized with radiation, then released into a population to breed with wild counterparts; no offspring result. The method has been used with other pests, such as mosquitoes, which were dropped by drones over Brazil this year as a test before the technology is used against outbreaks like the Zika virus.

Andrea Odell, shown at Alaska's Hansen Creek in August 2018, demonstrates proper salmon-flinging technique.

THE SCIENCE LIFE

Rotting salmon do a forest good

How much salmon would scientists sling if scientists could sling salmon? For one research team, the question isn't hypothetical, and the answer is ... tons.

During 20 years of monitoring salmon populations in a southwest Alaskan stream, ecologists found and flung a total of 267,620 kilograms of dead fish into the forest. Those rotting carcasses leeched enough nutrients to speed up tree growth, researchers report in the November *Ecology*.

Some of the fish had died of old age, and others had been torn apart by gulls or brown bears, says ecologist Thomas Quinn. He's been counting salmon, both dead and alive, in Hansen Creek every year since 1997 with a rotating cast of students from the University of Washington in Seattle. For each dead fish, students catalog the cause of death, then chuck the carcasses to one bank of the creek to avoid double counting.

Researchers have been surveying the salmon population in an Alaskan creek for decades.

Fish tossing is something of an art. The researchers use a gaff, a long pole with a hook on one end. The ideal motion is like a checked swing in baseball, when a batter starts to swing but instead lets the ball pass, Quinn says. If all goes well, the salmon carcass launches off the gaff in a graceful arc and lands far enough away that it won't be washed back into the stream.

"Some students are clumsy," he says. "Some are naturals." But with a little practice, everyone makes it work.

Two decades and 217,055 flung salmon later, Quinn and company have inadvertently tested the impact of changing nutrients over a two-kilometer stretch of stream, where one side received nearly six times as much salmon as the other. The idea that salmon can wash ashore and affect plant growth isn't new, but the effect has been difficult to test accurately. Earlier efforts have compared trees near streams with and without salmon, or trees above and below a salmon-stopping waterfall. But those sites differed in other ways that could affect tree growth.

On both sides of the creek, Quinn's team measured tree trunk diameters, yearly growth recorded in tree rings and nitrogen isotopes in the needles of white spruces. Trees on the salmon-fertilized bank grew faster during the 20-year study than in the previous 20 years. The trees on the other bank didn't have such a growth spurt. Plus, more of the nitrogen in the fish-fed spruce needles came from oceanic sources — evidence the salmon made a difference.

Just looking at the trees, the impact isn't apparent — "a nice reminder that ecology is about limits," Quinn says. "No matter how many carcasses you throw ... trees are still going to be limited by other things." — *Laurel Hamers*

FROM TOP: DAN DINICOLA/UNIV. OF WASHINGTON; DENNIS WISE/UNIV. OF WASHINGTON

MYSTERY SOLVED

Worms lure next meal

These worms have food delivery all figured out. Entomopathogenic, or insect-killing, nematodes feed on an insect and multiply, while attracting their next feast, scientists report October 13 at bioRxiv.org. But how?

Farmers use the *Heterorhabditis bacteriophora* nematode to control pests, such as rootworms. Scientists at Switzerland's University of Bern tested whether rootworm larvae, which eat corn roots, would avoid a plant's soil if infested with nematodes. Surprisingly, up to two-thirds of larvae in an experiment moved toward infested soil rather than uninfested. It turns out feasting nematodes release chemicals that smell irresistable to rootworms.

Four other insect species tested, including a fly and a moth, also fell for the chemical lures, which were specific to each prey species. It's still unclear how these chemicals draw prey insects to their doom. — *Yao-Hua Law*

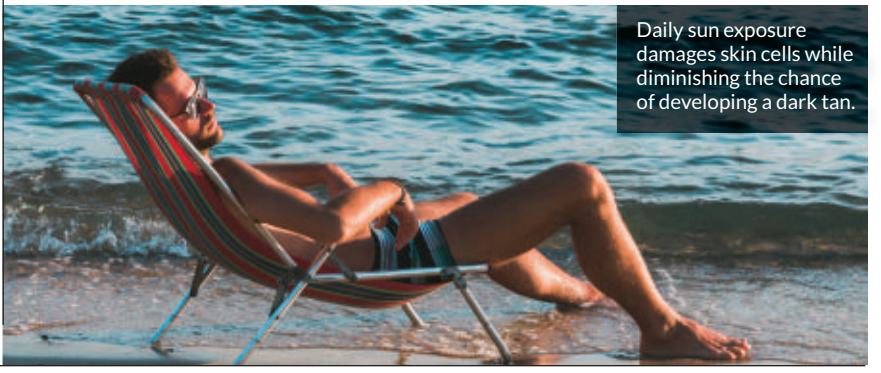
FOR DAILY USE

Don't sunbathe every day

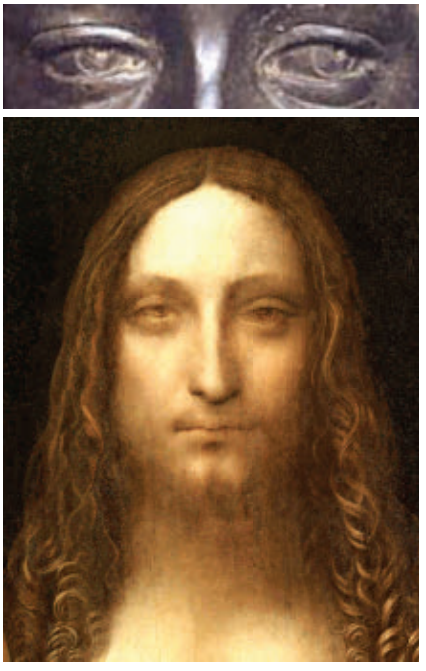
Sunbathing — if you must do it — should be limited to every other day. You'll get darker and prevent some skin damage, because skin makes the pigment melanin only every 48 hours, a study in the Nov. 1 *Molecular Cell* finds.

MITF protein coordinates melanin production with other skin protection mechanisms in response to ultraviolet light, molecular geneticist Carmit Levy of Tel Aviv University and her colleagues discovered. The team shone UV-B light on mice every 24, 48 or 72 hours for 60 days. Mice exposed to UV-B radiation on the 48-hour schedule developed darker skin and had less DNA damage than mice in the other groups. Mouse and human skin cells grown in lab dishes exposed to UV light every other day also made more melanin than cells irradiated daily.

Daily sunbathing, the researchers found, can disrupt melanin production and leave skin vulnerable to damage from UV light. — *Tina Hesman Saey*



Daily sun exposure damages skin cells while diminishing the chance of developing a dark tan.



A visual neuroscientist measured eye alignment in works of art believed to depict Leonardo da Vinci, such as the sculpture *David* (top) and the painting *Salvator Mundi* (bottom). Most suggest da Vinci had an eye misalignment.

FROM TOP: MARJAN_APOSTOLOVIC/ISTOCK.COM; C.W. TYLER/*JAMA OPHTHALMOLOGY* 2018; COLDCREATION/WIKIMEDIA COMMONS

RETHINK

Eye disorder may have given da Vinci an edge

If Leonardo da Vinci had a good eye doctor, he might not have become such a great artist. At least that's what an analysis of paintings, sculptures and drawings believed to be modeled after da Vinci suggests.

Visual neuroscientist Christopher Tyler of the City University of London examined six works of art. Five of them depict an eye misalignment consistent with a disorder called exotropia that can interfere with three-dimensional vision, Tyler reports online October 18 in *JAMA Ophthalmology*.

Exotropia, in which one or both eyes turn slightly outward, is one of several eye disorders collectively called strabismus. Today, strabismus affects 4 percent of the U.S. population, and is treated with special glasses, eye patches or surgery.

Tyler calculated the differences in eye alignment using the same measurements an optometrist would use when tailoring a pair of glasses. Most of the pieces of art showed the eyes misaligned, but *Vitruvian Man* by da Vinci himself did not. Tyler suspects da Vinci may have had intermittent exotropia, present only some of the time and perhaps controllable. Such people "can align their eyes and see in 3-D, but if they're inattentive or tired, the eye may droop," Tyler says.

If da Vinci could control his exotropia, Tyler speculates that it would have been an artistic advantage. "The artist's job is to paint on a 2-D surface," he says. "This can be difficult when you view the world three-dimensionally." Both eyes need to focus on a subject for 3-D vision. Many artists shut one eye when viewing a subject to more easily translate details into 2-D. But with intermittent exotropia, da Vinci could have switched from 3-D to 2-D and back with ease. — *Amanda B. Keener*

After five months of targeted electrical stimulation to his spinal cord, David Mzee, paralyzed in 2010, can now walk with some help supporting his weight (as seen in this composite image).

BODY & BRAIN

Targeted rehab restores walking

Spinal cord stimulation gets paralyzed people moving again

BY LAUREL HAMERS

Paralysis is becoming less permanent — at least for some.

There's now more evidence that stimulating the spinal cord can restore voluntary movement in paralyzed patients who haven't recovered after other treatments. After five months of training coupled with targeted stimulation of nerve cells in the spinal cord, three people who had a severe spinal cord injury regained the ability to walk with varying degrees of support, researchers report in the Nov. 1 *Nature*.

Stimulating nerve cells, or neurons, in the spinal cord with electric jolts works by amplifying signals coming from and going to the lower extremities, helping the brain and legs of paralyzed people communicate better. After undergoing the therapy, two of the patients were able to walk on crutches without the electrical stimulation. That suggests that the treatment may have helped strengthen neural connections between the brain and spinal cord that were not functional or barely working postinjury.

Such a level of recovery is "extremely exciting," says Chet Moritz, a neuroscientist at the University of Washington in Seattle who wasn't involved in the work.

All three patients were paralyzed from an injury at least four years earlier and hadn't regained movement after extensive rehabilitation, despite having some neural connections remaining at the injury site. The new finding comes on the heels of two other major studies, published in September, one in the *New England Journal of Medicine* and one in *Nature Medicine*, showing similar gains in patients who had a form of paralysis where the connections were completely nonfunctional (*SN: 10/27/18, p. 15*).

"Extending these findings into these two different populations is really important," says neuroscientist Susan Harkema of the University of Louisville in Kentucky. In patients with different kinds of chronic spinal cord injuries, "we've showed with training and stimulation, people ... have the capacity to recover," says Harkema, who coauthored the study in the *New England Journal of Medicine*.

The accomplishment was a technological challenge, says Grégoire Courtine, a neuroengineer at the Swiss Federal Institute of Technology in Lausanne and a coauthor of the new study. Like Harkema's team, Courtine and colleagues implanted a pulse-generating machine into patients. The matchbox-sized device was originally designed as a pain management therapy.

Certain patterns of spinal cord stimulation work better for triggering certain movements, like lifting a leg versus setting it down, previous research has shown. So rather than have the stimulator run constantly, as previous studies have done, Courtine's team designed a wireless system to control the stimulator so that it delivered targeted pulses of electricity to specific neurons at precise times, coordinated with desired muscle movements.

More targeted stimulation "takes [the therapy] to the next level," Moritz says.

Constant stimulation can also interfere with patients' abilities to sense their limbs in space, Courtine's team reports in a separate study published online October 31 in *Nature Neuroscience*. Feeling where limbs are in space is important for complex coordinated movements like walking, which requires many muscle groups to work together, Courtine says. The selective stimulation was better at improving movement in the patients the researchers tested, amplifying conversations between the extremities and the brain without drowning out sensation.

Patients receiving the pulses had to learn how to coordinate their own movements with the stimulation. At first, people had assistance from a contraption that supported their trunk and helped them remain upright. Within a week of starting the treatment, all three patients could walk while receiving spinal cord stimulation. By the end of the five-month training period, two patients had progressed to walking hands-free with just 35 percent of their body weight supported in the harness. A third, who had more severe injuries, needed more assistance.

All three patients regained the ability to move without the electrical stimulation running. Two patients could move from sitting to standing and walk short distances with crutches. The third patient could voluntarily move his legs.

That result is why Courtine and colleagues hope to test the technology in people who have been injured more recently. By starting rehab sooner, before muscles and nerves have atrophied as they usually do postparalysis, patients might make even greater strides. ■

BODY & BRAIN

Stop using pot and memory improves

Some harm can be reversed, a study of young people finds

BY LAURA SANDERS

Taking a monthlong break from pot helps clear away young people's memory fog, a small study suggests. The results show that not only does marijuana impair teenagers' and young adults' abilities to take in information, but that this memory muddling may be reversible.

Scientists have struggled to find clear answers about how pot affects the developing brain, in part because it's unethical to ask children to begin using a drug. But "you can do the opposite," says Randi Schuster, a neuropsychologist at Massachusetts General Hospital in Boston.

Schuster and her colleagues did just that for a study reported online October 30 in the *Journal of Clinical Psychiatry*. The team recruited 88 Boston-area people ages 16 to 25 who already used marijuana at least once a week and offered 62 of them money to quit for a month. Participants got more money as the experiment went along. Top earners banked $585 for their month without pot.

Along with regular drug tests, participants took attention and memory tests. Tricky tasks that required close monitoring of number sequences and the directions and locations of arrows revealed that, over the month, people's ability to pay attention didn't seem to be affected by their newfound abstinence.

But memory improved among those who avoided the drug. A week into the study, abstainers performed moderately better on memory tests than they had at the beginning. Those who continued using pot didn't improve. One aspect of memory, the ability to remember lists of words, seemed to drive the improvement.

Clinical neuropsychologist April Thames of the University of Southern California in Los Angeles wonders if there's a point of no return. "If somebody is using very heavily over a prolonged period of time, is there a point at which these functions may not recover?" ■

BODY & BRAIN

Appendix is implicated in Parkinson's

Appendectomy lowered people's risk of developing the disease

BY AIMEE CUNNINGHAM

The appendix, a once-dismissed organ now known to play a role in the immune system, may contribute to a person's chances of developing Parkinson's.

A large analysis of Swedes found that those who'd had their appendix removed had a lower overall risk of the disease. Also, appendix tissue from healthy individuals revealed protein clumps similar to those seen in the brains of Parkinson's patients, researchers report in the Oct. 31 *Science Translational Medicine*.

Together, the findings suggest that the appendix may play a role in the early events of Parkinson's, neuroscientist Viviane Labrie of the Van Andel Research Institute in Grand Rapids, Mich., said at a news conference October 30.

Globs of alpha-synuclein protein (red) found in the appendix add to evidence that the gut plays a role in Parkinson's disease.

V. LABRIE/VAN ANDEL RESEARCH INSTITUTE

Parkinson's is a neurodegenerative disease that leads to difficulty with movement, coordination and balance. One hallmark of the disease is the death of nerve cells in a brain region called the substantia nigra, which helps control movement. Lewy bodies, which are mostly made of clumped bits of alpha-synuclein protein (*SN: 1/12/13, p. 13*), also build up in those nerve cells, but the connection between the cells' death and the Lewy bodies isn't clear.

Parkinson's symptoms in the gut, such as constipation, can show up earlier than symptoms in the brain (*SN: 12/10/16, p. 12*). So Labrie and colleagues turned their attention to the appendix, a short, thin tube that protrudes from the large intestine. The team analyzed health records from 1.7 million Swedish people, some of whom were followed for as many as 52 years.

For people without an appendix, the incidence of Parkinson's was 1.6 per 100,000 people per year compared with about 2 per 100,000 per year for those with the organ. Removing the appendix was associated with a 19 percent drop in the risk of developing Parkinson's.

Surgical samples from a tissue bank of appendixes from 48 people without Parkinson's provided another link to the disease. The team discovered alpha-synuclein clumps in 46 of the samples similar to those seen in the brains of Parkinson's patients. The clumped protein has been found in other areas of the gut, and past research suggests that it's possible for the protein to travel along the main nerve that connects the gut to the brain (*SN: 12/10/16, p. 12*).

If the clumped protein in the appendix turns out to jump-start the disease, Labrie said, "preventing excessive alpha-synuclein clump formation in the appendix, and its departure from the gastrointestinal tract, could be a useful new form of therapy."

Ongoing clinical trials are investigating different strategies to remove alpha-synuclein from the brain. Perhaps such therapies would do the same for the appendix, says John Trojanowski, a neuropathologist at the University of Pennsylvania Perelman School of Medicine. "Every facet of what contributes to Parkinson's disease is important." ■

ATOM & COSMOS

Milky Way once ate another galaxy

Stars left over from the ancient feast are still around today

BY LISA GROSSMAN

In its youth, the Milky Way devoured a smaller galaxy, and stars from the victim still roam the skies today, a study finds.

"This is a major event in the history of the galaxy," says astronomer Amina Helmi of the University of Groningen in the Netherlands. "We're really starting to probe the ancestors of the Milky Way."

Helmi and her colleagues analyzed the speeds and positions of tens of thousands of stars in the Milky Way using data from the European Space Agency's Gaia space telescope. A group of about 30,000 stars seem to be moving backward, the team reports in the Nov. 1 *Nature*. Instead of rotating around the galactic center with the sun and the rest of the stars in the Milky Way's bright disk, these stars travel in the opposite direction.

That was one hint that the stars formed elsewhere. Another hint came from the Apache Point Observatory Galactic Evolution Experiment, or APOGEE, which uses the spectrum of light that stars emit to infer their chemistry and ages. The backward-moving stars had fewer heavy elements than sunlike stars. That suggests that the renegades formed earlier in the universe's history, before there was time for massive stars and supernovas to spread heavy elements around the galaxy.

Comparing the data with computer simulations, Helmi's team concluded that 10 billion years ago, the Milky Way collided with a galaxy about 20 to 25 percent of the mass of the Milky Way at the time.

That collision may explain why the Milky Way is split into different components: a thin disk of young stars organized into spiral arms, a thick disk of older stars surrounding the thin disk and a spherical halo of stars with trajectories that take them far from the disks. Many of the halo stars came from the gobbled-up galaxy.

Signs of foreign stars had been seen before, says astronomer Julio Navarro of the University of Victoria in Canada, who identified about 120 of them in a 2011 paper. And other groups have used Gaia and APOGEE data separately to identify odd stars. Seeing both datasets come together with thousands of stars "is quite comforting," Navarro says. "The main idea that the galaxy swallowed a pretty heavy satellite quite a while ago, I think that's probably beyond doubt."

Paula Jofré, an astrophysicist at Universidad Diego Portales in Santiago, Chile (*SN: 10/13/18, p. 26*), says the stars are like fossils that can help reveal what galaxies were like 10 billion years ago. ■

The Milky Way swallowed a smaller galaxy about 10 billion years ago. That galaxy's stars are shown with yellow arrows depicting their direction of motion in this artist's impression.

MATTER & ENERGY

Odd material has disorderly atoms

Insulator-turned-conductor could lead to faster electronics

BY MARIA TEMMING

For the first time, researchers have gotten a detailed view of how atoms in a compound called vanadium dioxide move when an ultrafast laser pulse transforms the material from an electrical insulator to a conductor — and it's nothing like scientists expected.

Rather than switching from one crystal formation to another in a direct, synchronized manner, like choreographed ballerinas, the atoms shift around in a disordered way, more like clumsy partygoers doing the Cha Cha Slide. This new insight, reported in the Nov. 2 *Science*, may inform engineers who are trying to harness the dual nature of the compound and others like it for new technologies.

Vanadium dioxide's insulator-to-metal transition happens when the material is heated above about 67° Celsius or hit with an ultrafast laser pulse. That electrical about-face is difficult to study, because it happens in about 150 femtoseconds, or quadrillionths of a second.

Previous experiments have measured only the average motions of atoms during this transformation. Those trends suggested a smooth shift from one crystal formation to another, but were not detailed enough to reveal small deviations in the atoms' movements.

Mariano Trigo, a physicist at SLAC National Accelerator Laboratory in Menlo Park, Calif., and colleagues got a closer look using ultrashort pulses of X-ray radiation. After hitting vanadium dioxide with a superfast flash of laser light to trigger the transition, the team zapped the compound with X-ray pulses, each a few tens of femtoseconds long.

X-rays scattered off atoms in the material, revealing the particles' positions at the time of each pulse, says study coauthor Olivier Delaire, a materials scientist at Duke University. The pulses were so rapid and intense that they tracked atoms' movements much more precisely than other experiments.

Vanadium dioxide's ultrafast insulator-to-metal transition may someday form the basis of superspeedy electronic components, or devices that exploit vanadium dioxide's weird relationship with light and electricity for camouflage or efficient heating and cooling. Understanding the material's internal structure could help engineers wrest better control over its properties, says Richard Averitt, a physicist at the University of California, San Diego. ■

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Watch the Milky Way eat a galaxy at **bit.ly/SN_MilkyWay**

Roaches fight off zombie-makers

Vigilance or kicks to the head may defeat a wasp attack

BY SUSAN MILIUS

Real-life fights against zombie-makers offer plenty of tips for avoiding undeath. Just ask cockroaches, targets of the emerald jewel wasp.

Female *Ampulex compressa* wasps specialize in attacking the American cockroach (*Periplaneta americana*). If a wasp succeeds in delivering crucial stings, she leads away a subdued roach like a dog on a leash just by tugging at a roach antenna. Then she lays an egg on the roach and buries the insect alive as living meat for a wasp larva. Though a normal roach could dig itself out, there's no sign that the wasp-stung ones even try.

To the roaches, the wasp "is a dedicated, goal-oriented, deft parasitoid coming for your brain," says Kenneth Catania, a neurobiologist at Vanderbilt University in Nashville. He has recently created an impressive collection of slo-mo attack videos, providing the first detailed look at how some roaches fight back.

To avoid being led to the tomb, vigilance was vital. In 28 out of 55 attacks that Catania filmed in a confined lab space, roaches didn't seem to notice the threat quickly enough. Their attackers needed only about 11 seconds on average to ease close and conquer.

More vigilant cockroaches, however, fought back. Seventeen managed to hold off the wasp for a full three minutes, which Catania counted as success, he reports online October 31 in *Brain, Behavior and Evolution*. In the wild, a jewel wasp would probably give up after such a feisty fight, or the cockroach would manage to dash away.

It's not mere ghoulish fascination that fuels such research. "There's a lot of recent interest in the jewel wasp, and for a good reason," says Coby Schal, a chemical ecologist at North Carolina State University in Raleigh who studies other aspects of cockroach behavior. Both the wasps and the roaches are relatively large and easy to experiment on for studying how behavior arises from brains and nerves.

> The emerald jewel wasp "is a dedicated, goal-oriented, deft parasitoid coming for your brain."
>
> KENNETH CATANIA

The attacking wasp needs victims with their nervous systems still working well enough to move. Otherwise the tiny jewel wasp would never be able to get a whole roach to an egg chamber. Every wasp needs living roach meat to start life, so the evolutionary forces that hone wasp attacks are extreme, says Catania. The jewel wasp has evolved an attack that subdues a roach in just two precise stings.

For the first sting, a wasp jumps and grabs the little shield over what's basically the back of the roach's neck. Within half a second, the wasp is positioned to deliver a sting that will paralyze the front legs, making them useless for defense. The wasp then bends her abdomen around, quickly feeling the way to the soft tissues of the roach throat. The stinger itself carries sensors and stabs up through the throat to deliver venom to the cockroach's brain.

Roaches then typically start grooming themselves, possibly as a side effect of the venom. The wasp doesn't have to do anything else. The roach "is sitting there not running away from this really terrifying creature that's going to eventually ensure it gets eaten alive," Catania says. It doesn't resist when the wasp bites an antenna down to half-length and takes a drink of the insect version of blood.

In Catania's experiments, luckier roaches noticed an approaching wasp. Their first, most effective defensive move was what he calls "stilt standing," the roach rising tall on its legs, which are "almost like a barbed wire fence," he says. While the plastic Halloween roaches Catania bought for his kitchen have misleadingly smooth legs, real roach legs are sensitive and bristle with spines that can stab a wasp.

In another strong move as the fight wears on, a roach may turn and, with one of its rear legs, kick the wasp in the head repeatedly. A roach leg isn't built for a straight kick, so the insect instead swings its leg a bit like a baseball bat. Juvenile roaches don't have much of a chance in the lab arena regardless, but a full-grown adult does.

These details of roach defense now open up a range of research questions, such as teasing out how different evolutionary pressures hone defenses and attacks. And for a bit of (maybe) practical advice should fictional zombie-makers jump off a movie screen, Catania offers: "Protect your throat." ■

BOTH: K.C. CATANIA/*BRAIN, BEHAVIOR AND EVOLUTION* 2018

A small emerald jewel wasp needs just two stings to turn an American cockroach into walking, unresisting meat. First, the female wasp grasps the edge of a shield that covers the back of the roach's neck (left) and delivers a sting that paralyzes the roach's front legs. Then the wasp bends her body around to deliver a sting through the throat up into the roach's brain (right). The roach will be able to walk only if the wasp initiates the movement by pulling on a roach antenna.

Watch a cockroach fight a wasp at **bit.ly/SN_Wasp**

HUMANS & SOCIETY

Ancient Texas tools led to Clovis points

Artifacts offer clues to how people spread into North America

BY BRUCE BOWER

Stone spearpoints from roughly 15,000 years ago suggest that descendants of some of the earliest American settlers went on to create the Clovis culture.

Excavations at a site in Central Texas yielded about 100,000 stone artifacts, including 12 spearpoints, that date to between 15,500 and 13,500 years ago. The shapes of those spearpoints show a progression from stemmed points to a short triangular blade. That progression means the artifacts may have been precursors to long, triangular Clovis points, researchers report October 24 in *Science Advances*.

By about 13,500 years ago, Clovis people had settled across North America. For years, scientists thought that these people were the first inhabitants of the continent. But researchers have found a growing number of pre-Clovis human sites in the Americas (*SN: 8/4/18, p. 7*).

In 2011, pre-Clovis finds were unearthed at the Buttermilk Creek Complex, part of the Debra L. Friedkin archaeological site and the same place in Texas where the new artifacts are from. But none of those 2011 finds could be linked to later Clovis points from the site.

Now, researchers show that 11 of the 12 new spearpoints had been chipped into leaf shapes that taper into slightly narrower stems. The exception is a short, triangular spearpoint with a flat base that dates from 14,000 to 13,500 years ago.

New discoveries, including this roughly 15,000-year-old spearpoint (main image), suggest that the descendants of some of the earliest Americans made Clovis artifacts (inset).

"We have discovered two previously unknown spearpoint styles that predate Clovis," says geoarchaeologist Michael Waters of Texas A&M University in College Station. Finding artifacts in sediment showing a clear progression from stemmed points to a triangular point to Clovis points over a roughly 2,000-year period raises the likelihood that one style led to the next, Waters holds.

Buttermilk Creek's stemmed spearpoints look similar to several found at another site in Central Texas called Gault, which dates to at least 16,700 years ago. The researchers contend that early American settlers crafted stemmed spearpoints and probably traveled down the Pacific coast starting around 16,000 years ago.

Some ancient Pacific coast migrants moved inland at various points, leaving stemmed spearpoints at North and South American sites dating to at least 13,000 years ago, Waters' team suggests. In one possible scenario, makers of stemmed spearpoints at Buttermilk Creek developed short, triangular spearpoints. Or, the scientists say, other groups of migrants moving inland from the Pacific coast or via an ice-free corridor brought triangular spearpoints to Buttermilk Creek. In either case, the researchers regard the Buttermilk Creek triangular blade as a Clovis precursor.

Geoarchaeologist Jessi Halligan of Florida State University in Tallahassee agrees. She served as field director of Friedkin site excavations in 2008, 2009 and 2011 but did not participate in the new research.

"At least in Central Texas," she says, "people arrived well before Clovis, discovered a source of excellent stone for tools and passed their knowledge on to their descendants who eventually started making Clovis artifacts." ■

MATTER & ENERGY

Atomic mapping leaps ahead

Quick chemical structures may accelerate drug development

BY CARMEN DRAHL

The one-hour photo booth has met its molecular match. By adapting a technique for determining protein structures, two independent teams have charted chemical structures of antibiotics, hormones and other compounds with unprecedented speed. Depending on the molecule, it took between 30 minutes and a day to determine structures. Traditional techniques can take months to years.

The approach could help forensic chemists and sports officials identify illicit drugs and accelerate drugmakers' pursuits. The work was published online October 16 in *Angewandte Chemie* and October 17 at ChemRxiv.org.

"I haven't been this excited about a finding in chemistry in a long time," says organic chemist Donna Huryn of the University of Pittsburgh. "It's going to change the way everybody works."

For molecular scientists, knowing the atom-by-atom connectivity of what they're working with is essential. It's how pharmaceutical companies verify drugs' composition and purity, for instance. But most methods for discerning chemical structures are indirect. Imagine having a fingerprint, an artist's sketch and dental records when what you want is a photo, says Caltech organic chemist Brian Stoltz, a coauthor of the ChemRxiv study.

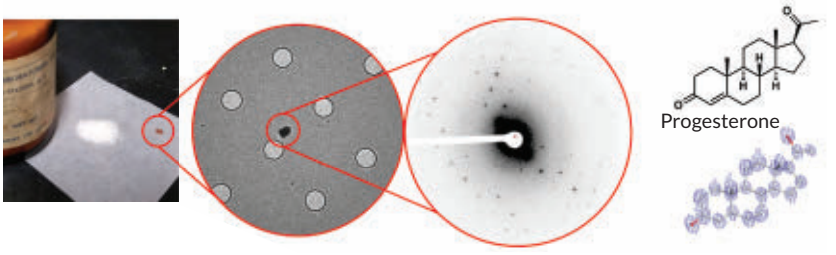
The closest thing to a camera for molecules is X-ray crystallography. The method involves bombarding a crystal — a tiny rock candy–like solid made from many copies of one molecule stacked together — with X-rays and then calculating a structure based on how the X-rays bounce off the crystal's atoms. But creating big enough crystals for this approach, at least 50 micrometers on one side, can take years and doesn't always work.

To avoid that size bottleneck, the two teams fired electrons at molecules.

Electrons bounce off matter more readily than X-rays, which mostly pass through, says Tamir Gonen, an electron crystallography expert at UCLA and a coauthor of the ChemRxiv study. With this technique, called 3-D electron diffraction, it's possible to derive structures from tiny crystals about 100 nanometers on a side. Such crystals are available in bottles of chemicals straight off the shelf.

In the study in *Angewandte Chemie*, crystallographer Tim Gruene of the Paul Scherrer Institute in Villigen, Switzerland, and his team cracked open a capsule of cold medicine containing a mixture of ingredients. From a speck of powder, the team determined the structure of acetaminophen inside. That previously solved structure isn't exciting, Gruene says, but the fact that it came from a mishmash of ingredients is. While not every molecule will produce the tiny crystals needed, crime labs analyzing trace samples could find this technique handy. It could also be useful in contested drug patent cases; the method unambiguously verifies structures from crushed-up pills, Gruene says.

Powder to picture A sample from a bottle of progesterone (left), applied to a Swiss cheese–like sample holder (middle left), produces a pattern of spots after electron bombardment (middle right) that can be translated into a chemical structure in under 30 minutes (bottom right).



Using electrons to map structures isn't new. The 2017 Nobel Prize in chemistry went to scientists who used the concept to map proteins with hundreds of thousands of atoms. And a few scientists previously obtained structures of organic molecules with a few dozen atoms, but those results didn't catch on among chemists.

By making the value of this technique clear, these studies have provoked wonderment on chemistry blogs and social media. It took a couple of years to overcome technical hurdles, says UCLA organic chemist Hosea Nelson, a coauthor of the ChemRxiv study. But once the team did, it obtained six or seven structures in one afternoon. As Nelson recalls, "we said — with expletives mixed in — that this was the most exciting day as scientists that we'd ever experienced." ■

BODY & BRAIN

Cystic fibrosis therapies show promise

If approved, triple-drug approach could work for most patients

BY AIMEE CUNNINGHAM

For years, scientists have struggled to find a therapy that works for most cystic fibrosis sufferers. Now, two new triple-drug approaches still undergoing testing are offering hope.

Cystic fibrosis is caused by genetic mutations that result in the body either making defective versions of a protein called CFTR or none of the protein at all. The new therapies partly fix problems with one type of defective protein.

The two triple-drug approaches, taken for four weeks, each improved the lung function of people with a mutation that is found in 90 percent of cystic fibrosis patients. The drugs were also safe, with tolerable side effects, researchers report in two studies in the Oct. 25 *New England Journal of Medicine*.

With continued testing and approval, a triple-drug combination might provide the first effective treatment for the vast majority of cystic fibrosis patients.

The approach produced "a really robust improvement in pulmonary function," says pediatrician Hartmut Grasemann of the Hospital for Sick Children in Toronto, who was not part of the research. And it "works for almost all patients with cystic fibrosis, which is quite amazing."

In cystic fibrosis, which affects about 30,000 people in the United States, the lack of fully functional CFTR causes the lungs to become clogged with sticky, thick mucus, which traps invaders like bacteria. As a result, patients have persistent infections that damage the lungs over time, leading to lung failure. Life expectancy of people with cystic fibrosis varies widely, from less than 30 years to about 50.

The new triple-drug treatment builds on the success of an earlier drug, ivacaftor, approved in 2012 for patients who have a rare mutation that causes the body to make another type of defective CFTR protein. The drug enhanced activity in the protein, increasing lung function and quality of life, says pulmonologist Steven Rowe of the University of Alabama at Birmingham School of Medicine, a coauthor of one of the new studies. "They are in the hospital much less," he says, and "the way they feel on a day-to-day basis is substantially improved."

In the two latest clinical trials, an experimental drug, a type of a corrector, was added to ivacaftor and to another corrector called tezacaftor (each trial studied a different version of that third drug). Correctors help fix the CFTR protein's shape. The triple-drug therapies improved lung function compared with a placebo. On average, patients began the trial with a lung function that was about 60 percent of normal, based on a breathing test. The lung function of patients taking the therapy increased to about 70 to 74 percent of normal.

"It's the most exciting thing we've seen," says pulmonologist Jennifer Taylor-Cousar of National Jewish Health in Denver, a coauthor of one of the studies. If the drugs make it through the final phase of clinical testing, "it will hopefully be life-changing for 90 percent of people with cystic fibrosis." ■

C.G. JONES *ET AL*/CHEMRXIV.ORG 2018

LIFE & EVOLUTION

First vertebrates arose in shallow seas

Researchers resolve mystery of where the earliest fish lived

BY CAROLYN GRAMLING

The cradle of vertebrate evolution was limited to a zone of shallow coastal waters, no more than 60 meters deep.

In those waters, fish — the first vertebrates — appeared about 480 million years ago, a new study finds. For nearly 100 million years, those fish rarely strayed from that habitat, where they diversified into a dizzying array of new forms, scientists report in the Oct. 26 *Science*.

Researchers have long debated whether backboned animals appeared first in the shallows or the deep, or in fresh or salty water. "The main problem is that the fossil record [of vertebrates] is absolutely terrible for the first 50 million to 100 million years of their existence," says paleobiologist Lauren Sallan of the University of Pennsylvania. "And when [there are] fossils, they're in tiny pieces. It's hard to tell what exactly's going on."

So Sallan and colleagues amassed 2,827 fossils of jawed and jawless fishes that lived between 480 million and 360 million years ago. To that database, the team added information on the environments that the creatures lived in, based on both the geology of the rocks that the fossils were found in and the invertebrate fossils also in the rocks.

Then the team used mathematical calculations to predict the habitats of the most ancient vertebrates, filling in those gaps on the fish family tree. Rather than living in rivers or lakes or the deeper ocean waters around coral reefs, the first vertebrates stuck to a nearshore environment, Sallan and colleagues say.

The creatures stayed in the shallows for about 100 million years, acquiring adaptations before eventually moving into new areas. Some fish gained streamlined, graceful bodies good for fast swimming in deeper waters. Others had stronger, armored bodies and stayed close to shore or moved into rivers or lakes.

Catalina Pimiento, a paleobiologist at Swansea University in Wales who wrote a commentary in the same issue of *Science*, says the results are "so robust." The finding makes a lot of sense too. "It's just well-known that these coastal habitats [have supported] biodiversity," she says, because such locations tend to offer both abundant food and shelter. ■

After evolving about 480 million years ago, the first vertebrates, fish, stayed in shallow coastal waters for about 100 million years, diversifying into many forms, like the ones illustrated here.

ALL: NOBUMICHI TAMURA

HUMANS & SOCIETY

South Americans tamed chocolate

Oldest signs of domesticated cacao uncovered in Ecuador

BY BRUCE BOWER

South Americans domesticated and ate cacao, the plant from which chocolate is made, long before other people did.

Artifacts with traces of cacao suggest that a culture in what's now Ecuador developed a taste for cacao 5,450 to 5,300 years ago, scientists report October 29 in *Nature Ecology & Evolution*. Societies in Mexico and Central America didn't start concocting their better-known chocolatey drinks for another 1,500 years or so.

"This is not only the earliest archaeological evidence so far reported for cacao use in the Americas, but also the only archaeological evidence for cacao use in South America," says study coauthor and archaeologist Michael Blake of the University of British Columbia in Vancouver.

Reports of heightened genetic diversity among modern domesticated cacao plants in the upper Amazon — near where the artifacts were found — have suggested that domesticated cacao (*Theobroma cacao*) began there. Differences in the genetic makeup of related populations of organisms accumulate gradually, so the most diverse populations are presumed to have evolved first. The new study confirms the genetic scenario for cacao.

Objects that held the cacao clues were unearthed at Santa Ana-La Florida, a settlement of the Mayo-Chinchipe culture. The items came from in and around household structures and tombs. The researchers suspect that the plant served as food, drink, medicine, a stimulant and perhaps a ceremonial substance.

Three lines of evidence point to cacao use. First, starch grains characteristic of domesticated cacao were recovered from charred food stuck to six pottery shards. Second, traces of theobromine, a bitter chemical compound found in seeds of a domesticated cacao species but not in its wild relatives, were identified in 25 ceramic and 21 stone artifacts. Finally, genetic signs of domesticated and wild cacao were found in several artifacts.

Cameron McNeil, an archaeobotanist at the City University of New York, says it's interesting that ancient South Americans consumed cacao seeds as well as pulp. Some researchers have speculated that the earliest cacao users would have avoided the time-consuming process of preparing seeds and focused on pulp as a readily available stimulant.

Once cacao got to Central America and Mexico, its status as a prestigious plant may have blossomed as people further domesticated it, McNeil says, probably to enhance the flavor of seeds that were also used as currency (*SN: 8/4/18, p. 16*). ■

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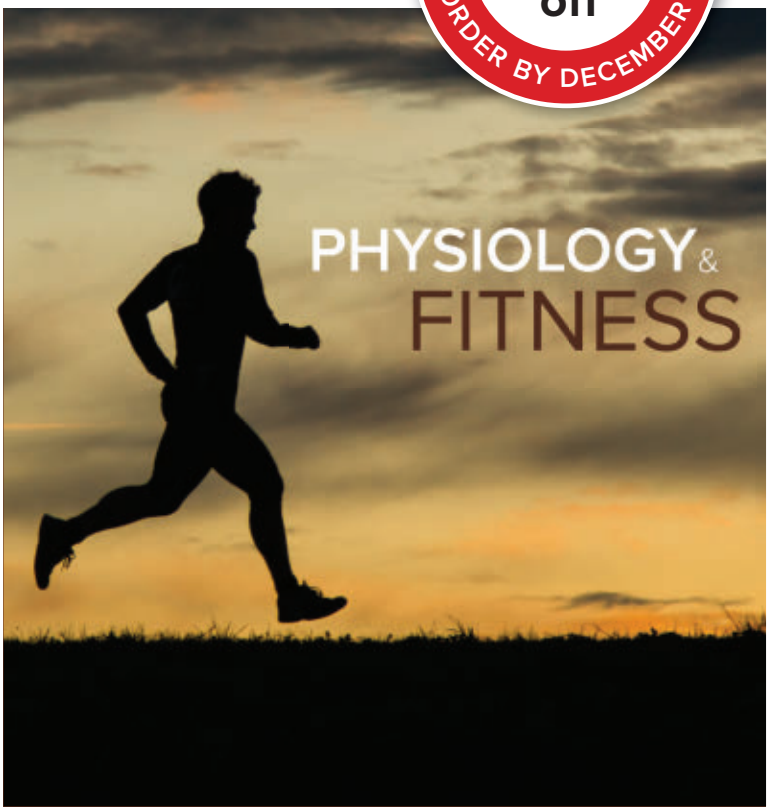

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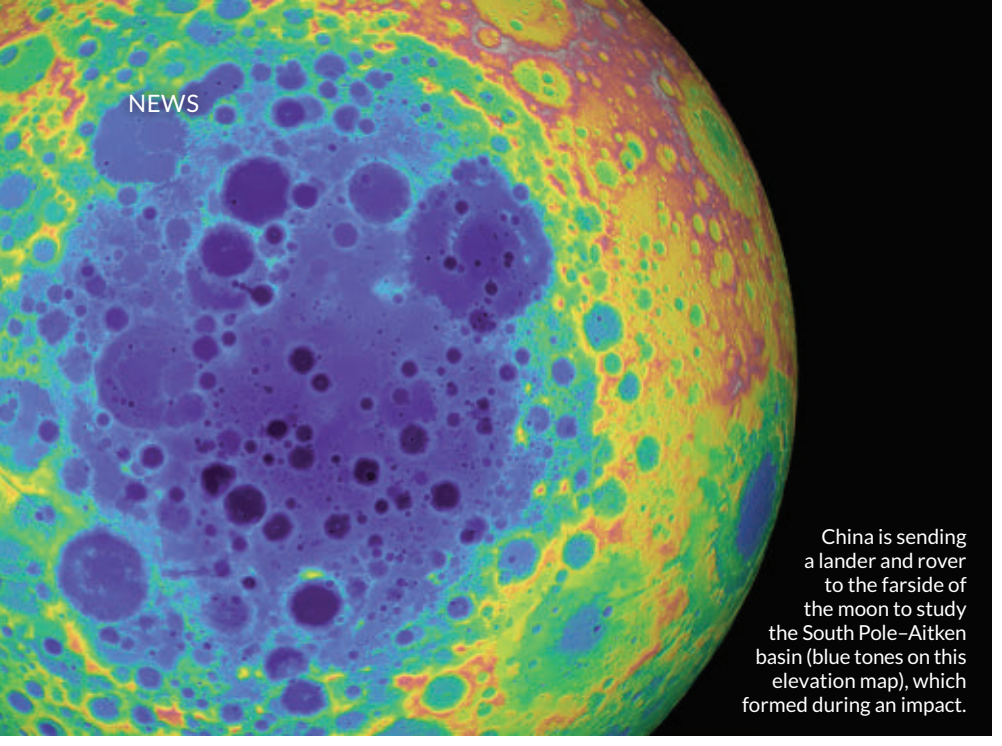


China is sending a lander and rover to the farside of the moon to study the South Pole–Aitken basin (blue tones on this elevation map), which formed during an impact.

ATOM & COSMOS

Visiting the moon's uncharted territory

Chinese probes will explore the farside and collect new samples

BY LISA GROSSMAN

China is about to make space history. In December, the country will launch the first spacecraft ever to land on the farside of the moon. Another craft, slated for takeoff in 2019, will be the first to bring lunar rocks back to Earth since 1976.

These two missions — the latest in China's lunar exploration series named after the Chinese moon goddess, Chang'e — are at the forefront of renewed interest in exploring our nearest celestial body. India's space agency as well as private companies based in Israel and Germany are also hoping for robotic lunar missions in 2019. And the United States aims to have astronauts orbiting the moon starting in 2023 and to land astronauts on the lunar surface in the late 2020s.

The time is ripe for new lunar exploration. Despite decades of study, Earth's only natural satellite still contains mysteries about its formation as well as clues to the history of the solar system (*SN: 4/15/17, p. 18*). "There are too many things we don't know," says planetary scientist Long Xiao of China University of Geosciences in Wuhan. He is a coauthor of two studies published in June and July in the *Journal of Geophysical Research: Planets* describing the landing sites of the new Chinese missions, Chang'e-4 and -5.

To figure out what secrets the moon may still be hiding, scientists are excited to get their hands on new rock samples. The Chang'e-5 sample return mission "no doubt will have additional rock types that we haven't sampled yet," says planetary scientist David Blewett of Johns Hopkins University Applied Physics Laboratory in Laurel, Md. "If you came to the Earth and landed in Great Britain and made all your conclusions about the Earth from what you saw ... you really wouldn't have the whole picture."

Journey to the dark side

The Chang'e-4 spacecraft includes a lander and a rover that were originally built as backups for the 2013 Chang'e-3 mission, which marked China's first moon landing — and the first moon landing at all since the 1970s (*SN Online: 12/16/13*). The uncrewed Chang'e-3 lander-rover duo touched down in a vast lava plain in the north known as Mare Imbrium, where the craft measured the composition and thickness of the lunar soil and discovered what might be a new type of basalt, or lava-based rock.

This time, China has its sights set on lunar regions never before explored. Chang'e-4 is aiming for the moon's largest, deepest and possibly oldest known feature created by an impact, the South Pole–Aitken basin, on the lunar farside, which always faces away from Earth. The whole basin, which is 2,500 kilometers wide and up to 8.2 kilometers deep, is too big for the rover to explore. So Chang'e-4 is shooting for the 186-kilometer-wide Von Kármán crater within the larger basin for a cosmic hole in one.

The enormous impact that formed the South Pole–Aitken basin is thought to have excavated parts of the lunar mantle, the once-molten layer of denser rock that sits below the crust. Exploring the crater could offer a window into the moon's interior.

"There's a big argument about the composition of the lunar mantle," Xiao says. For instance, is the mantle "wet" and full of hydrated minerals, or dry? If it is wet, how did water survive the colossal impact thought to have formed the moon? Chang'e-4 won't solve those mysteries, but its measurements can help calibrate future remote observations.

Three cameras, an infrared spectrometer and two ground penetrating radars, like those used in the Chang'e-3 mission, will help the spacecraft conduct its investigation of Von Kármán crater. Chang'e-4 also carries some newer tech: a Swedish instrument to study how charged particles from the sun interact with the lunar surface; a German instrument to gauge radiation levels, which could be important for future astronauts; and a container with seeds and insect eggs to test whether plants and insects, if they hatch, can grow together on the moon.

Because the moon always shows the same face to Earth, astronomers on the ground won't be able to communicate directly with Chang'e-4. So in May, the Chinese space agency launched a transmission relay satellite to a point beyond the moon to bounce data and communication signals back and forth between the lunar surface and Earth

GSFC/NASA, UNIV. OF ARIZONA

(*SN Online: 5/20/18*). That satellite, called Queqiao, is named after the mythical bridge of magpies that spans the Milky Way once a year to enable a tryst between two lovers.

Delving into geologic history

Sometime in 2019, the Chang'e-5 craft will visit a region on the near side of the moon that no spacecraft or astronaut has been to before. And that mission will give scientists something they haven't had in more than four decades — new lunar rock samples.

So far, scientists have studied rocks from lava fields formed early in the moon's history, about 3.5 billion years ago. Those were brought to Earth by the U.S. Apollo missions, which ended in 1972, and the Soviet Luna missions, ending in 1976. Together, those missions brought back more than 380 kilograms of moon material.

Chang'e-5's lander will scoop surface rocks and dig two meters deep in a 58,000-square-kilometer area called the Rümker region that's strewn with minerals dating to a variety of periods of volcanic activity. The craft will then bundle up to two kilograms of material into a rocket, which will launch to meet Chang'e-5's orbiter and return to Earth.

Studying samples from this region could reveal if the moon has been geologically active more recently than previously thought. "According to the study of Apollo samples, people think the moon was dead" for the last 3 billion years, Xiao says. But observations from previous orbiters suggest that Rümker includes basalt from lava flows that are less than 1.4 billion years old. "If the young mare basalt were confirmed, we would rewrite the heat history of the moon" — in other words, when the moon's hot liquid rock cooled and hardened (*SN: 8/5/17, p. 7*).

Understanding the moon's volcanic history could shed light on competing ideas about how the moon came to be. For instance, scientists still don't agree on whether our neighbor formed from one giant impact with Earth in the early days of the solar system, around 4.5 billion years ago, or from about 20 small ones, or something else. Finding evidence for more recent geologic activity could be a ding for the single impact hypothesis.

What's more, the returned samples would also be stored and preserved "so that future scientists who aren't born yet can answer future questions we haven't asked yet, with tools we haven't invented yet," says astrochemist Jamie Elsila of NASA's Goddard Space Flight Center in Greenbelt, Md. She would know: Born nearly two years after the last Apollo mission, Elsila published a study in 2016 that used modern techniques to show that Apollo soil samples contain amino acids mostly derived from Earth.

Tricky access to new moon rocks

The prospect of studying those new rocks has excited NASA researchers and other scientists. Sample return is "the gift that keeps on giving," says former Apollo astronaut Harrison "Jack" Schmitt, the only geologist to walk on the moon. "All of my colleagues who work directly with the samples certainly would like to get their hands on [those new rocks]."

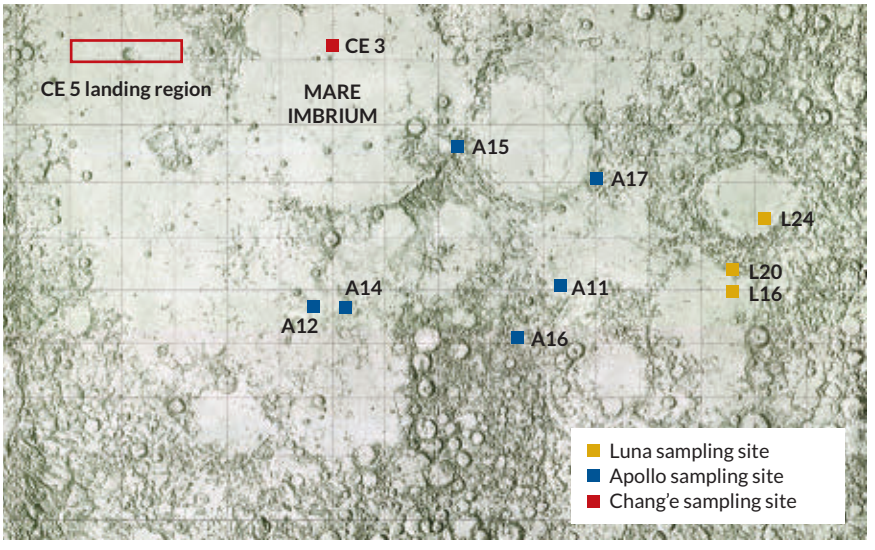
But U.S. scientists face roadblocks to studying the new samples, thanks to the Wolf Amendment, a 2011 federal budget clause that requires congressional approval before U.S. scientists can collaborate with China or any Chinese-owned company.

"In terms of space science, I think with the Wolf Amendment, the United States took very careful aim and shot ourselves in the foot," says space policy analyst Joan Johnson-Freese of the U.S. Naval War College in Newport, R.I. "We've made it very difficult for American scientists to work with otherwise unobtainable data."

Difficult, but not impossible. American scientists could join scientists from other countries who can work directly with China, using their colleagues as a sort of go-between. The United States could also trade Apollo samples for Chang'e-5 samples, says space policy analyst Scott Pace, the executive secretary of the U.S. National Space Council.

"I think the U.S. and Russia would certainly be open to being part of a sample exchange process," Pace says. "From a purely science standpoint, we'd love to have that. Whether the politics allows it, we'll have to see."

From China, Xiao agrees that collaboration is essential to understanding the moon's history. "We don't want this kind of thing to badly impact the science." ■



Marking the spot Moon rocks brought back by the Soviet Union's Luna missions (yellow) and NASA's Apollo missions (blue) in the 1960s and '70s all came from ancient lava flows mostly clustered around the moon's equator. In 2013, China's Chang'e-3 (red square) landed in a different zone of old flows farther north, but brought back no samples. The Chang'e-5 mission will return volcanic rocks from an area that has never been sampled before (outlined in red).

DATA: USGS, BACKGROUND IMAGE: NASA

BODY & BRAIN

Liverworts contain a painkiller similar to the one in marijuana

A chemical compound found in moss-like liverworts may provide the pain and inflammation relief of pot's THC but without the same kind of high.

Both the liverwort's molecule, called perrottetinene, and THC — or tetrahydrocannabinol, the mind-altering substance found in marijuana — have similar molecular structures. And lab tests with human brain cells and in mice revealed that, like THC, perrottetinene dampens the effects of pain signals, researchers report October 24 in *Science Advances*.

The researchers created synthetic versions of perrottetinene and tested them on mice. The team tracked the animals' pain response, body temperature and movement — measures of the compound's psychoactivity. The results suggest that perrottetinene is slightly less psychoactive than THC, says study coauthor and biochemist Jürg Gertsch of the University of Bern in Switzerland. The researchers hope that pharmaceutical companies will eventually manufacture the substance as a potential alternative to marijuana. — *Jennifer Leman*

HUMANS & SOCIETY

Hominids migrated through a 'green' Arabia 300,000 years ago

Although now characterized by inhospitable deserts, the Arabian Peninsula was a lush spot for migrating members of the human genus, *Homo*, at least 300,000 years ago, scientists say.

Stone tools found among fossils of antelopes, elephants and other animals at Saudi Arabia's Ti's al Ghadah site date to between 300,000 and 500,000 years ago, archaeologist Patrick Roberts and colleagues say. At that time, the site was located in a grassy region that got regular rains, the researchers report online October 29 in *Nature Ecology & Evolution*.

The finds support the idea that Arabia had a climate friendly to either *Homo sapiens* or another *Homo* species from Africa, say Roberts, of the Max Planck Institute for the Science of Human History in Jena, Germany, and his team.

Homo sapiens originated in Africa about 300,000 years ago. Traditionally, scientists have estimated that human migrations from Africa began about 60,000 years ago. But recent Arabian finds have indicated that these dispersals began much earlier (*SN: 5/12/18, p. 12*).

Probable butchery marks on two animal fossils found at Ti's al Ghadah indicate that hunting occurred there. Analyses of diet-related chemicals in 21 animal teeth unearthed at the site point to an environment similar to modern-day savannas in East Africa. — *Bruce Bower*

MATTER & ENERGY

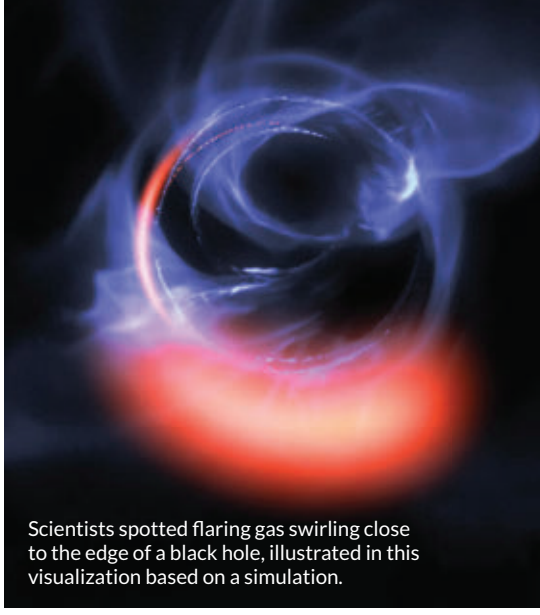
Cloud-zapping laser could help create a quantum internet

Cloudy weather limits scientists' ability to send data to satellites via lasers, because the clouds scatter the lasers' light. But a powerful, fast-pulsing laser can zap a tiny, cloud-free channel, allowing a second laser to slip through the hole and transmit information, a new study finds. The technique could assist scientists working to create worldwide quantum communications networks that rely on lasers to transmit particles of light, or photons.

University of Geneva researchers demonstrated the idea using a laboratory cloud chamber. When the first laser passed through a cloud, it rapidly heated the air, setting up a shock wave that shoved the cloud's water droplets away from the beam, the team reports in the Oct. 20 *Optica*. That action created a channel about a millimeter wide in the cloud, which allowed more of the second laser's light to make it through the haze.

Someday, quantum physics could allow for ultrasecure transmission of data. But first, scientists must construct a quantum internet to send delicate quantum particles from one continent to another. As a step toward that goal, last year, China created the first quantum satellite (*SN: 12/23/17, p. 27*), which exchanges laser light with stations on the ground.

Researchers developing such satellites have had to work around nasty weather. But now, it could be blue skies ahead. — *Emily Conover*



Scientists spotted flaring gas swirling close to the edge of a black hole, illustrated in this visualization based on a simulation.

L. CALÇADA/GRAVITY CONSORTIUM/ESO

ATOM & COSMOS

Three gas clouds nearly grazed the edge of the Milky Way's black hole

As far as close shaves with a black hole go, it doesn't get much closer than this.

Scientists have spotted clouds of gas hurtling around the monster black hole at the Milky Way's center, not far from the behemoth's edge. Observed on three occasions, the gas clouds careened along at unimaginably fast speeds — 30 percent of the speed of light, researchers report in the October *Astronomy & Astrophysics*.

The gas seemed to be near a boundary known as the innermost stable circular orbit — the closest matter can circle the black hole without falling in. The clumps, observed when the gas caused flares of infrared light, orbited at a distance just a few times the radius of the black hole's event horizon, the boundary from beyond which nothing can return. That's equivalent to about a quarter of the distance from Earth to the sun. Members of the GRAVITY collaboration observed the clouds using the Very Large Telescope array in Chile.

Scientists had already tracked the motion of a star orbiting near the black hole (*SN: 8/18/18, p. 12*). But that star was hundreds of times farther away than the gas.

These up-close encounters reaffirm scientists' belief that the Milky Way has a black hole lurking at its center. Such measurements could also help physicists test Einstein's theory of gravity, general relativity, says Harvard University astrophysicist Avi Loeb, who was not involved with the study. — *Emily Conover*

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FEATURE

Drinkability

Engineering better paths to safe drinking water

By Laurel Hamers

In a large shed-turned-laboratory on the outskirts of the University of Massachusetts Amherst, engineer David Reckhow has started a movement. More people want to use his lab to test new water treatment technologies than the building has space for.

Researchers, students and start-up companies all want access to test ways to disinfect drinking water, filter out contaminants or detect water-quality slipups. Parked behind the shed is the almost-ready-to-roll newcomer. Starting in 2019, the Mobile Water Innovation Laboratory will take promising new and affordable technologies to local communities for testing.

The facility's popularity reflects a persistent concern in the United States: how to ensure affordable access to clean, safe drinking water. Although U.S. drinking water is heavily regulated and pretty clean overall, recent high-profile contamination cases, such as the 2014 lead crisis in Flint, Mich. (*SN: 3/19/16, p. 8*), have exposed weaknesses in the system and shaken people's trust in their tap water.

In 2013 and 2014, 42 drinking water–associated outbreaks resulted in more than 1,000 illnesses and 13 deaths, based on reports to the U.S. Centers for Disease Control and Prevention. The top culprits were *Legionella* bacteria and some form of chemical, toxin or parasite, according to data published in November 2017.

Those numbers tell only part of the story, however. Many of the contaminants that the U.S. Environmental Protection Agency regulates through the 1974 Safe Drinking Water Act cause problems only when exposure happens over time; the effects of contaminants like lead don't appear immediately after exposure. Records of EPA rule violations note that in 2015, 21 million people were served by drinking water systems that didn't meet standards, researchers reported in a February study in the *Proceedings of the National Academy of Sciences*. That report tracked trends in drinking water violations from 1982 to 2015.

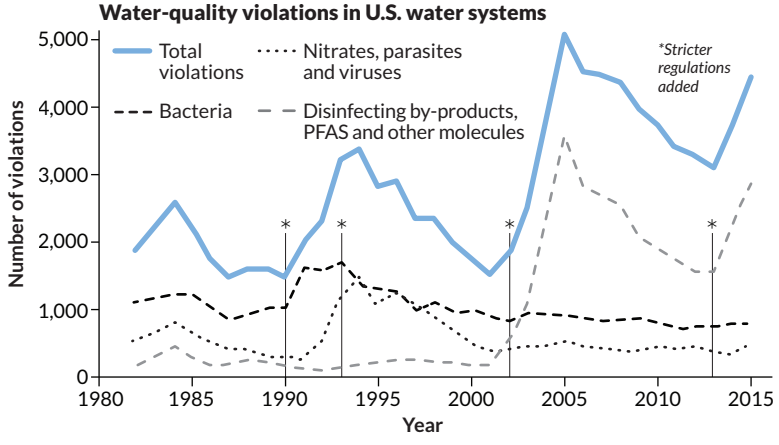
21 million
Number of U.S. residents served by drinking water systems that violated EPA standards in 2015
SOURCE: M. ALLAIRE, H. WU AND U. LALL/*PNAS* 2018

Current technology can remove most contaminants, says David Sedlak, an environmental engineer at the University of California, Berkeley. Those include microbes, arsenic, nitrates and lead. "And then there are some that are very difficult to degrade or transform," such as industrial chemicals called PFAS.

Smaller communities, especially, can't always afford top-of-the-line equipment or infrastructure overhauls to, for example, replace lead pipes. So Reckhow's facility is testing approaches to help communities address water-quality issues in affordable ways.

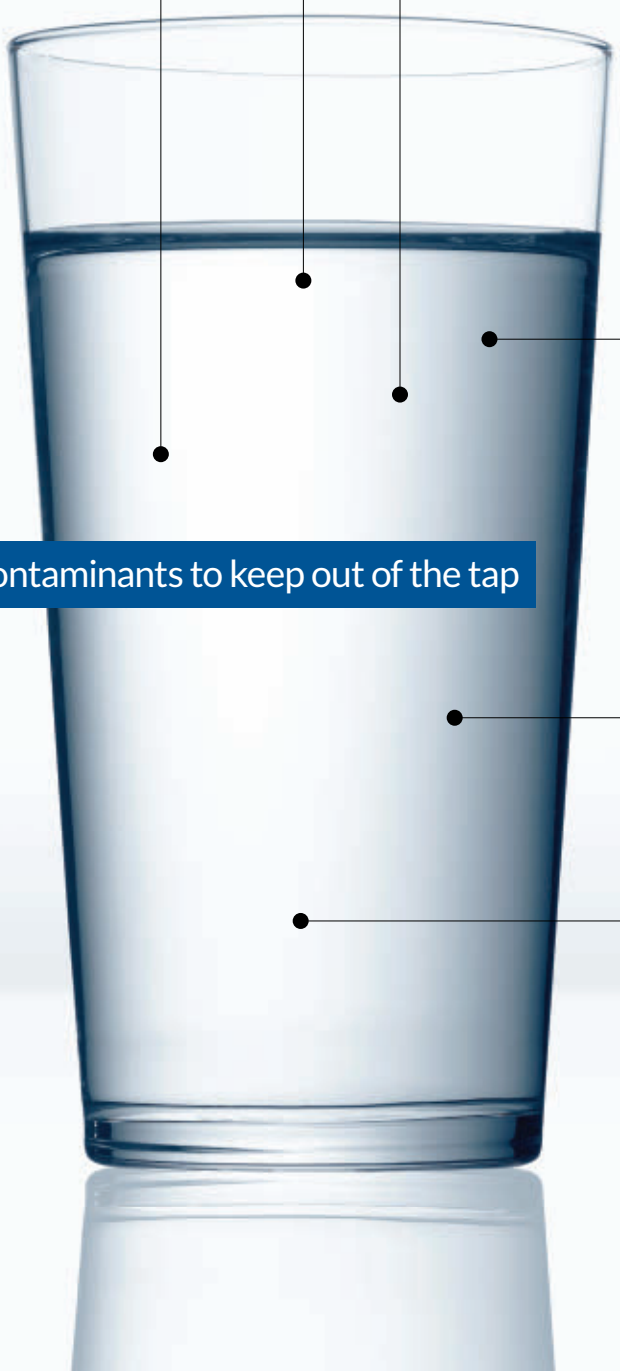
Some researchers are adding technologies to deal with new, potentially harmful contaminants. Others are designing approaches that work with existing water infrastructure or clean up contaminants at their source.

New rules boost violations The Safe Drinking Water Act regulates levels of contaminants in public water supplies. This graph tracks violations of the act over time. Spikes in violations often coincide with new, more stringent rules.



M. ALLAIRE, H. WU AND U. LALL/*PNAS* 2018, ADAPTED BY E. OTWELL

Contaminants to keep out of the tap



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Microbes
Untreated water can host harmful bacteria and viruses. When U.S. cities began disinfecting drinking water with chlorine in the early 1900s, rates of microbe-driven illnesses, such as cholera and typhoid, dropped sharply. Typhoid, caused by a type of *Salmonella* bacteria, affected 100 people per 100,000 in 1900. In 2006, the rate was down to 0.1 per 100,000.

By-products of disinfection
Disinfectants such as chlorine and bromine can clear water of dangerous microbes. But these chemicals can react with other molecules to form dangerous by-products such as chloroform, which is toxic to the kidneys, liver and central nervous system.

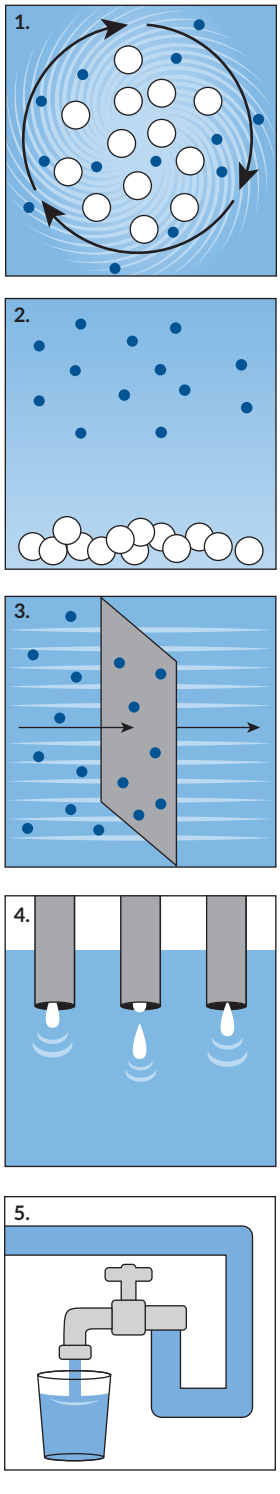
Industrial chemicals
Per- and polyfluoroalkyl substances, or PFAS, widely used to make nonstick coatings and firefighting foams, are a large group of industrial chemicals that are hard to remove from drinking water and hard to track. With superstrong carbon-fluorine bonds, PFAS don't break down in the environment. Some research has linked them to a higher risk of certain cancers, learning problems, growth deficits and fertility problems. Close to 5,000 PFAS exist today, very few of which are regulated, says Jamie DeWitt, a toxicologist at East Carolina University in Greenville, N.C. Chemical companies have no obligation to disclose what they use if the chemical isn't already regulated, DeWitt says. In June, a report by the U.S. Centers for Disease Control and Prevention suggested much lower safe exposure limits for some PFAS than current federal guidelines. Some states, including New Jersey and Vermont, have set stricter limits.

Arsenic
Arsenic is a concern for the 14 percent of U.S. residents who draw their drinking water from private wells instead of public water systems. Arsenic occurs naturally, but can also get into groundwater via agriculture or mining. Exposure to high levels of the heavy metal has been linked to skin, bladder and lung cancers, as well as lower IQ and birth defects. More than 2 million people in the United States may be exposed to levels of arsenic above the U.S. Environmental Protection Agency limit of 10 parts per billion, a 2017 report in *Environmental Science and Technology* estimated.

Nitrates
Nitrates enter water supplies largely through runoff from farms and fertilized lawns. In excess, the chemicals can prevent red blood cells from carrying oxygen through the body. The Clean Water Act of 1972 restricts factories from polluting waterways, but agricultural pollution goes largely unchecked. Farming states like Iowa have been hardest hit, says engineer Christopher Jones of the University of Iowa in Iowa City. Despite a decade of efforts to minimize the amount of nitrates swept down the Mississippi River, a source of drinking water for several states, nitrate levels in Iowa watersheds are consistently higher today than they were 20 years ago, Jones reported in April in *PLOS ONE*.

Lead
Lead pipes still carry water in 11,000 U.S. communities, which serve some 15 million to 22 million people, according to a 2016 survey by the American Water Works Association. The EPA mandates that cities adjust water chemistry to minimize the amount of lead that leaches from pipes into tap water, but those corrosion-controlling measures are not foolproof. The Flint lead crisis occurred after the city switched to a more corrosive source of drinking water, but didn't adjust the chemicals used to compensate. Some communities have committed to replacing every lead service line — a costly endeavor.

How is your water treated?



A typical drinking water treatment plant sends water through a series of steps. First, coagulants are added to the water. These chemicals clump together sediments, which can cloud water or make it taste funny, so they are bigger and easier to remove. A gentle shaking or spinning of the water, called flocculation, helps those clumps form (1). Next, the water flows into big tanks to sit for a while so the sediments can fall to the bottom (2). The cleaner water then moves through membranes that filter out smaller contaminants (3). Disinfection, via chemicals or ultraviolet light, kills harmful bacteria and viruses (4). Then the water is ready for distribution (5).

There's a lot of room for variation within that basic water treatment process. Chemicals added at different stages can trigger reactions that break down chunky, toxic organic molecules into less harmful bits. Ion-exchange systems that separate contaminants by their electric charge can remove ions like magnesium or calcium that make water "hard," as well as heavy metals, such as lead and arsenic, and nitrates from fertilizer runoff. Cities mix and match these strategies, adjusting chemicals and prioritizing treatment components, based on the precise chemical qualities of the local water supply.

Some water utilities are streamlining the treatment process by installing technologies like reverse osmosis, which removes nearly everything from the water by forcing the water molecules through a selectively permeable membrane with extremely tiny holes. Reverse osmosis can replace a number of steps in the water treatment process or reduce the number of chemicals added to water. But it's expensive to install and operate, keeping it out of reach for many cities.

Well owners are on their own

Fourteen percent of U.S. residents get water from wells and other private sources that aren't regulated by the Safe Drinking Water Act. These people face the same contamination challenges as municipal water systems, but without the regulatory oversight, community support or funding.

"When it comes to lead in private wells ... you're on your own. Nobody is going to help you," says Marc Edwards, the Virginia Tech engineer who helped uncover the Flint water crisis. Edwards and Virginia Tech colleague Kelsey Pieper collected water-quality data from over 2,000 wells across Virginia in 2012 and 2013. Some were fine, but others had lead levels of more than 100 parts per billion. When levels are higher than its 15 ppb threshold, the EPA mandates that cities take steps to control corrosion and notify the public about the contamination. The researchers reported those findings in 2015 in the *Journal of Water and Health*.

> "When it comes to lead in private wells ... you're on your own. Nobody is going to help you."
>
> MARC EDWARDS

To remove lead and other contaminants, well users often rely on point-of-use treatments. A filter on the tap removes most, but not all, contaminants. Some people spring for costly reverse osmosis systems.

New tech solutions

These three new water-cleaning approaches wouldn't require costly infrastructure overhauls.

Ferrate to cover many bases

Reckhow's team at UMass Amherst is testing ferrate, an ion of iron, as a replacement for several water treatment steps. First, ferrate kills bacteria in the water. Next, it breaks down carbon-based chemical contaminants into smaller, less harmful molecules. Finally, it makes ions like manganese less soluble in water so they are easier to filter out, Reckhow and colleagues reported in 2016 in *Journal–American Water Association*. With its multifaceted effects, ferrate could potentially streamline the drinking water treatment process or reduce the use of chemicals, such as chlorine, that can yield dangerous by-products, says Joseph Goodwill, an environmental engineer at the University of Rhode Island in Kingston.

Ferrate could be a useful disinfectant for smaller drinking water systems that don't have the infrastructure, expertise or money to implement something like ozone treatment, an approach that uses ozone gas to break down contaminants, Reckhow says. Early next year, in the maiden voyage of his mobile water treatment lab, Reckhow plans to test the ferrate approach in the small Massachusetts town of Gloucester.

Charged membranes

Filtering membranes tend to get clogged with small particles. "That's been the Achilles' heel

E. OTWELL

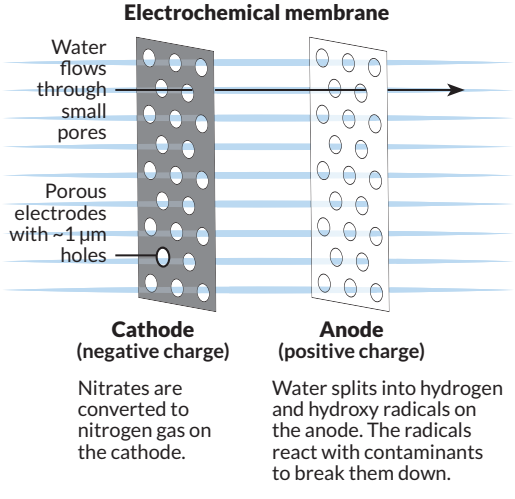
Patrick Wittbold, UMass Amherst quality assurance manager, helped design the Mobile Water Innovation Laboratory (left), a trailer that will test new drinking water technologies around Massachusetts. Inside the van is a flexible setup of filters, pipes and chemicals (right).

of membrane treatment," says Brian Chaplin, an engineer at the University of Illinois at Chicago. Unclogging the filter wastes energy and increases costs. Electricity might solve that problem and offer some side benefits, Chaplin suggests.

His team tested an electrochemical membrane made of titanium oxide or titanium dioxide that both filters water and acts as an electrode. Chemical reactions happening on the electrically charged membranes can turn nitrates into nitrogen gas or split water molecules, generating reactive ions that can oxidize contaminants in the water. The reactions also prevent particles from sticking to the membrane. Large carbon-based molecules like benzene become smaller and less harmful.

In lab tests, the membranes effectively filtered and destroyed contaminants, Chaplin says. In one test, a membrane transformed 67 percent of the nitrates in a solution into other molecules. The finished water was below the EPA's regulatory nitrate limit of 10 parts per million, he and colleagues reported in July in *Environmental Science and Technology*. Chaplin expects to move the membrane into pilot tests within the next two years.

Filter and destroy An electrochemical membrane filters out contaminants like a traditional membrane. As a bonus, it also breaks down contaminants via chemical reactions on the membrane's surface. SOURCE: B. CHAPLIN



Obliterate the PFAS

The industrial chemicals known as PFAS present two challenges. Only the larger ones are effectively removed by granular activated carbon, the active material in many household water filters. The smaller PFAS remain in the water, says Christopher Higgins, an environmental engineer at the Colorado School of Mines in Golden. Plus, filtering isn't enough because the chunky chemicals are hard to break down for safe disposal.

Higgins and colleague Timothy Strathmann, also at the Colorado School of Mines, are working on a process to destroy PFAS. First, a specialized filter with tiny holes grabs the molecules out of the water. Then, sulfite is added to the concentrated mixture of contaminants. When hit with ultraviolet light, the sulfite generates reactive electrons that break down the tough carbon-fluorine bonds in the PFAS molecules. Within 30 minutes, the combination of UV radiation and sulfites almost completely destroyed one type of PFAS, other researchers reported in 2016 in *Environmental Science and Technology*.

Soon, Higgins and Strathmann will test the process at Peterson Air Force Base in Colorado, one of nearly 200 U.S. sites known to have groundwater contaminated by PFAS. Cleaning up those sites would remove the pollutants from groundwater that may also feed wells or city water systems. ■

Explore more

- EPA. "Reducing PFAS in drinking water with treatment technologies." August 23, 2018. bit.ly/EPAreducingPFAS

TOP TWO: JOHN SOLEM/UMASS AMHERST; BOTTOM: E. OTWELL

A MAMMO

How ice age beasts competed with other animals and lost

By Alexandra Witze

The Gray Fossil Site, a sinkhole in northeastern Tennessee, is full of prehistoric treasures. Between 7 million and 4.5 million years ago, rhinoceroses, saber-toothed cats and other creatures, even red pandas, perished here by the edge of a pond. But that bounty of fossils pales next to the site's biggest find: a mastodon's skeleton, nearly 5 million years old, preserved in exquisite detail all the way down to its ankle bones. "It is just fantastic," says Chris Widga, a paleontologist at East Tennessee State University in nearby Johnson City.

The ancient elephant relative became known as Ernie because it was enormous, calculated soon after its 2015 discovery to have weighed 16 tons in life. The name came from musician Tennessee Ernie Ford, known for the coal-mining song "Sixteen Tons." Since then the researchers have revised the mastodon's weight down to 10.5 tons, says Widga, but the name stuck.

Ernie is still the biggest mastodon ever found in North America. He would have dwarfed today's large African elephants, which average up to six tons.

SERGIO DE LA ROSA

TH WORLD

A Columbian mammoth (*Mammuthus columbi*), an American mastodon (*Mammut americanum*) and a gomphothere (*Cuvieronius*) were among the prehistoric elephant relatives that roamed North America and Eurasia until the end of the last ice age.

Excavators are working to dig up the rest of Ernie's bones before this winter, with an eye to reassemble the ancient beast, the researchers reported in October in Albuquerque at a meeting of the Society of Vertebrate Paleontology.

Ernie is a jaw-dropping example of the ancient elephants that once roamed Earth. Scientists have found the remains of mastodons and their relatives, the mammoths, throughout the Northern Hemisphere — from huge tusks buried in the Alaskan permafrost to mummified baby mammoths in Siberia (*SN Online: 7/14/14*).

Now, researchers are knitting together these scattered discoveries into a more coherent picture of the lives and deaths of mammoths and mastodons. Scientists are exploring what plants these megaherbivores ate as they rambled across the landscape, and how they competed with other animals — including humans — as climate changed and the last ice age ended some 11,700 years ago.

Clues to these mysteries lie in ancient teeth and bones. Tiny scratches on the teeth of mastodons from North America suggest that they ate a surprisingly varied diet of grasses, twigs and other plants, depending on their environment. A recent analysis of the chemistry of European mammoth bones reveals that those animals probably struggled with dwindling food sources as the climate warmed, which probably hastened the animals' demise.

These foot bones are from Ernie, a mastodon measuring 3.2 meters at the shoulder, the tallest ever found in North America.

FOOT BONES: ETSU MUSEUM OF NATURAL HISTORY

Mastodon teeth (top) featured sharp cusps that were well-adapted to grinding up woody material such as twigs and leaves. Mammoth teeth (one shown, bottom) were flatter, to better grind grasses.

Excavating some of the last known sites where mammoths and humans coexisted points to how early Americans gathered around a kill, making the most of the giant carcass to feed themselves.

Scientists hope to better understand the extinct elephants' role in ancient ecosystems. "How did these big herbivores respond to climatic shifts, both before and after humans arrived?" asks Hendrik Poinar, a geneticist and anthropologist at McMaster University in Hamilton, Canada. "How resilient were these populations — or not?"

The answers may even help biologists eke out lessons about how modern elephants might cope as habitats shrink and hunting pressures rise.

Regional diets

Roughly a dozen species of mammoths and mastodons ranged across the globe at different times in the last 25 million years. The last of them died out for the most part at the end of the Pleistocene Epoch, which marked the end of the last ice age. The most famous is the woolly mammoth (*Mammuthus primigenius*), which appeared on the scene relatively late, around 350,000 years ago, and survived long enough to coexist with early humans in North America, Europe and Asia (see map on Page 26). Its shaggy coat and upturned tusks have made it an ice age icon, famous for roaming northern grasslands alongside saber-toothed cats, cave bears and other extinct beasts.

North America also had the Columbian mammoth (*Mammuthus columbi*), which arose about 1 million years ago and was bigger and less hairy than the woolly mammoth. It wandered as far south as Central America and left its heavy footprints in places like White Sands National Monument in New Mexico. Park rangers there have studied vast "trample grounds," where herds of Columbian mammoths once thundered across the landscape.

A third extinct relative of elephants is the mastodon, including the American version (*Mammut americanum*). Mastodons were typically smaller and longer-bodied than mammoths, and quite a bit heftier. "We often think of mammoths as the supermodels of the Pleistocene, long, slender, very tall animals for their weight," Widga says. In contrast, "mastodons are stocky."

To tell a mammoth from a mastodon, start at the teeth. Mastodon teeth have cone-shaped tips, unlike the broad, flat teeth of mammoths. That suggests that mastodons gnawed on more branches, twigs and leafy things as opposed to the grasses that mammoths ground between their teeth.

With new detailed dental studies, researchers are getting a closer look at the animals' diets. Paleoecologists Gregory Smith and Larisa DeSantis of Vanderbilt University in Nashville recently teamed up with Jeremy Green, a paleontologist at Kent State University in Ohio. They looked at patterns of wear, like the small pits left by nuts or acorns and the elongated scratches left by

FROM TOP: ALIZADA STUDIOS/SHUTTERSTOCK; VITALII HULAI/SHUTTERSTOCK

A look at some ancient elephant relatives

American mastodon (*Mammut americanum*)
Size: Up to 3 meters at the shoulder, weight up to six tons
Diet: Primarily trees and other woody material

Gomphothere (*Cuvieronius*)
Size: Up to 2.3 meters at the shoulder, weight up to 3.5 tons
Diet: Grasses, trees and a wide variety of other plants

blades of grass. The team's study of 65 mastodons from across North America, dating from 51,000 to 11,000 years ago, showed one group of mastodons ate very different plants than another, depending on where the animals lived. In Florida, the teeth indicated that the mastodons had been chewing on relatively soft material, perhaps the delicate tips of cypress trees. In Missouri, mastodons ate harder materials, such as seeds and bark. In New York, they chewed on conifer needles and twigs.

This rare effort to look at mastodon diets across a big geographic area, reported last year in *Palaeogeography, Palaeoclimatology, Palaeoecology*, shows that mastodons were adaptable. They chomped whatever trees and shrubs were common in their habitat. "It really hadn't been proven until we started looking at it," Smith says.

Those mastodons, at least, were flexible enough to change food sources as they migrated across the landscape. Another big ice age herbivore was not as adaptable, Smith reported in October at the Albuquerque meeting.

Living across both North and South America were the gomphotheres (including the genus *Cuvieronius*). These elephant relatives were smaller than mammoths and mastodons and had a body shape and size more like a modern elephant. Gomphotheres were hunted by early Americans (*SN: 8/9/14, p. 7*), but the creatures had also begun to dwindle well before people arrived on the scene.

The decline of the gomphotheres is surprising because they could eat just about any plant, from woody material to grasses. In theory, the animals should have been able to adapt to any food source. And yet they were apparently unable to cope as mammoths and mastodons moved into their chomping grounds, and as climate change squeezed the available resources.

To find out why, Smith compared patterns of tooth wear and other evidence from mammoths, mastodons and gomphotheres that once lived along the Gulf coastal plains of Texas and Florida. Starting around 1.8 million years ago, gomphotheres switched from grazing to eating a wider range of foods, Smith found. But the mammoths were already well specialized for eating grasses, and mastodons for eating the woodier plants. Gomphotheres couldn't compete with the other elephants, Smith reported.

A cast of a lower leg bone of a modern-day African elephant is dwarfed by the fossilized lower leg of Ernie, the enormous Tennessee mastodon.

ETSU MUSEUM OF NATURAL HISTORY

Ultimately, gomphotheres began to disappear from the scene. Only a few lingered until their final extinction, by at least 11,000 years ago.

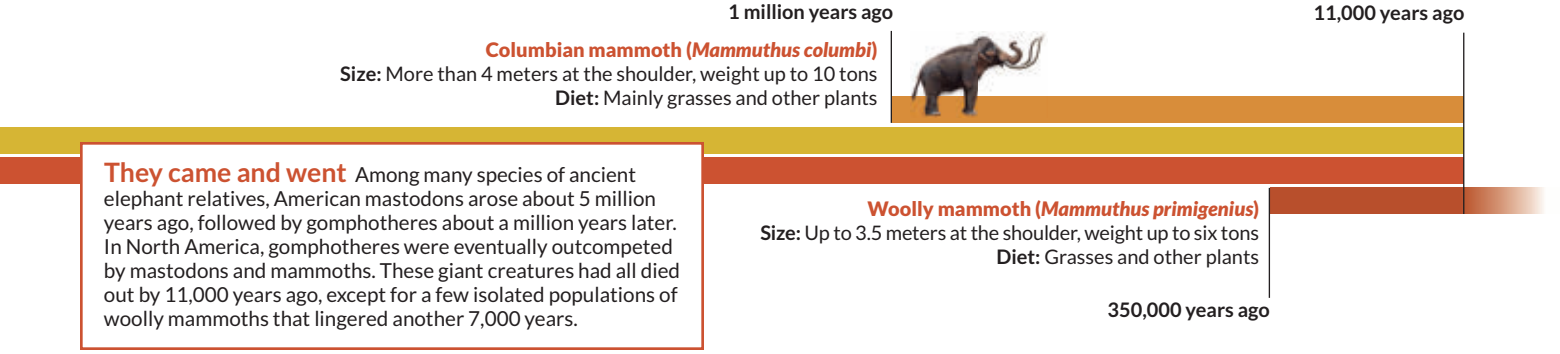
Competing interests

On the other side of the Atlantic Ocean, a similar battle for resources in the face of climate change unfolded. This time, though, mammoths were competing with horses.

Chemical clues in an animal's teeth and bones show variations of elements, or isotopes, specific to the types of plants or meat eaten.

Certain plants contain extra neutrons in the atomic nuclei of some of their elements. That distinction is reflected in the isotopic makeup of the skeletons of animals that ate those plants. Meat eaters retain a record of the plant eaters that they ate.

Compared with other herbivores, mammoths have unusual isotopes. Their bones are typically higher in the isotope nitrogen-15, even when



They came and went Among many species of ancient elephant relatives, American mastodons arose about 5 million years ago, followed by gomphotheres about a million years later. In North America, gomphotheres were eventually outcompeted by mastodons and mammoths. These giant creatures had all died out by 11,000 years ago, except for a few isolated populations of woolly mammoths that lingered another 7,000 years.

Huts built of mammoth bones, like this one excavated at Mezhyrich, Ukraine, show how early humans relied on the creatures for many of their daily needs. Human hunting contributed to the animals' extinction in many places.

compared with horses and other grazing animals in the same region. It may be that mammoths preferred to eat mature and dry grasses, which are higher in nitrogen-15 than younger, greener grasses preferred by other grazers.

But there's one place where mammoths did not show the high nitrogen-15 levels: a site called Mezhyrich in Ukraine, which is famous for its prehistoric huts made of mammoth bones. Mezhyrich bones contain far less nitrogen-15 than is typical for mammoths. "For me, it was something absolutely new and unusual," says biogeochemist Dorothée Drucker of the University of Tübingen in Germany.

To see what was going on, she and colleagues recently studied mammoth bones from other sites near Mezhyrich. All date to around 18,000 to 17,000 years ago, a time when the landscape was gradually warming. These other bones, too, contained surprisingly low levels of nitrogen-15. In fact, they were as low as the nitrogen-15 levels found in horse bones from nearby and dating to the same time period, the researchers reported in a paper published online in June in *Quaternary Research*.

That suggests that mammoths weren't grazing on their usual grasses rich in nitrogen-15. Instead, something had apparently forced them to shift to a new menu. Perhaps the changing climate altered the types of vegetation growing in the mammoth landscape, shifting from rich and diverse grasslands to a less productive shrubland. Having to compete with other grazers, such as horses, for this less-preferred diet some 17,000 to 13,800 years ago may have been one of the last straws.

Dinner camp

Of course, climate change wasn't the only thing stressing mammoths and mastodons as the last ice age wound to a close.

People hunted mammoths across Europe and northern Asia for thousands of years, possibly contributing to the animals' gradual decline (*SN: 7/27/13, p. 10*). In North America, the downfall was more abrupt. Mammoths and mastodons roamed without major predators for hundreds of thousands of years or more. Then humans crossed a land bridge from Siberia to Alaska probably some time after 16,000 years ago (*SN Online: 8/8/18*), bringing with them the knowledge of how to use spears to take down the huge hairy beasts.

Scientists have argued for decades about how much human hunting versus climate and other environmental changes contributed to the death of North America's mammoths and mastodons. Todd Surovell, an archaeologist at the University of Wyoming in Laramie, says the evidence points mostly to people. "Humans arrived to a continent full of large naïve animals," he says. The mammoths were "easy pickings," he says, "practically like a herd of cattle."

Surovell studies archaeological sites where humans butchered mammoths, mastodons or gomphotheres. He and colleagues have spent the last few years excavating a 12,900-year-old site known as La Prele, in eastern Wyoming. It is one of about 15 butchery sites known of in North America.

When first discovered in 1986, the site yielded part of a mammoth and a few stone tools. In 2014,

Northern exposure One dominant species of mammoth, the woolly, ranged across large swaths of the Northern Hemisphere (brown) near the end of the last ice age. The species crossed the land bridge between Siberia and Alaska but could not conquer mountain chains such as the Himalayas.

FROM TOP: HIP/ART RESOURCE, NY; RALF-DIETRICH KAHLKE/SENCKENBERG RESEARCH STATION OF QUATERNARY PALAEONTOLOGY WEIMAR, GERMANY

Surovell and his team stumbled on archaeological gold. While widening a path 12 meters away from the 1986 find, a team member's shovel struck a large stone artifact, a tool probably used for chopping. "All of a sudden the site expanded hugely," Surovell says.

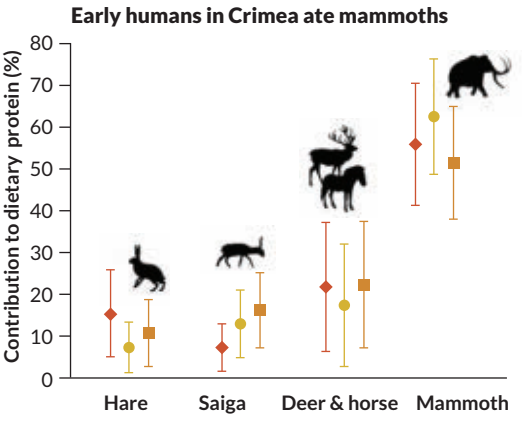
Since then, the researchers have unearthed a dramatic story of how early hunters gathered triumphantly around their kill. The mammoth bones mark where the animal lay; nearby is a string of fire pits, presumably where people camped as they butchered the meat. Near the campfires lie domestic artifacts such as bone needles and bone beads, which suggest that several families or a small village temporarily settled around the mammoth kill.

"We always expected to find campsites associated with animals, but this is only the second time we've found this kind of thing archaeologically" in North America, Surovell says. For a smaller animal, hunters might have cut up the carcass and carried the meat back to their camp. That wasn't possible for a mammoth, which could have weighed up to 10 tons. Instead, the people "moved their camp to the mammoth," he says. Surovell has presented findings from the La Prele site at various small archaeology meetings.

Based on the number of artifacts at La Prele, Surovell thinks the people may have stayed around the carcass for perhaps a week, feasting and drying meat to take with them. There's no question that humans ate mammoth; Drucker, among others, has found high nitrogen-15 levels in the bones of early European humans, which suggest the people derived a large fraction of their protein from mammoth meat.

Ultimately, many experts say, mammoths and mastodons probably went extinct because of some combination of human hunting and climate change, with those factors varying around the globe. Different species winked out at different times in different locations; most vanished by around 11,000 years ago as the great northern ice sheets receded and temperatures rose. A few isolated herds hung on for another few thousand years.

One group of woolly mammoths made it until about 5,600 years ago on St. Paul Island, north of Alaska's Aleutian Islands. The animals probably died out when the island's lakes dried up (*SN Online: 8/1/16*). Another group survived all the way until 4,000 years ago on Wrangel Island off Siberia, where genetic studies suggest that the creatures eventually succumbed to too much inbreeding.



Heavy eaters Three humans who lived in Crimea 38,000 to 33,000 years ago ate mammoth and other meat, as determined by unique nitrogen values in their bones (each color bar represents a person's protein intake).

Once those last animals vanished, it was the end of the mammoth lineage. But understanding their fate may help researchers help modern elephants. Across Asia and Africa, elephants are facing some of the same stresses that mammoths and mastodons did long ago. Climate change is reshaping the landscape. Humans are hunting elephants and destroying their habitat.

The lessons of the past might help conservationists come up with new ways to help elephants survive, Smith says. "The fossil record can tell us what happened in the past in similar circumstances," he says. "My hope is that a better understanding of ancient ecology can give us some insight into the future."

Poinar agrees. He and grad student Emil Karpinski are working on the biggest analysis of mastodon DNA. They have more than 100 samples gathered from around the Northern Hemisphere. (Sadly, Tennessee Ernie is too old for good DNA preservation.) The researchers hope to show how mastodon populations grew and shrank over time, and how those changes were linked to shifting climate and to human hunting.

"It's no shock to say that humans have played a drastic role in extinctions in the past and are doing so as we speak," Poinar says. "But if we were to leave species on their own, how would climate change affect their ability to be resilient?"

The answers, when they come, may just show what today's elephants need to survive. ■

Explore more

- Daniel C. Fisher. "Paleobiology of Pleistocene proboscideans." *Annual Review of Earth and Planetary Sciences.* May 2018.

D.G. DRUCKER *ET AL*/*SCIENTIFIC REPORTS* 2017, ADAPTED BY C. CHANG

INTERVIEW

Science is a game for this former chemistry instructor

A physicist, a gamer and two editors walk into a bar. No, this isn't the setup for some joke. After work one night, a few *Science News* staffers tried out a new board game, Subatomic. This deck-building game combines chemistry and particle physics for an enjoyable — and educational — time.

Subatomic is simple to grasp: Players use quark and photon cards to build protons, neutrons and electrons. With those three particles, players then construct chemical elements to score points. Scientists are the wild cards: Joseph J. Thomson, Maria Goeppert-Mayer, Marie Curie and other Nobel laureates who discovered important things related to the atom provide special abilities or help thwart other players.

The game doesn't shy away from difficult or unfamiliar concepts. Many players might be unfamiliar with quarks, a group of elementary particles. But after a few rounds, it's ingrained in your brain that, for example, two up quarks and one down quark create a proton. And Subatomic includes a handy booklet that explains in easy-to-understand terms the science behind the game. The physicist in our group vouched for the game's accuracy but had one qualm: Subatomic claims that two photons, or particles of light, can create an electron. That's theoretically possible, but scientists have yet to confirm it in the lab.

The mastermind behind Subatomic is John Coveyou, who has a master's degree in energy, environmental and chemical engineering. As the founder and CEO of Genius Games, he has created six other games, including Ion (*SN: 5/30/15, p. 29*) and Linkage (*SN: 12/27/14, p. 32*). Next year, he'll add a periodic table game to the list. Because *Science News* has reviewed several of his games, we decided to talk with Coveyou about where he gets his inspiration and how he includes real science in his products. The following discussion has been edited for length and clarity. — *Kyle Plantz*

John Coveyou (second from right) plays one of his science board games, Cytosis, which focuses on cell biology, with several game testers.

When did you get interested in science?

My mom was mentally and physically disabled, and my dad was in and out of prison and mental institutions. So early on, things were very different for me. I ended up leaving home when I was in high school, hopscotching around from 12 different homes throughout my junior and senior year. I almost dropped out, but I had a lot of teachers who were amazing mentors. I didn't know what else to do, so I joined the army. While I was in Iraq, I had a bunch of science textbooks shipped to me, and I read them in my free time. They took me out of the environments I was in and became extremely therapeutic. A lot of the issues we face as a society can be worked on by the next generation having a command of the sciences. So I'm very passionate about teaching people the sciences and helping people find joy in them.

Players build elements in John Coveyou's newest game, Subatomic.

Why did you start creating science games?

I was teaching chemistry at a community college, and I noticed that my students were really intimidated by the chemistry concepts before they even came into the classroom. They really struggled with a lot of the basic terminology. At the same time, I've been a board gamer pretty much my whole life. And it kind of hit me like, "Whoa, wait a second. What if I made some games that taught some of the concepts that I'm trying to teach my chemistry students?" So I just took a shot at it. The first couple of games were terrible. I didn't really know what I was doing, but I kept at it.

How do you test the games?

We first test with other gamers. Once we're ready to get feedback from the general public, we go to middle school or high school students. Once we test a game with people face-to-face, we will send it across the world to about 100 to 200 different play testers, and those vary from your hardcore gamers to homeschool families to science teachers, who try it in the classroom.

How do you incorporate real science into your games?

I pretty much always start with a science concept in mind and think about how can we create a game that best reflects the science that we want to communicate. For all of our upcoming games, we include a booklet about the science. That document is not created by Genius Games. We have about 20 to 30 Ph.D.s and doctors across the globe who write the content and edit each other. That's been a real treat to actually show players how the game is accurate. We've had so many scientists and teachers who are just astonished that we created something like this that was accurate, but also fun to play. ■

FROM TOP: COURTESY OF SARAH CONARD, LADUE NEWS; BRITTANIE BOE/BE BOLD GAMES

Learn more about Subatomic at **bit.ly/SubatomicGame**

Science News for Students

***Science News for Students* (sciencenewsforstudents.org)** is an award-winning, free online magazine that reports daily on research and new developments across scientific disciplines for inquiring minds of every age — from middle school on up.

Studies report new risks to teens from secondhand smoke

People who never touch a cigarette can be harmed by smoking. They merely have to inhale the airborne pollutants exhaled by a smoker. That secondhand smoke can linger in the air for days. Teens who can't avoid breathing it in may develop coughing and trouble breathing, a new study suggests. And that's not the worst of it. Another study found that teens who were exposed to that smoke for years could develop far more serious lung diseases such as asthma. — *Meenakshi Prabhune*

Read more: www.sciencenewsforstudents.org/secondhand-smoke

Microplastics take flight in the bellies of mosquitoes

Mosquito larvae, like those at right, can eat tiny bits of plastic that pollute their watery homes. Scientists found that much of this plastic — which is smaller than half a centimeter — stays in the mosquitoes as they grow into adults. Birds and bats that eat these mosquitoes may get a mouthful of plastic. And any animal that eats those birds or bats may also get a side order of microplastics with their meals. It's not yet known how harmful it is to eat microplastics, says zoologist Amanda Callaghan of the University of Reading in England. "If we wait to find out, it may be too late to do anything about it." — *Sharon Oosthoek*

Read more: www.sciencenewsforstudents.org/plastic-mosquito

SNS debuts year-long Climate Change Chronicles

No single species has ever been responsible for big changes on Earth. Until now. Human activities — particularly the burning of fossil fuels — have emerged as a driving force in changing the chemistry of Earth's atmosphere. The average temperatures near the planet's surface and its upper oceans are increasing. That warming, in turn, has begun to alter the global climate. Through news stories, features and explainers, we are investigating these changes, focusing on the new science behind climate change and exploring how Earth's life — including humans — are adapting. — *Janet Raloff, Editor*

Read more: www.sciencenewsforstudents.org/climate-change-chronicles

FROM TOP: TONKOVIC/ISTOCK.COM; APISITWILAIJIT/ISTOCK.COM; MYILLO/ISTOCK.COM, ADAPTED BY E. OTWELL

OCTOBER 13, 2018

Point, counterpoint

*In "The SN 10: Scientists to watch" (*SN: 10/13/18, p. 18*),* Science News *profiled 10 early- and mid-career scientists who are pushing boundaries to answer pressing questions facing science and society.* Some readers had strong reactions to the profiles.

Charles Eby praised stories about the SN 10 scientists. "Of course I love to read about new discoveries, but with this article, I realized how much more I enjoy hearing about the people and their discoveries," he wrote. "A well-written book about science is filled with stories about the scientists and their struggles and idiosyncrasies, their successes and failures. Your stories about the SN 10 were well written and most enjoyable as well as inspiring."

Barry Maletzky shared a different opinion. "While it is within human nature to compare, compete and award winners while ignoring runners-up, in my opinion, science should not be addressed *ad hominem*," he wrote. "By the mere process of selection, you are lionizing the few while relegating others to anonymity who have contributed equally to our accumulation of knowledge." **Maletzky** continued: "I humbly suggest you achieve your objective of disseminating scientific advances by continuing your excellent coverage of the works accumulated by the *teams* of scientists working in their fields and leave the awards to Hollywood."

Shapely storms

Scientists have observed a second hexagonal vortex over Saturn's north pole, ***Christopher Crockett*** *reported in "Saturn has two hexagons, not one, swirling around its north pole" (*SN: 10/13/18, p. 14*).* Online reader **motey joe** wondered what could be responsible for forming the planet's six-sided storms.

A strong current called a jet stream drives the storms, says planetary scientist **Leigh Fletcher** of the University of Leicester in England. One theory is that Saturn's unstable atmosphere is responsible for the jet stream's wobbly pattern, which helps shape the swirling hexagons, **Fletcher** says. "Experiments in large rotating tanks, as well as large-scale computer simulations, are also able to produce these features and other polygonal shapes," he says.

Well deserved

Astrophysicist Jocelyn Bell Burnell won the Special Breakthrough Prize in Fundamental Physics for her 1967 discovery of pulsars. She discussed with ***Lisa Grossman*** *using the $3 million prize to promote diversity in science in "Jocelyn Bell Burnell wins big in physics" (*SN: 10/13/18, p. 5*).* Burnell's accomplishments and outlook struck a chord with readers.

"She really is an incredible advocate for physics and science in general," Twitter user **@physcamy** wrote. "As both a fellow Northern Irish person and a soon-to-be physics student," he says he found her inspiring.

Online reader **Maia** echoed that sentiment, adding that Bell Burnell is even more inspiring "because of how she's decided to spread the good around."

Twitter user **@RealHainesEason** expressed appreciation for *Science News*' coverage. "Stories like this AND your regular science reporting combined are why I've kept you in my feed long after I unfollowed many other outlets," he wrote.

Corrections

The book review "*Einstein's Shadow* explores what it takes to snap a black hole's picture" (*SN: 10/13/18, p. 30*) incorrectly stated that intense gravity warps space and time near a black hole's event horizon. Space and time are warped by the black hole's huge mass.

"The next malaria menace" (*SN: 11/10/18, p. 22*) mischaracterized the World Health Organization's position on monkey malaria. The agency excludes monkey malaria parasites from its malaria eradication goals because those particular parasites have not been shown to transmit among humans. And three photos in the story were credited to K. Fornace, but they were taken by Joshua Paul of the London School of Hygiene and Tropical Medicine.

Join the conversation

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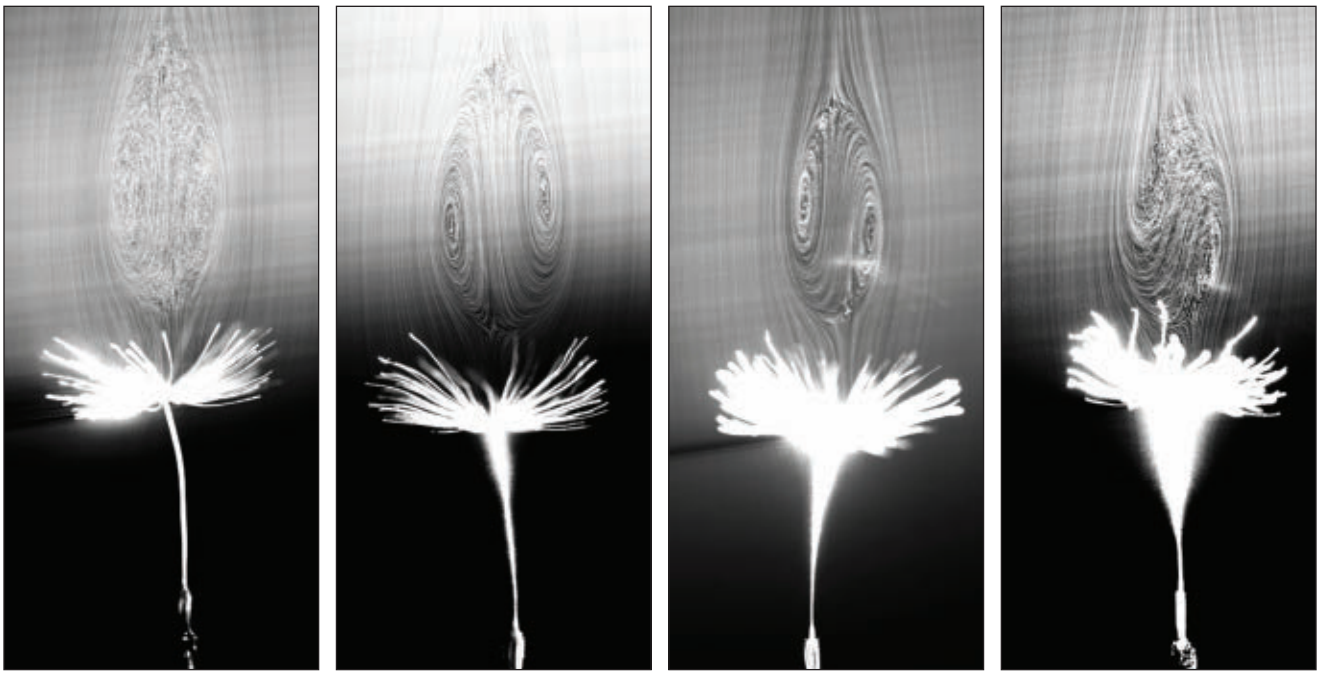
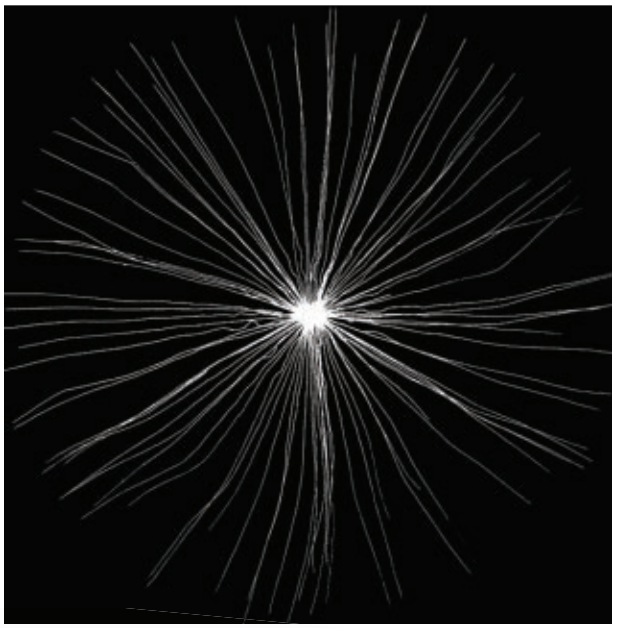
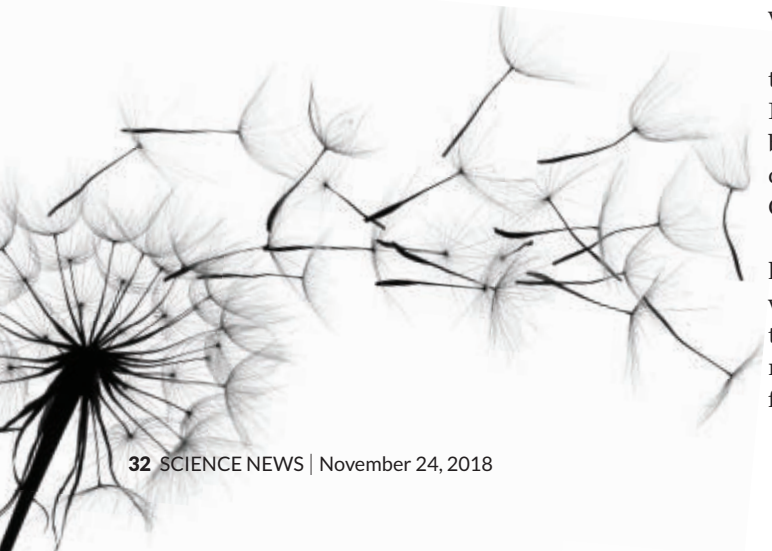






How dandelion seeds ride the wind

When you're a little ball of fluff, flying is hard.

To soar through the air, dandelion seeds stir up an unusual type of vortex in the air directly above them (shown above with seeds in a laboratory wind tunnel). The new finding resolves a long-standing question about how the seeds stay aloft, researchers report in the Oct. 18 *Nature*.

Scientists knew that the fluffy structure that extends from a dandelion seed, called the pappus, helps keep seeds airborne. But the pappus is made up of tiny hairlike filaments (top-down view at left), making it mostly empty space. "Nobody really knew, in terms of the physics, how it could fly," says study coauthor Naomi Nakayama, a biophysicist at the University of Edinburgh.

So Nakayama and her colleagues dug into the weeds. High-speed video and mathematical simulations revealed that the pappus filaments act together like a uniform sheet and create drag — a force that counters gravity. Air also flows around the pappus and gets sucked into the area just above it. This air forms a swirling bubble that the researchers call a separated vortex ring, which adds to the drag.

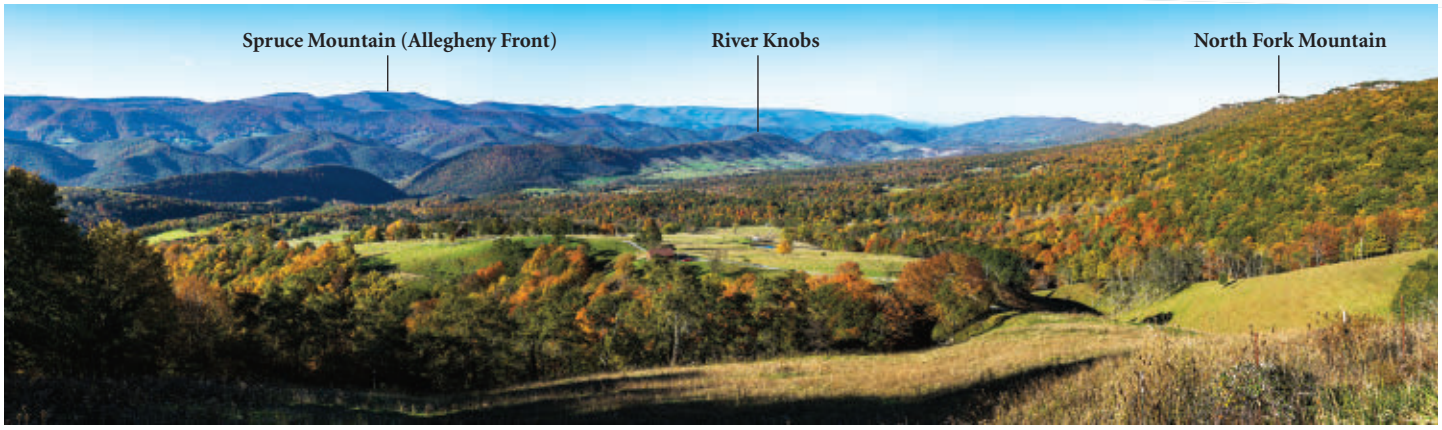
As vortex rings go, the dandelion's is odd. Normally, such vortices stay attached to an object or totally separate and disappear. But the dandelion's vortex does a little bit of both: It separates but then hangs out above the seed. "When you show it to a fluid dynamicist, it blows their mind," says study coauthor Cathal Cummins, a fluid dynamicist also at the University of Edinburgh.

The vortex stays in place because the filament parachute is leaky. As air gets through the pappus, a pressure gradient forms with low pressure above the filaments and high pressure below them, keeping the vortex stable. This low pressure, the team reports, is also what sucks in air flowing around the filaments to form the vortex in the first place. — *Helen Thompson*

BOTTOM LEFT: SUNNYBEACH/ISTOCK.COM; ALL OTHERS: C. CUMMINS *ET AL*/*NATURE* 2018

See a dandelion's vortex in action at **bit.ly/SN_Dandelion**

GEOLOGIC ROAD TRIP OF THE MONTH



View to the north from Germany Valley scenic overlook. Ordovician rocks in the valley constitute the core of the Wills Mountain Anticline, while the younger Tuscarora Sandstone on North Fork Mountain to the east (far right) and the River Knobs to the west (left center) are the limbs. The Allegheny Front rises in the distance.

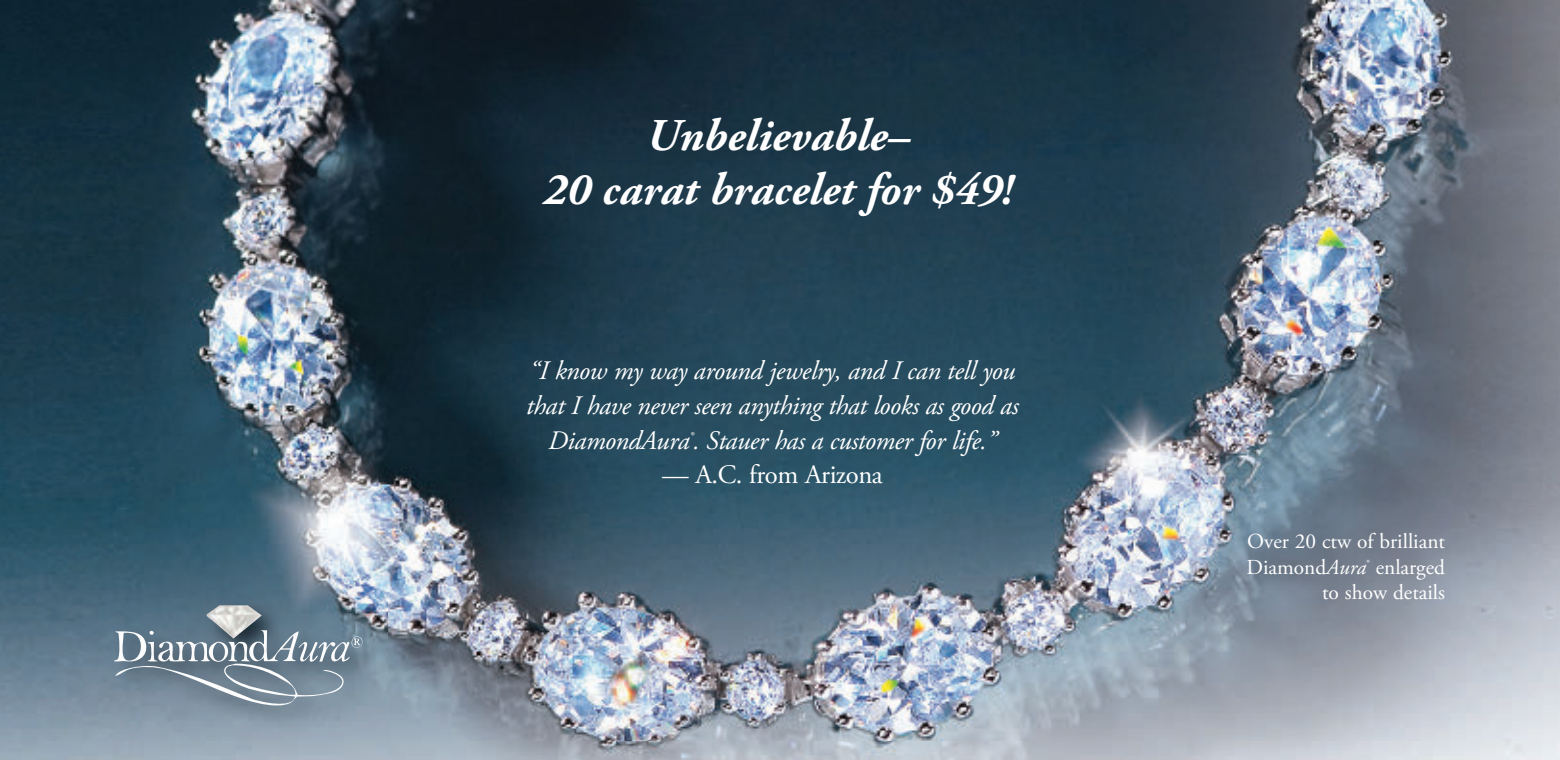
GERMANY VALLEY OVERLOOK

As US 33 ascends the west side of North Fork Mountain, look for a blue sign with white lettering announcing a scenic overlook. It is well worth a stop, but use caution both entering and exiting because the road curves sharply in both directions. The overlook is approximately 3,350 feet in elevation; at Judy Gap, the elevation was 1,940 feet, and the summit of North Fork Mountain is 3,580 feet. As the sign at the overlook indicates, to the north lies Germany Valley—the hollowed-out core of the Wills Mountain Anticline, which is plunging to the north. The floor of the valley slopes down to the west.

The Wills Mountain Anticline is asymmetrical, and the less steep east limb, visible to the upper right (northeast), dips about 40 degrees to the east. The tall cliffs on top of North Fork Mountain create a common topographic feature of the Valley and Ridge Province called a hogback, a vernacular term adopted by geologists to identify steeply sloped ridges, 20 degrees or more, with narrow summits. The hogbacks form when resistant rock caps one side of a ridge, protecting the softer units underneath from erosion.

To visualize the entire anticline, imagine a time when German Valley did not exist. The cliffs of Tuscarora that cap the North Fork Mountain hogback were connected to the vertical Tuscarora of the River Knobs in a continuous layer, arching above the older units that made up the core of the anticline before erosion hollowed it out. Weathering and erosion of anticlines in the Valley and Ridge are often aided by extensional fractures that form on the upper surface of the rock as it is stretched during folding. Think of an anticline as comparable to a sponge that has been folded. The holes in the middle of the upper surface of the sponge get wider as it is bent. In rock layers, water then enters the pores and fractures and breaks the layers into pieces as it alternately freezes and thaws.

To the west beyond River Knobs is the elevated edge of the high plateaus and the Allegheny Front. This is a particularly good location to see the Front in its entirety. Of note are the Fore Knobs, which are the eroded remnants of the Late Devonian rock unit that bears their name. The Fore Knobs give the face of the Front a "stepped" appearance as it slopes down to the Valley and Ridge Province. Such striking contrasts in elevation are characteristic of the Valley and Ridge Province.



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