A Century of King Tut | Starlight Gets Pushy

ScienceNews

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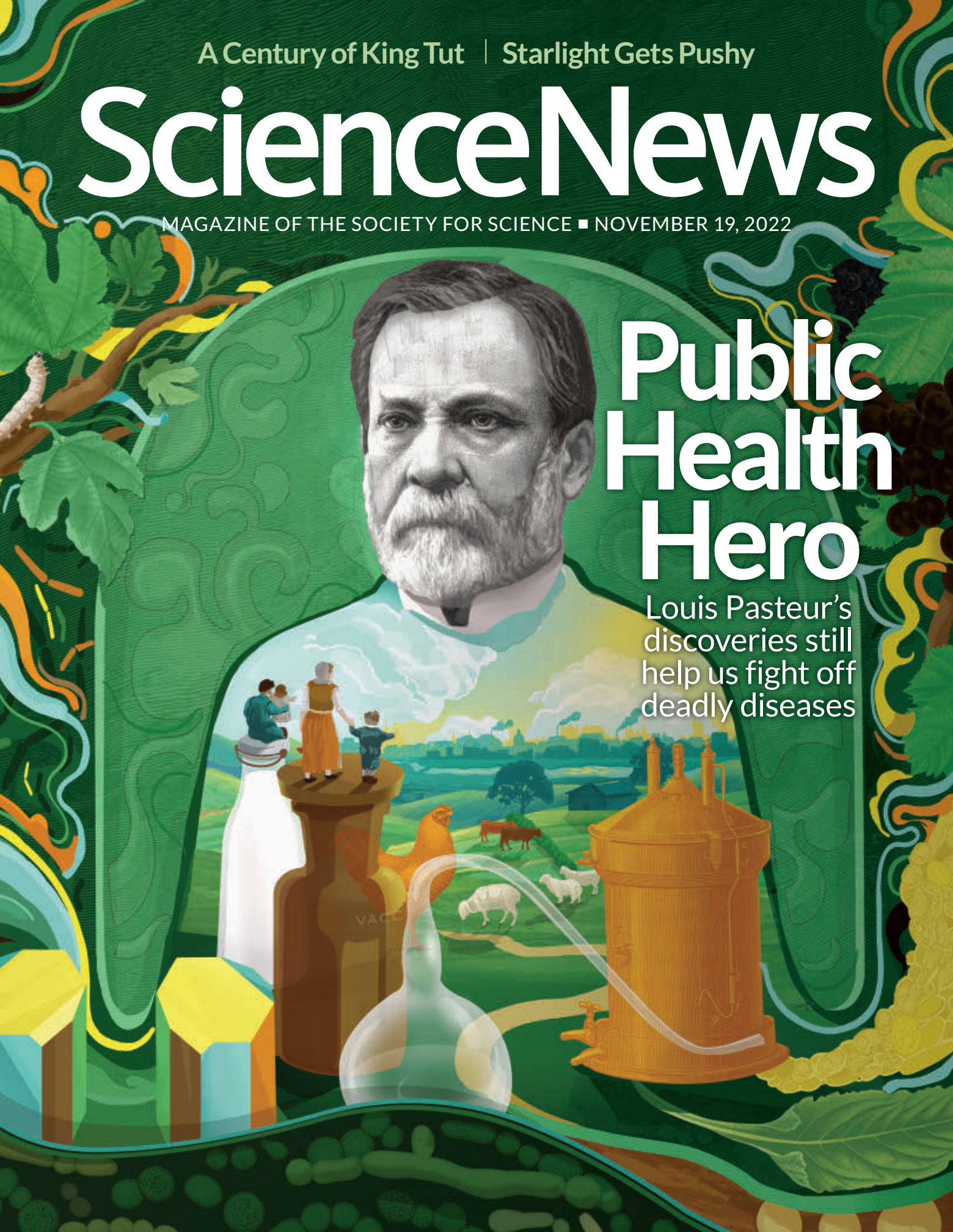

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Louis Pasteur's discoveries still help us fight off deadly diseases

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COVER Louis Pasteur's legacy includes developing vaccines, making milk safe to drink and saving France's brewing and wine industries. *Sam Falconer*

FROM TOP: STEFANIA PELFINI, LA WAZIYA PHOTOGRAPHY/GETTY IMAGES PLUS; NASA, ESA, HEIC AND THE HUBBLE HERITAGE TEAM/STSCI/AURA; COPERNICUS SENTINEL-1/ESA (CC BY-SA 3.0 IGO)

Forever chemicals' health risks are getting attention

For decades, scientists, public health officials and citizen advocates have sounded the alarm over perfluoroalkyl and polyfluoroalkyl substances, commonly known as PFAS. These manufactured chemicals are used to make pans nonstick, clothing waterproof, and furniture and carpets stain resistant.

All nice things, but these molecules are built on strong carbon-fluorine bonds that don't degrade, hence the nickname "forever chemicals." PFAS can end up in rivers, soil and air. They're in our bodies too. That's not so nice, because these chemicals can increase the risk of a host of health issues, including certain cancers, obesity, pregnancy complications and a weakened immune system.

In this issue, freelance writer Melba Newsome explains how the U.S. federal government is finally making moves to try to limit PFAS exposure in humans, in an effort to reduce health impacts (Page 18).

Newsome first learned about PFAS when the chemicals were discovered by scientists in the Cape Fear River in North Carolina, her home state. "These scientists got some fancy piece of equipment and went to test it in the river," she told me. "That's when they discovered that [companies] had been dumping crap in our river for 40 years."

The discovery became a huge issue in North Carolina, and subsequent research found that PFAS contamination of drinking water, food and air is ubiquitous. "When I first started looking at this I said, 'Why [are] PFAS in everything, for goodness sake?'" Newsome, a health and environment journalist, recalled. "It was like this miracle product. It's even in makeup." That startled me. Evidently PFAS are used in waterproof mascara and to make foundation last longer.

Increased focus from Environmental Protection Agency Administrator Michael S. Regan, who is from North Carolina, and other officials is giving it more attention, Newsome said. The agency has substantially lowered levels of PFAS in drinking water that are considered safe. And in late August, the EPA proposed designating two specific types of PFAS—known as PFOA and PFOS—as hazardous substances, which would require companies to report releases into the environment above certain levels and would hold polluters accountable for cleaning up contamination.

Manufacturers have stopped using some PFAS, but because of their longevity, those chemicals will linger in peoples' bodies for years. "Even if they ingested it 15 or 20 years ago," Newsome said. Newer "GenX" alternatives are also raising health concerns.

New federal limits for PFAS contamination should help reduce future exposures, but how do we protect ourselves from the chemicals already out there? Efforts to dispose of PFAS safely or clean up contaminated water and soil will take time, and it will take time for municipal water systems to gear up to filter out the chemicals.

I had one last question for Newsome: Do I really have to pack up my nonstick pan? "Yes, you do," Newsome told me. "Cast iron is a much better piece of cookware anyway." Maybe I won't send those nonstick pans to the landfill, where the PFAS can leach into the groundwater. But I'm happy to dust off my cast iron skillet. —*Nancy Shute, Editor in Chief*

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For the Man Who Gives Everything and Expects Nothing

If you're anything like my dad, you give your family everything. Your name, your time, your values — the people in your life know they can depend on you for practically anything. In exchange for imparting all of this energy and experience, you expect nothing in return.

The point? You deserve to treat yourself once in a while. You do so much for the people you care about. Now it's time to focus on you for just a few minutes. That's where the Men's Due Volta Watch comes in. This astonishing innovation provides a digital readout that's powered by a precise quartz engine, combining both analog and digital timekeeping.

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50 YEARS AGO

A get-sober pill?

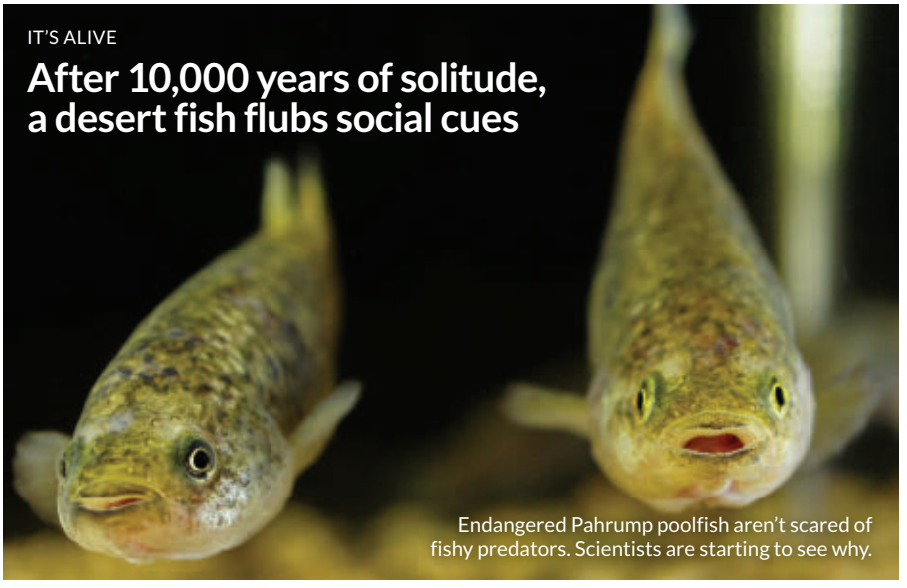
Researchers at the Tucson Veterans Administration Hospital have been able to reduce intoxication time in rats by administrating harmless chemicals.... Injections of vitamin B3, and vitamin B5 with cystine, were successful.... Glyceraldehyde, however, was effective when ingested, and sodium acetate (still untested orally) is expected to be even more effective.

UPDATE: Inebriation and the dreaded hangover that follows still don't have cures — but scientists haven't stopped searching. A compound in the seeds of Japanese raisin trees appeared to fend off drunkenness in rats and sober them up (*SN: 2/11/12, p. 14*), but follow-up research found no effect. Remedies that *have* worked in rodents have not yet led to treatments for people.

In July, an antihangover supplement became available in the United Kingdom and may soon appear in U.S. stores. The Swedish company that makes this probiotic pill, Myrkl (pronounced "miracle"), claims that it can break down 70 percent of the alcohol in a person's system in one hour. But the claim is based on a single study conducted by the company.

IT'S ALIVE

After 10,000 years of solitude, a desert fish flubs social cues



Endangered Pahrump poolfish aren't scared of fishy predators. Scientists are starting to see why.

Getting out into society after a long isolation gets awkward. Ask the Pahrump poolfish, loners in a desert for some 10,000 years.

This hold-in-your-hand-size fish (*Empetrichthys latos*) has a torpedo shape and looks as if it's almost smiling. Until the 1950s, this species had three forms, each evolving in its own spring. Just one form survives, which evolved in a spring-fed oasis west of Las Vegas in the Mojave Desert.

Fish in a desert aren't that weird when you take the long view. Some desert valleys were once ancient lakes. As the lakes dried up and stranded species adapted to quirks of their private puddles, a desert-fish version of the Galápagos Islands' diverse finches arose.

> "Darwin, if he had a different travel agent, could have come to the same conclusions just from the desert."
>
> **CRAIG STOCKWELL**

"Darwin, if he had a different travel agent, could have come to the same conclusions just from the desert," says evolutionary biologist Craig Stockwell of North Dakota State University in Fargo.

E. latos' desert "island" was Manse Spring in the Pahrump Valley. By the 1960s, irrigation for farms threatened the water supply. And a new predator arrived: discarded pet goldfish. Conservationists fought back, but neither poison nor dynamite wiped out the invaders. In August 1975, the spring dried up.

Some poolfish had been moved to other springs by then, but the loners didn't seem to get the danger of living with other fishes, upping their risk of getting eaten.

Lab tests of staged fish-murder scenes may help explain why. Stockwell and colleagues tainted aquariums with pureed fish bits. Minnows spooked when they sensed traces of dead minnow and huddled low in the tank. Pahrump poolfish in tanks befouled with their blender-whizzed bretheren just kept swimming in the upper waters as if corpse taint were no scarier than tap water. As a control, the team ran a fear test with just dechlorinated tap water. Poolfish didn't huddle then either, the scientists reported in the Aug. 31 *Proceedings of the Royal Society B*.

Then, while visiting rescued poolfish in cattle tanks, dragonflies caught the team's attention. Before maturing into aerial marvels, the young prowl underwater, jutting out their jaws to scoop up fish eggs and larvae. With young dragonflies stalking pool bottoms, poolfish moving up the water column "would be a good way to reduce their risk," Stockwell says. Testing of that idea has begun.

Fish that people thought were naïve may be savvy in a different way. Especially after isolation in a desert with dragons. — *Susan Milius*

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MYSTERY SOLVED

Jazz gets its swing from small, subtle delays

It don't mean a thing if it ain't got that swing—all you've got to do is stagger your timing. For decades, fans of jazz music have debated why some songs have swing, the characteristic swaying feeling that compels feet to tap and heads to bop. Now science may finally have an answer: the timing of jazz soloists.

After listening to original and digitally tweaked song recordings, jazz musicians were nearly 7.5 times as likely to rate music as swinging when the soloist's timing was partially delayed with respect to the rhythm section, physicist Theo Geisel and colleagues report October 6 in *Communications Physics*.

Jazz musicians are trained to swing eighth notes, or extend the duration of their downbeats and shorten the beats in between to create a galloping rhythm. But the technique on its own doesn't explain swing, says Geisel, of the Max Planck Institute for Dynamics and Self-Organization in Göttingen, Germany. Past research hinted that swing arises from differences in the timing between musicians within a band. So the team varied only the timing of the soloists in recordings and asked 37 musicians to rate each recording's swing. The team also analyzed 456 performances and found that soloists' downbeats were delayed by 30 milliseconds on average. The average held across the jazz subgenres of bebop, swing and hardbop. —*Nikk Ogasa*

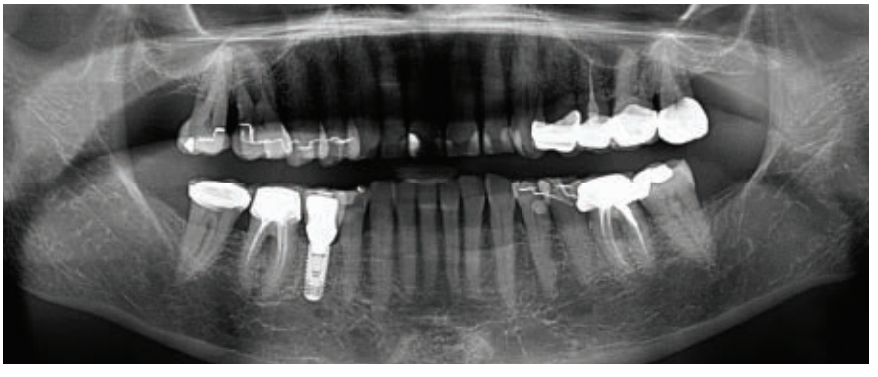
TEASER

Prosthetic teeth might make great hearing aids

Vibrations applied to replacements for lost teeth travel well through jawbones to the inner ear, researchers report in the September *Journal of the Acoustical Society of America*. The finding could lead to discreet alternatives to traditional hearing aids and cochlear implants that people with hearing impairments often use (SN: 7/23/16, *p.* 4).

Previous tooth-based hearing aid designs clipped onto molars and received sound wirelessly from a microphone placed behind the ear. Dental researcher Jianxiang Tao of Tongji University in Shanghai and colleagues want to take the concept further by turning tooth implants into hearing aids. Electronics that impart sound vibrations would be built into the portion of a false tooth anchored into the jawbone.

In 38 people with hearing loss and one regular dental implant, the team applied tones to the implant, natural teeth or the mastoid bone, which is behind the ear. Volunteers heard a wide range of frequencies through the implant just as well as, or better than, through natural teeth or the mastoid bone. Front-tooth implants worked slightly better than back-tooth implants, perhaps because the front of the jaw has harder bone than the back, the team says. —*James R. Riordon*



A screw anchors a fake tooth to a person's lower jaw in this X-ray image. Such dental implants can transmit sound well and could be used as part of a novel hearing aid design.

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THE –EST

Meet the brightest gamma-ray burst ever

A gamma-ray burst that lit up a distant galaxy on October 9 has been dubbed the BOAT, for Brightest of All Time.

Officially named GRB 221009A, this new burst was probably triggered by a supernova birthing a black hole in a galaxy about 2 billion light-years from Earth, scientists announced October 13. The birth set off jets of gamma rays that happened to be pointing toward our planet—and NASA space telescopes.

In the 50 years of observing these rare explosions, GRB 221009A's brightness "stands head and shoulders above the rest," says Jamie Kennea, head of science operations for NASA's Swift Observatory, which glimpsed an afterglow of X-rays about an hour after the blast (above). The burst may have released as much energy as roughly three suns converting all of their mass to pure energy.

Astronomers around the world rushed to spy on the BOAT in nearly every type of light. Even some radio telescopes typically used as lightning detectors saw a disturbance associated with the blast, suggesting the BOAT stripped electrons from atoms in Earth's atmosphere.

The proximity of the BOAT to us may have boosted its intrinsic brightness, Kennea says. A couple billion light-years might seem far, but the average gamma-ray burst is more like 10 billion light-years away. Studying the BOAT will challenge some assumptions of how gamma-ray bursts work and change theories that scientists thought "were pretty solid," Kennea says. —*Lisa Grossman*

News

Shells of dust form when winds from two stars (center) in the Cygnus constellation collide. The shells are then blown outward by the pressure of light from those stars.

ATOM & COSMOS

Scientists see starlight push dust

First-of-its-kind sighting helps show how light sculpts space

BY JAMES R. RIORDON

A pair of stars in our galaxy is revealing how light pushes around matter. It's the first time anyone has directly seen how the pressure of light from stars changes the flow of dust in space.

Such radiation pressure influences how dust clears from the regions near young stars and guides the formation of gas clouds around dying stars. The dust pattern surrounding a stellar pair 5,400 light-years from Earth in the Cygnus constellation provides a rare laboratory to observe the effect in action, astronomers report in the Oct. 13 *Nature*.

Scientists have long known that the dust emerging from the star WR 140 and its companion is formed by gas from these two stars colliding and condensing into soot. But images of the pair taken over 16 years show that the dust accelerates as it travels away from the stars.

Dust initially departs the stars at about 6.5 million kilometers per hour, the team reports, and over the course of a year, accelerates to nearly 10 million km/h. At that speed, the dust could make the trip from our sun to Earth in a mere 15 hours.

The revelation came from comparing the positions of concentric dust shells year to year and deducing a speed. Calculations show that the force accelerating the dust is the pressure exerted by light radiated from the stars, says Yinuo Han of the University of Cambridge. "Radiation pressure [becomes apparent] only when we put all the images next to each other."

Not only do those layers of dust feel light's push, they also extend out farther from the stars than any telescope could see — until this year. Images from the James Webb Space Telescope depict more of the dusty layers around WR 140 and its companion than ever seen before, Han and another team report October 12 in *Nature Astronomy*.

At first glance, the intricate patterns surrounding the stars resemble a gigantic spider web. But an analysis reveals that they are actually enormous, expanding, cone-shaped dust shells. They're nested inside each other, with a new one forming every eight years as the stars complete another journey in their orbit around

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ATOM & COSMOS

Stretchier proton puzzles physicists

Its response to electric fields doesn't match predictions

BY JAMES R. RIORDON

Protons might be stretchier than they should be.

The subatomic particles are built of quarks, smaller particles that are bound together by a powerful interaction known as the strong force. Experiments seem to show that the quarks respond more than expected to an electric field pulling on them, physicist Nikolaos Sparveris and colleagues report October 19 in *Nature*. The result suggests that the strong force isn't quite as strong as theory predicts.

It's a finding at odds with the standard model of particle physics, which describes the particles and forces that combine to make up us and everything around us. The result has some physicists stumped about how to explain it, or whether to even try.

"It is certainly puzzling for the physics of the strong interaction, if this thing persists," says Sparveris, of Temple University in Philadelphia. Such stretchiness has turned up in other labs' experiments but wasn't as convincing, he says. The stretchiness that he and colleagues measured was less extreme than in other experiments but also came with less experimental uncertainty. That increases the team's confidence that protons are oddly stretchy.

At the Thomas Jefferson National Accelerator Facility in Newport News, Va., the team probed protons by firing electrons at a target of ultracold liquid hydrogen. Electrons scattering off protons in the hydrogen revealed how the protons' quarks respond to electric fields. The higher the energy of the electrons fired at the target, the deeper the researchers could see into the protons, and the more the electrons revealed about how the strong force works inside protons.

For the most part, the quarks moved as expected when interactions with electrons' electric fields pulled the particles in opposite directions. But at one point, as the electron energy was ramped up, the quarks appeared to respond more strongly than predicted by theory.

But it happened only for a small range of electron energies, leading to a bump in a plot of proton stretch. "Usually, behaviors of these things are quite, let's say, smooth and there are no bumps," says physicist Vladimir Pascalutsa of the Johannes Gutenberg University Mainz in Germany.

Pascalutsa says he's often eager to dive into puzzling problems. But "you need to

each other. The shells look like sections of rings because we observe them from the side, Han says.

The patterns don't completely surround the stars because the distance between the stars changes as they orbit one another. When the stars are far apart, the density of the colliding gas is too low to condense into dust — an effect the researchers expected.

What surprised them is that the gas doesn't condense well when the stars are closest together either. That suggests there's a Goldilocks zone: Dust forms only when the distance between the stars is just right, creating a series of concentric dust shells rippling away from the duo.

"Their Goldilocks zone is a new idea," says astrophysicist Andy Pollock of the University of Sheffield in England. "A similar sort of thing happens in my field of X-rays."

In his work, Pollock has observed that WR 140 and its partner emit more X-rays as the stars approach each other, but then fewer as they get very close together. "It would be interesting to see if there's any connection" between these two types of Goldilocks zones, he says. "All of this must somehow fit together." ■

be very, very inventive to come up with a whole framework which somehow finds you a new effect" to explain the bump, he says. "I don't want to kill the buzz, but yeah, I'm quite skeptical as a theorist that this thing is going to stay."

Forthcoming research in Switzerland could be more persuasive. It will use hydrogen atoms that have muons in place of the electrons that usually orbit atoms' nuclei. Muons orbit much closer to the nucleus of an atom, offering a closer look at the proton inside. The experiment will involve stimulating the "muonic hydrogen" with lasers rather than scattering other electrons or positrons from them.

"The precision in the muonic hydrogen experiments will be much higher than whatever can be achieved in scattering experiments," Pascalutsa says. If the stretchiness turns up there, "then I would start to look at this right away." ■

ALMA/ESO, NAOJ AND NRAO

ATOM & COSMOS

Planets may have more time to form

Young stars' planet-building disks may last longer than expected

BY KEN CROSWELL

Good news for late bloomers: Planets may have millions of years more time to arise around most stars than previously thought.

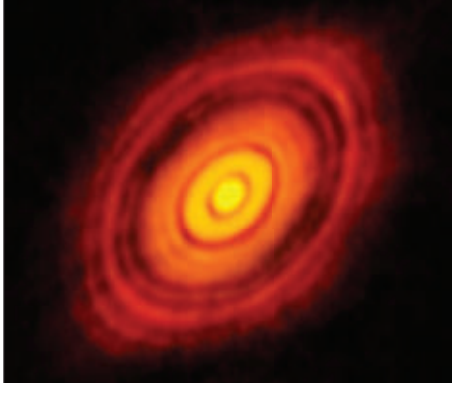
Planet-making disks around young stars typically last for 5 million to 10 million years, researchers report in the Nov. 1 *Astrophysical Journal Letters*. That lifetime, based on a survey of nearby young star clusters, is a good deal longer than the previous estimate of 1 million to 3 million years.

"One to three megayears is a really strong constraint for forming planets," says astrophysicist Susanne Pfalzner of Forschungszentrum Jülich in Germany. "Finding that we have a lot of time just relaxes everything" for building planets around young stars.

Planets large and small develop in the disks of gas and dust that swirl around young stars. Once a disk vanishes, it's too late to make any more new worlds.

Past studies have estimated disk lifetimes by looking at the fraction of young stars of different ages that still have disks — in particular, by observing star clusters with known ages. But Pfalzner and colleagues discovered something odd: The farther a star cluster is from Earth, the shorter the estimated disk lifetime. Why should the lifetime of a protoplanetary disk depend on how far it is from us?

Planet-building disks of gas and dust (one shown) may survive for millions of years longer around young stars than scientists realized.



The answer is simple: It doesn't. But in clusters that are farther away, it's harder to see most stars. "When you look at larger distances, you see higher-mass stars," says Pfalzner, because those stars are brighter and easier to see. "You basically don't see the low-mass stars." But the lowest-mass stars constitute the vast majority. These stars — orange and red dwarfs — are cooler, smaller and fainter than the sun.

So Pfalzner and colleagues examined only the nearest young star clusters, those within 650 light-years of Earth, and found that the fraction of stars with planet-making disks is much higher than previously reported. This analysis shows that low-mass stars have disk lifetimes as long as 5 million to 10 million years, she says. In contrast, disks around higher-mass stars are known to disperse faster than this, perhaps because the star's brighter light pushes the gas and dust away more quickly.

This isn't definite proof for such long disk lifetimes around orange and red dwarfs, says Álvaro Ribas, an astronomer at the University of Cambridge. "But it's quite convincing." To bolster the result, he'd like to see observations of more distant star clusters, perhaps with the James Webb Space Telescope, to determine the fraction of the faintest stars that have preserved their planet-making disks for between 5 million and 20 million years.

If the disks around the lowest-mass stars do indeed have long lifetimes, that may explain a difference between our solar system and those of most red dwarfs, Pfalzner says. The latter often lack gas giants like Jupiter, which are about 10 times the diameter of Earth. Instead, those stars frequently have numerous ice giants like Neptune, about four times the diameter of Earth. Perhaps Neptune-sized planets arise in larger numbers when a planet-making disk lasts longer, Pfalzner says, accounting for why these worlds tend to abound around smaller stars. ■

BODY & BRAIN

Colonoscopy study comes with caveats

Research doubting the screening test's benefits has limitations

BY AIMEE CUNNINGHAM

A recent study reported a smaller-than-expected benefit of using colonoscopies to screen for colorectal cancer. But the study has key caveats, gastroenterologists say, making it ripe for misinterpretation.

The research was the first randomized controlled trial — considered the gold standard for testing medical interventions — of the procedure. Published in the Oct. 27 *New England Journal of Medicine*, the study followed participants invited to have a colonoscopy and compared how they fared with participants who weren't invited to undergo the procedure. The risk of colorectal cancer at 10 years was 18 percent lower in the invited group. But there wasn't a meaningful difference in the risk of death from colorectal cancer between the two groups.

This was disappointing, gastroenterologists say, as past research has shown screening colonoscopies to be effective in reducing the risks of developing and dying from colorectal cancer. But those data were from observational studies, which don't randomly assign patients to get, or not get, a treatment.

A closer look at the new study's details reveals why it shouldn't be interpreted as a slam dunk against the screening test. First, less than half of the people invited to have a colonoscopy actually did. The study also didn't follow patients long enough to fully assess the risk of death from colorectal cancer. And some of the physicians who did the procedure didn't meet a minimum quality benchmark.

These issues limit what the study can say about screening colonoscopies. On top of that, it shouldn't be used to cast doubt on colorectal cancer screening in general, says Folasade May, a gastroenterologist and health services researcher at UCLA Health. "Screening is effective, and it saves lives," she says. "We have enough data to promote screening."

Colorectal cancer is the second leading cause of cancer deaths for men and women combined, according to the American Cancer Society. It's expected to kill more than 52,000 Americans in 2022.

The U.S. Preventive Services Task Force recommends screening for colorectal cancer in adults ages 45 to 75 years old. Screening options include colonoscopy, which examines the whole colon; sigmoidoscopy, which looks at a portion of the colon; and stool-based tests. Average-risk individuals — those who don't have a family history of colorectal cancer or other conditions that increase risk — can choose the option that works for them. "We just want people to get screened," says gastroenterologist Sophie Balzora of the New York University Grossman School of Medicine.

The fecal immunochemical test, or FIT, and colonoscopy are commonly performed in the United States. The FIT, taken at home, detects tiny amounts of blood in the stool, a potential sign of colorectal cancer.

During a colonoscopy, a physician looks for and removes polyps, growths of tissue that can become cancerous. But the procedure's expense, time and preparation can be prohibitive for some patients, says Carol Burke, a gastroenterologist at the Cleveland Clinic. People may not be able to take time off work or have someone available to drive them home, for example.

> "If you don't actually have the test, it can't possibly protect you."
>
> **AASMA SHAUKAT**

The potential barriers mean it's not enough to just tell someone to get a colonoscopy. That's also the case in Poland, Norway and Sweden, where colonoscopies are not commonly used to screen for colorectal cancer. In the new study, one-third of roughly 85,000 people from these countries were invited to get colonoscopies. The other two-thirds made up the not-invited group. "The intervention was an invitation, not a colonoscopy," Balzora says. Only 42 percent of the people invited to get the procedure had one, limiting what the study can say about colonoscopy benefits.

"If you don't actually have the test, it can't possibly protect you," says gastroenterologist Aasma Shaukat of the NYU Grossman School of Medicine.

Another limitation has to do with time. Most polyps don't become cancerous, but for those that do, it can take 10 years or more. Then it takes time for the cancer to spread and become fatal. A follow-up of at least 15 years is needed to look at the impact on cancer deaths, Shaukat says. The study's report at 10 years isn't enough.

And the quality of the colonoscopies varied. One standard is the adenoma detection rate, the number of colonoscopies that turn up a precancerous polyp, or adenoma, divided by the number of colonoscopies performed over a period of time. In the study, nearly 30 percent of the physicians doing the procedures had rates below the minimum quality rate. This may have affected cancer detection.

The authors acknowledge these limitations. The invitation approach may have underestimated a colonoscopy's benefits. They also say that reductions in cancer risk are expected to appear before reductions in death risk. The team will report results again at 15 years of follow-up.

The study needs to be considered among other evidence for colonoscopy effectiveness, Shaukat says. For example, an analysis that combined data from observational studies of colonoscopy, published in 2014 in the *BMJ*, reported that the procedure reduces both colorectal cancer incidence and mortality by nearly 70 percent.

Another observational study looked at an organized screening program that used colonoscopy, sigmoidoscopy and FIT. The program led to a boost in screening that was linked to a 25 percent decrease in the annual incidence of colorectal cancer from 2000 to 2015 and a 52 percent drop in deaths from the cancer, researchers reported in *Gastroenterology* in 2018.

An ongoing U.S. randomized controlled trial will compare the effectiveness of screening colonoscopy versus FIT in average-risk people. "We haven't closed the door on colonoscopy," May says. ■

EARTH & ENVIRONMENT

U.S. rivers are spiking more fevers

The heat waves can cause trouble for wildlife and water quality

BY JUDE COLEMAN

U.S. rivers are getting into hot water. The frequency of river and stream heat waves is on the rise, a new analysis shows.

Like marine heat waves, riverine heat waves occur when water temperatures creep above their typical range for five or more days (*SN: 2/26/22, p. 15*). Using 26 years of U.S. Geological Survey data, ecosystem ecologist Spencer Tassone and colleagues compiled daily temperatures for 70 sites in rivers and streams across the United States. The team then calculated how many days each site experienced a heat wave per year. From 1996 to 2021, the annual average number of heat wave days per river climbed from 11 to 25, the researchers report October 3 in *Limnology and Oceanography Letters*.

The study is the first assessment of heat waves in rivers across the country, says Tassone, of the University of Virginia in Charlottesville. His team tallied nearly 4,000 heat wave events (the number of events jumped from 82 in 1996 to 198 in 2021) that amounted to more than 35,000 heat wave days. The frequency of extreme heat increased at sites above reservoirs and in free-flowing conditions but not below reservoirs—perhaps because dams release cooler water downstream.

Most heat waves with temperatures that were the highest above typical ranges occurred outside of summer, between December and April, pointing to warmer wintertime conditions, Tassone says.

Human-caused global warming plays a role in riverine heat waves, the team says, with heat waves partially tracking air temperatures. Additional factors are probably also driving the trend. For example, less precipitation and lower water volume in rivers mean waterways warm up easier.

Compared with a gradual increase in temperature, sudden heat waves can have a greater impact on river-dwelling plants and animals by quickly pushing them past their thermal tolerance, Tassone says. Salmon and trout are particularly sensitive to heat waves because the animals rely on cold water to get enough oxygen, regulate their body temperature and spawn.

There are chemical consequences to heat waves as well, says Sujay Kaushal, a hydrologist at the University of Maryland in College Park who was not involved in the work. Higher temperatures can speed up chemical reactions that contaminate water, in some cases contributing to toxic algal blooms (*SN: 3/17/18, p. 5*).

The findings can be used as a springboard to help mitigate heat waves in the future, Kaushal says, such as by increasing shade cover from trees or managing stormwater. In some rivers, beaver dams show promise for reducing water temperatures (*SN: 9/10/22, p. 8*). "You can actually do something about this," he says. ■

EARTH & ENVIRONMENT

How an Antarctic iceberg broke its 'finger'

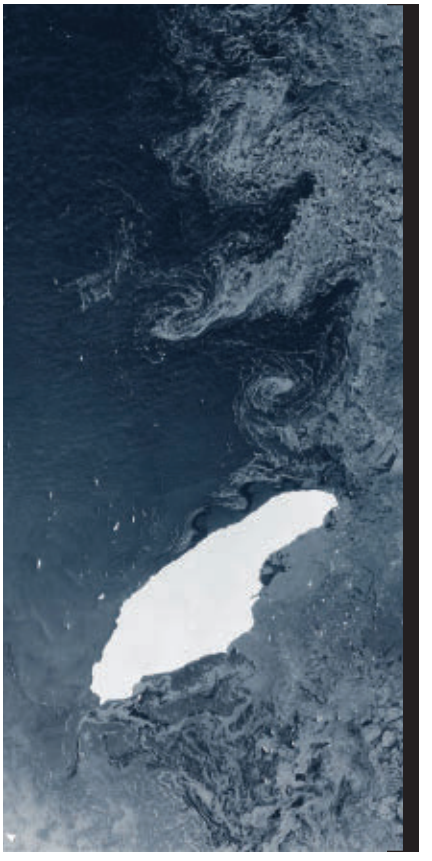
It was the rift watched 'round the world. In July 2017, after weeks of anticipation, a massive iceberg about the size of Delaware split from the Antarctic Peninsula (*SN: 8/5/17, p. 6*). Satellite images show that the orphaned iceberg, known as A68, ultimately disintegrated in the Southern Ocean. Now, researchers say they have pieced together the powerful forces that led to that final breakup.

Polar scientist Alex Huth of Princeton University and colleagues combined observations of the iceberg's drift with simulations of ocean currents and wind stress. Iceberg A68a (shown in a July 2020 satellite image, right), the largest remaining chunk of the original berg, was caught in a tug-of-war between ocean currents. The strain of those opposing forces probably pulled the chunk apart, the team reports October 19 in *Science Advances*.

After separating from the Larsen C ice shelf, A68 lingered in the neighborhood for a year and eventually split in two (*SN: 8/18/18 & 9/1/18, p. 7*). By December 2020, satellite images show, chunk A68a had drifted north and shrunk by one-third.

The new simulations suggest how A68a probably met its fate. On December 20, 2020, a long slender "finger" at one end of the iceberg drifted into a strong and fast current while the rest of the ice remained outside the current. The tension rifted the iceberg, and the finger broke off within a few days.

Shear stress is a previously unknown mechanism for large iceberg breakup and isn't included in climate simulations, the team says. Melting massive bergs can be a large source of cold freshwater to the Southern Ocean's surface. That, in turn, can have a big impact on ocean circulation and the global climate. —*Carolyn Gramling*



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HUMANS & SOCIETY

Fuzzy definitions mar social science

A lack of conceptual clarity impedes research progress

BY SUJATA GUPTA

U.S. millennials are rejecting suburbia and moving back to the city. That was a theory I stumbled across in 2019, when I started as the social sciences reporter at *Science News*. But when I dug into a possible story on the phenomenon, I found an incoherent mess. Some research showed that suburbs were growing, others that suburbs were shrinking. Yet others showed growth in both suburbs and cities.

Unable to make sense of that maze of findings, I shelved the story. Several months later, I discovered a Harvard University white paper explaining that the disagreement stems from competing definitions of what distinguishes a city from a suburb. Some researchers define the suburbs as areas falling outside census-designated cities. Others look only for markers of suburbanism, such as a wealth of single-family houses and car-based commutes, the researchers explained.

I have encountered this type of fuzziness around definitions of all sorts of terms and concepts in the social sciences. Sometimes researchers simply assume that their definition of a key concept is *the* definition. Or they nod briefly at other definitions, and then go forth with whichever one they choose, without much explanation of why. Other times, researchers in one subfield choose one definition, and researchers in another subfield choose a different one — each without ever knowing of the other's existence.

"If you look … you will find this morass of definitions and measurements" in the social sciences, says quantitative psychologist Jessica Flake of McGill University in Montreal. My experience was a common one, she assured me.

Definitional morasses exist in other scientific fields too. Biologists frequently disagree about how best to define the term "species" (*SN: 11/11/17, p. 22*). Virologists squabble over what counts as "alive" when it comes to viruses. And not all astronomers are happy with the decision to define "planet" in a way that leaves Pluto out in the cold as a mere dwarf planet (*SN: 8/28/21, p. 20*).

But the social sciences have some special challenges, Flake says. The field is a youngster compared with a discipline like astronomy, so has had less time to sort out its definitions. And social science concepts are often inherently subjective. Describing abstract ideas like motivation or feelings can be squishier than describing, say, a meteorite.

It's tempting to assume, as I did initially, that a single, imperfect definition for individual concepts is preferable to this definitional cacophony. And some researchers encourage this approach. "While no suburban definition will be perfect, standardization would increase understanding of how suburban studies relate to each other," the Harvard researchers wrote in that suburbia paper.

But a recent study taking aim at how we define the middle class showed me how alternative definitions can lead to a shift in perspective.

> "Depending on what definition you start with, you will see different facts."
>
> **ANNA ALEXANDROVA**

While most researchers use income as a proxy for social class, these researchers used people's buying patterns. That revealed that a fraction of people who appear middle class by income struggle to pay for basic necessities, such as housing, child care and groceries, the team reported August 23 in *Social Indicators Research*. That is, they live as if they are working class.

What's more, that vulnerable group skews Black and Hispanic, a disparity that arises, in part, because these families of color often lack the generational wealth of white families, says study coauthor Melissa Haller, a geographer at Binghamton University in New York. So when calamity strikes, families without that financial cushion can struggle to recover. Yet a government or nonprofit organization looking to direct aid toward the neediest families, and relying solely on income-based metrics, would overlook this vulnerable group.

"Depending on what definition you start with, you will see different facts," says Anna Alexandrova, a philosopher of science at the University of Cambridge. A standardized definition of middle class, for example, could obscure some of those key facts.

In the social sciences, what's needed instead of conceptual unity, Alexandrova says, is conceptual clarity.

Though social scientists disagree about how to go about solving this problem of clarity, Flake says, failure to tackle the issue jeopardizes the field as much as other crises rocking the discipline, such as concerns over reproducibility. That's because how a topic is defined determines the scales, surveys and other instruments used to study that concept. That in turn shapes how researchers crunch numbers and arrive at conclusions.

Defining key terms and then selecting the right tool is usually straightforward when relying on large, external datasets. For instance, instead of using national income databases, as is common in the study of the middle class, Haller and her team turned to the federal government's Consumer Expenditure Surveys to understand people's daily and emergency purchases.

But often social scientists, particularly psychologists, develop their own scales and surveys to quantify subjective concepts, such as self-esteem, well-being or mood. Definitions of those terms — and the instruments used to study them — can take on a life of their own, Flake says.

In the May-June *American Psychologist*, she and colleagues showed how this process plays out. They combed through the 100 original studies and 100 replications included in a massive reproducibility project in psychology. The team zoomed in on 97 multi-item scales — measuring concepts such as gratitude, motivation and self-esteem — used in the original and replication studies, and found that 54 of those scales had no citations to

show where the scales originated. That suggests that the original authors defined their idea, and the tool used to measure that idea, on the fly, Flake says. Research teams then attempted to replicate 29 of those studies without digging into the scales' sources, calling into question the meaning of their results.

For Flake, the way to achieve conceptual clarity is straightforward, if unlikely. Researchers must hit the brakes on generating new ideas, or replicating old ideas, she says, and instead interrogate the morass of old ones.

She points to one promising effort: the Psychological Science Accelerator, a collaboration of over 1,300 researchers in 84 countries. The project aims to identify big ideas in psychology, such as face perception and gender prejudice, and accumulate all the instruments and resulting data used to make sense of those ideas to discard, refine or combine existing definitions and tools.

"Instead of running replications, why don't we use [this] massive team of researchers who represent a lot of perspectives around the world and review concepts first," Flake says. "We need to stop replicating garbage." ■

LIFE & EVOLUTION

Fire drove big cats to take more risks

Mountain lions crossed the road more often after a blaze

BY BETHANY BROOKSHIRE

A mountain lion wearing a tracking collar leads her cubs through the brush. Collars on cats like these allow scientists to track where the cats go when wildfires ravage their homes.

NATIONAL PARK SERVICE

Mountain lions have no interest in people, or the built-up areas we enjoy. But after a wildfire in California, local lions took more risks, crossing roads more often and moving around more in the daytime, scientists report October 20 in *Current Biology*. It's another way human development could be putting pressure on vulnerable wildlife — in this case, potentially pushing them toward our bumpers.

The Woolsey Fire began near Los Angeles on November 8, 2018, and burned more than 35,000 hectares in the Santa Monica Mountains and Simi Hills. Nearly 300,000 people evacuated, and three people died. Animals fled too, including mountain lions (*Puma concolor*). Many of the lions wore tracking collars, allowing scientists to study how the fire changed their behavior.

Of the 11 collared mountain lions in the area at the time, nine made it to safety during the fire itself. "They have really large home ranges, so it's nothing to them to be able to cover many kilometers in a day," says Rachel Blakey, a global change biologist now at Cal Poly Pomona.

No matter how much they moved, the mountain lions avoided people. One collared cat, P-64, initially fled the fire — until he got close to human habitation. Given the choice between fire and people, the lion retreated back into the burning area. "That's where his movements stopped," Blakey says. The National Park Service later found P-64's remains. He'd burned his paws, and it's possible that he was unable to hunt and starved to death.

Using data from the nine lions that survived the fire and others collared afterward, Blakey and colleagues showed that the cats generally avoided the severely burned parts of their territories. With vegetation gone, the cats had little cover for stalking and ambushing prey.

Instead, the lions stuck to unburned areas and continued to avoid people. But they took more risks around human infrastructure, increasing their road crossings from an average of about three times per month to five. These weren't all two-lane country highways. The first collared lion to successfully cross Interstate 405, which has 10 lanes in places, did it after the fire. A cat tended to cross U.S. Route 101 once every four months. Before the fire, it was once every two years.

Mountain lion territories also overlapped more often, increasing the potential for deadly encounters between the solitary cats. And the generally nocturnal animals increased activity during daytime from 10 percent to 16 percent, boosting the chances of bumping into a human.

Road crossing is what Blakey calls a "risk mismatch." Lions in areas with lots of people appear to weigh the risk of encountering humans as more dangerous. But "running across a freeway is a lot more likely to be fatal," she says. That risk, combined with the risk of running into other cats, can be deadly. One young collared male ended up dead on a freeway in the months after the fire. He was fleeing a fight with an older, uncollared male.

Intense burns like the Woolsey Fire highlight the resilience of mountain lions, says Winston Vickers, a wildlife research veterinarian at the University of California, Davis. "They have amazing mobility. They mostly can get away from the immediate fire," he notes. The changes in risk-taking, he says, could reflect how confined the population is, hemmed into the mountains by human development.

Wildlife crossings, such as the Wallis Annenberg Wildlife Crossing being built over the 101, will hopefully give the big cats a safer option for roaming, though the main goal is to promote gene flow between lion populations, Blakey says. In a landscape where fire, humans and highways combine, it's good to have somewhere to run. ■

LIFE & EVOLUTION

Dinosaur mummies may not be flukes

Rapid burial isn't the only way to preserve skin, a study hints

BY JAKE BUEHLER

It might be easier for dinosaurs to mummify than scientists thought.

Unhealed bite marks on fossilized dinosaur skin suggest that the animal's carcass was scavenged before being covered in sediment, researchers report October 12 in *PLOS ONE*. The finding challenges the traditional view that burial very soon after death is required for dinosaur mummies to naturally form.

The new work centers on Dakota, an *Edmontosaurus* fossil discovered in North Dakota in 1999. About 67 million years ago, Dakota was a roughly 12-meter-long duck-billed dinosaur that ate plants. Today, Dakota's fossilized limbs and tail still contain large areas of well-preserved fossilized scaly skin, a striking example of dinosaur mummification.

The creature isn't a true mummy because its skin has turned into rock. Still, researchers call fossils with preserved skin and other soft tissues mummies.

In 2018, paleontologist Clint Boyd of the North Dakota Geological Survey in Bismarck and colleagues examined the dinosaur fossil and found what looked like tears in the tail skin and puncture holes on Dakota's right front foot. The holes closely match bite marks from prehistoric relatives of crocodiles, the team says. "This is the first time that's been seen in dinosaurian soft tissues," says study coauthor Stephanie Drumheller, a paleontologist at the University of Tennessee in Knoxville.

Marks on the tail are larger than those on the front limb, suggesting that at least two carnivores munched on Dakota. Those carnivores were probably scavengers, the team says, since the wounds didn't heal.

But scavenging doesn't fit into the traditional view of mummification, which assumes that burial has to happen soon after death. If scavengers had enough time to snack on Dakota's body, then the dead dino had been in the open for a while.

Observing Dakota's skin shrink-wrapped to the bone with no muscle or organs, Drumheller had a eureka moment. "I had seen something like this before … in the forensics literature," she says.

When modern scavengers like raccoons feed on a larger carcass, the scavengers rip open the body. That lets gases and fluids from decomposition escape and allows any remaining skin to dry out. Burial and fossilization could happen afterward.

The scientists "make a very good point," says Raymond Rogers, a researcher at Macalester College in Saint Paul, Minn., who studies how organisms decay and fossilize. "It would be very unlikely for a carcass to achieve advanced stages of desiccation and also experience rapid burial," he says. "These two generally presumed prerequisites for mummification seem to be somewhat incompatible."

Fossilization of soft tissues is rare but not unheard of. If soft tissue can't be fossilized without "some spectacular confluence of weird events," Drumheller says, then such mummification "is far more common than you would expect." Mummies originating from common carcass fates could explain this.

Paleontologist Evan Thomas Saitta of the University of Chicago isn't convinced. "I still suspect that this actual process is a very precise sequence of events, where if you get the timing wrong, you end up without a mummy dinosaur," he says. ■

Unhealed wounds on the right front foot (shown) of a duck-billed dinosaur mummy hint that the dino was scavenged before it naturally mummified.

GENES & CELLS

Plague immunity left a lasting mark

A gene tied to Crohn's disease helped fight the Black Death

BY WYNNE PARRY

A genetic variant that appears to have boosted medieval Europeans' ability to survive the Black Death centuries ago may contribute — albeit in a small way — to an inflammatory disease afflicting people today.

Researchers used DNA collected from centuries-old remains to discern the fingerprints that bubonic plague left on Europeans' immune systems during the Black Death. This devastating wave of disease tended to spare those who possessed a variant of a gene known as *ERAP2*, causing it to become more common, researchers report October 19 in *Nature*. That variant was already known for slightly increasing the odds of developing Crohn's disease, in which errant inflammation harms the digestive system.

The results show "how these studies on ancient DNA can help actually understand diseases even now," says Mihai Netea, an infectious diseases specialist at Radboud University Medical Center in Nijmegen, Netherlands, who was not involved with the study. "And the tradeoff is also very clear."

Caused by the bacterium *Yersinia pestis*, bubonic plague can kill about 60 percent of those infected if left untreated (SN: 7/16/22 & 7/30/22, *p.* 16). In the ancient and medieval world, it caused successive waves of misery, including the Black Death. Often dated from 1346 to 1350, this episode wiped out at least 25 million people — about a third or more of the European population.

By sparing individuals whose immune systems bear certain traits, pathogens such as *Y. pestis* have shaped the evolution of the human immune system. Studies are teasing out the ways the massive winnowing of the plague altered Europeans' immune-related genetics.

In this most recent study, population

geneticist Luis Barreiro of the University of Chicago and colleagues collected DNA samples from the remains of 516 people in London and Denmark who died between about 850 and 1800, including those buried during the Black Death. The researchers examined stretches of DNA for immune-related genes and areas associated with autoimmune and inflammatory diseases in 360 of the individuals.

Within those regions, the team identified four locations on chromosomes that had strong evidence of genetic changes driven by the Black Death. One change in particular stood out: an increase in the frequency of a variant of ERAP2 only in people who lived after the Black Death.

In experiments, immune cells from people with this version of ERAP2 that were infected with Y. *pestis* more effectively killed the bacteria than cells from people lacking the variant. Studies of modern populations have linked that same variant to Crohn's disease.

While the researchers calculate that the ERAP2 variant improved the odds of surviving the Black Death by as much as 40 percent, it only slightly increases the risk for Crohn's disease. For complex disorders like Crohn's, "you require probably hundreds, sometimes thousands of genetic variants to actually increase your risk in a significant manner," Barreiro says.

For some time now, scientists have theorized that adaptations that helped our ancestors fortify their immune systems against infectious diseases can contribute to excessive, damaging immune activity.

Earlier studies of plague offer support for this idea. A genetic analysis seeking traces of historical disease in modern Europeans and a study of DNA from the remains of 16th century German plague victims both turned up what appear to be protective changes against the plague that, like the ERAP2 variant, are linked with inflammatory and autoimmune conditions.

Likewise, this latest discovery suggests that genetic changes that have amped up the human immune response in the past, empowering it to better fight off ancient infections, can come at a cost. "If you turn the heat too much, that leads to disease," Barreiro says. ■

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HUMANS & SOCIETY

Siberian Neandertals had small social circles

DNA from a group of Neandertals who lived together and a couple of others who lived nearby has yielded the best genetic peek to date into the social worlds of these ancient hominids.

As early as around 59,000 years ago, Neandertal communities in a mountainous part of Central Asia consisted of small groups of close relatives and adult female newcomers, researchers report in the Oct. 20 *Nature*.

That scenario comes courtesy of DNA extracted from the teeth and bones of 13 Neandertals found at two caves in the foothills of southern Siberia's Altai Mountains. Estimates of overall genetic similarity among these Stone Age folks indicate that they formed communities of about 20 individuals, with females often migrating from their home groups to those of their mates, say evolutionary geneticist Laurits Skov of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and colleagues.

Skov's team studied the DNA of 11 Neandertals from Chagyrskaya Cave and two Neandertals from Okladnikov Cave. The Chagyrskaya individuals included a father and his teenage daughter as well as an adult female and an 8- to 12-year-old boy, who was possibly her nephew or grandson.

In the Chagyrskaya group, mitochondrial DNA, typically inherited from the mother, displayed greater diversity than DNA from the Y chromosome, which is inherited only by males. That suggests females frequently moved into that community while the males stayed put, the team says. — *Bruce Bower*

HUMANS & SOCIETY

King Tut's tomb still harbors secrets

The pharaoh's burial, found 100 years ago, has more stories to tell

BY BRUCE BOWER

One hundred years ago, archaeologist Howard Carter stumbled across the tomb of ancient Egypt's King Tutankhamun. Carter's life was never the same. Neither was the young pharaoh's afterlife.

Newspapers around the world ran stories about Carter's discovery of a long-lost pharaoh's grave and the wonders it might contain, propelling the abrasive Englishman to worldwide acclaim. A boy king once consigned to ancient obscurity became the most famous of pharaohs.

It all started on November 4, 1922, when excavators led by Carter discovered a step cut into the valley floor of a largely unexplored part of Egypt's Valley of the Kings. By November 23, the team had uncovered stairs leading down to a door. A hieroglyphic seal on the door identified what lay beyond: King Tutankhamun's tomb.

Tut had assumed power around 1334 B.C., when he was about 10 years old. His reign lasted nearly a decade until his untimely demise. Although a minor figure among Egyptian pharaohs, he is one of the few whose burial place was found largely intact.

An unusually meticulous excavator for his time, Carter organized a 10-year project to document, conserve and remove over 6,000 items from the tomb. While some objects, like Tut's gold burial mask, are now iconic, many have been in storage for decades. But that's about to change. About 5,400 of Tutankhamun's tomb furnishings are slated to go on display when the new Grand Egyptian Museum, near the Pyramids of Giza, opens in 2023.

Even as more of Tut's story is poised to come to light, here are four things to know on the 100th anniversary of the discovery of his tomb.

Tut may not have been frail

Tutankhamun has a reputation as a fragile young man. Some researchers suspect a weakened immune system led to his death.

But "recent research suggests it's wrong to portray Tut as a fragile pharaoh," says Egyptologist and mummy researcher Bob Brier. His new book, *Tutankhamun and the Tomb That Changed the World*, chronicles how 100 years of research have shaped Tut's story and archaeology itself.

Clues from Tut's mummy and tomb items boost his physical standing, says Brier, of Long Island University in Brookville, N.Y. He might even have participated in warfare. Military chariots, leather armor and archery equipment buried with Tut show that he wanted to be viewed as a hunter and a warrior, Brier says. Inscribed blocks from his temple, which were reused in later building projects before researchers identified them, portray the pharaoh leading charioteers in undated battles.

If more blocks turn up showing battle scenes marked with dates, it would suggest Tut probably participated in those conflicts, Brier says. Pharaohs typically recorded dates of actual battles depicted in their temples.

The frail story line has been built in part on the potential discovery of a deformity in Tut's left foot, along with 130 walking sticks found in his tomb. But ancient Egyptian officials were often depicted with walking sticks as signs of authority, not infirmity, Brier says.

Opinions also vary about whether Tut's bones show serious deformities. In 2005, after reviewing CT images of Tut's mummy, researchers led by Zahi Hawass, former Egyptian minister of antiquities, said there were no signs of a misshapen ankle that would have caused a limp. But a 2009 reexamination of the images by the same researchers indicated that the left foot did have a deformity generally associated with walking on the ankle or the side of the foot, the team reported. The team's radiologist, Sahar Saleem of Cairo University, says the images show that Tut had a mild left clubfoot, bone tissue death at the ends of two long bones that connect to the second and third left toes, and a missing bone in the second left toe.

King Tutankhamun's gold burial mask is one of the most iconic artifacts from his tomb.

KHALED DESOUKI/AFP VIA GETTY IMAGES

Those problems would have "caused the king pain when he walked or pressed his weight on his foot, and the clubfoot must have caused limping," Saleem says.

Brier doubts that scenario. Tut's legs appear to be symmetrical in the CT images, he says, indicating that any left foot deformity was too mild to cause the pharaoh to regularly put excess weight on his right side while walking.

What is clear is that Tut died around age 19. Yet his cause of death is elusive. In a 2010 study of DNA extracted from Tut's mummy, Hawass and colleagues argued that malaria, plus the tissue-destroying bone disorder seen in the CT images, hastened death. But other researchers, including Brier, disagree. Further DNA studies using new tools for extracting and testing genetic material from the mummy could help solve that mystery.

Initial obscurity led to Tut's fame

After Tutankhamun's death, ancient Egyptian officials did their best to erase references to him. That's because his father, Akhenaten, was a "heretic king" who banished the worship of all Egyptian gods save for one.

"Akhenaten is the first monotheist recorded in history," Brier says. Ordinary Egyptians who had prayed to hundreds of gods suddenly could worship only Aten, a sun god once regarded as a minor deity.

After Akhenaten died, Egyptians reclaimed their old religion. Akhenaten's son, Tutankhamun, became king. Later pharaohs omitted from written records

any mentions of either Akhenaten or Tutankhamun. Tut's tomb was treated just as dismissively. Huts of craftsmen working on the tomb of King Ramses VI, nearly 200 years after Tut's death, were built over the stairway leading down to Tut's nearby, far smaller tomb.

The huts remained in place until Carter showed up. While Carter found evidence that the boy king's tomb had been entered twice after it was sealed, whoever had broken in took no major objects.

"Tutankhamun's ignominy and insignificance saved him" from tomb robbers, says UCLA Egyptologist Kara Cooney.

British archaeologist Howard Carter and a colleague examine Tutankhamun's remains after removing the lid of the pharaoh's carved stone sarcophagus in February 1923.

PICTORIAL PRESS LTD/ALAMY STOCK PHOTO

Tut's tomb was a rush job

Pharaohs usually prepared their tombs over decades, building many rooms to hold treasures and extravagant coffins.

Because Tutankhamun died prematurely, craftsmen had little time to finish crucial tomb items, many of which required a year or more to make. Those objects include a carved stone sarcophagus that encased three nested coffins, four shrines, hundreds of servant statues, a gold mask, chariots, jewelry and an alabaster chest that contained four miniature gold coffins for Tutankhamun's internal organs removed during mummification.

Evidence points to workers repurposing many objects from other people's tombs. Even then, time ran out.

Consider the sarcophagus. Two of four goddesses on the stone container lack fully carved jewelry. Workers painted missing jewelry parts. And the granite sarcophagus lid is a mismatch for the quartzite bottom. Something must have happened to the original quartzite lid, so workers carved a new lid from available granite and painted it to look like quartzite, Brier says.

The sarcophagus may originally have been made for Smenkare, a mysterious individual who some researchers identify as Tut's half brother. Little is known about Smenkare, who possibly reigned for about a year after Akhenaten's death, just before Tutankhamun, Brier says. But Smenkare's tomb has not been found, leaving the sarcophagus puzzle unsolved.

Even Tut's tomb may not be what it appears. Egyptologist Nicholas Reeves of the University of Arizona Egyptian Expedition in Tucson argues that the burial place was intended for Akhenaten's wife Nefertiti. He argues that Nefertiti briefly succeeded Akhenaten as Egypt's ruler and was the one given the title Smenkare.

No one has found Nefertiti's tomb yet. But Reeves predicts that one wall of Tut's burial chamber blocks access to a larger tomb where Nefertiti lies. Painted scenes and writing on that wall depict Tut performing a ritual on Nefertiti's mummy, he asserts. And the gridded structure of those paintings was used by Egyptian artists years before Tutankhamun's burial but not at the time of his interment.

Tut's tomb changed archaeology

Carter's stunning discovery occurred as Egyptians were protesting British colonial rule and helped fuel that movement.

Egyptian nationalists wanted political independence and an end to foreign adventurers bringing ancient Egyptian finds back to their home countries. Tut's tomb pushed authorities toward enacting laws and policies that helped to end the colonial state and reduce the flow of antiquities out of Egypt, Brier says, though it took decades. Egypt became a totally independent nation in 1953. A 1983 law decreed that antiquities could no longer be taken out of Egypt (though those removed before 1983 are still legal to own and sell).

In 1922, Carter regarded many objects as his for the taking, Brier says. That was the way that Valley of the Kings excavations worked, in a system that divided finds between Cairo's Egyptian Museum and an expedition's home institution. Taking personal mementos was also common.

French Egyptologist Marc Gabolde of Paul-Valéry Montpellier 3 University has tracked down beads, jewelry, a headdress fragment and other items taken from Tut's tomb by Carter and his financial backer, the British aristocrat Lord Carnarvon.

Still, it's undeniable that the Tut excavation set a benchmark for future excavations, Brier says. Carter started his career by copying paintings in Egyptian tombs for excavators. He later learned excavation techniques and took tomb documentation to a new level, rounding up a crack team consisting of a photographer, a conservator, two draftsmen, an engineer and an authority on ancient Egyptian writing.

Their decade-long effort also made possible the new Tut exhibition at the Grand Egyptian Museum. Both museum visitors and researchers will have unprecedented access to the pharaoh's tomb trove. "Most of Tutankhamun's [tomb] objects have been given little if any study beyond what Carter was able to do," says UCLA's Cooney.

That won't be true for much longer, as the most famous tomb in the Valley of the Kings enters the next stage of its public and scientific afterlife. ■

LIFE & EVOLUTION

Bees may order numbers left to right

Experiments suggest mental number lines are innate, not learned

BY DARREN INCORVAIA

Like many humans, honeybees seem to prefer their numbers ordered from left to right.

Honeybees trained to recognize a specific number tend to fly left when presented with two identical side-by-side panels showing a new, smaller number and right when the panels show a new, larger number, a new study claims. The finding suggests that honeybees have a left-to-right "mental number line" and that this association has biological roots, researchers report in the Nov. 1 *Proceedings of the National Academy of Sciences*.

While some scientists agree that the study makes a compelling case for a mental number line in honeybees, others argue that the new work is an oversimplification of complex human behavior.

Many people have a mental number line that often puts smaller numbers on the left and bigger numbers on the right. If asked to organize several bunches of grapes by size, you'd likely line them up by increasing number of grapes from left to right. Whether this association is present at birth or learned later in life has long been a subject of debate.

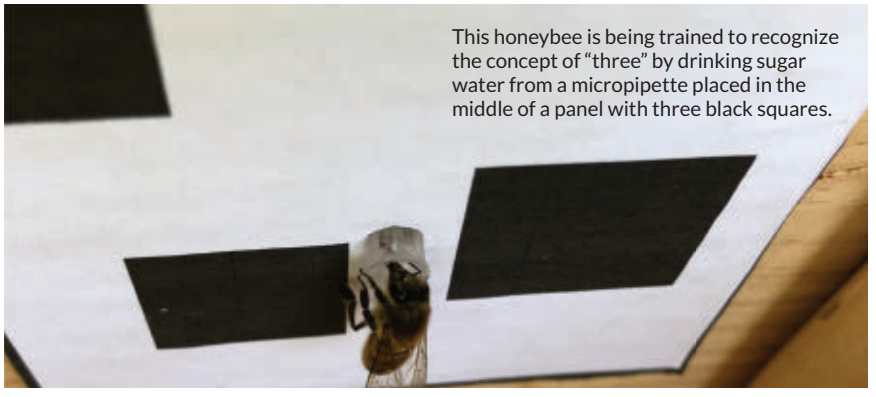
Previous work has shown that honeybees can count and even understand the concept of zero (SN: 7/7/18, *p.* 7). So an obvious question is whether they also have a mental number line, says Martin Giurfa, a biologist at the Université Paul Sabatier in Toulouse, France.

Working from home during COVID-19 lockdowns, Giurfa tested the number-ordering abilities of 134 western honeybees (*Apis mellifera*) using a design developed with researchers who had done similar experiments with chicks and human babies (SN: 3/7/15, *p.* 15).

First, Giurfa taught bees to recognize numbers. Using sugar water, he lured honeybees into a testing chamber built from a repurposed wine box. For each bee, he hung a panel on the back of the box with a certain number of symbols on it — one, three or five — and fed bees the sugar water so they'd learn to associate the number with food. By varying what the symbols looked like between visits, he ensured the bees were learning the number itself and not certain shapes or arrangements.

After 30 trips to the box, it was time to test whether the bees organized small to large numbers from left to right. Giurfa removed the training panel and set up two mirror-image panels, one on the left wall of the box and one on the right. These new panels either had the same number of symbols as the training panel, fewer symbols or more.

In one example, bees were shown "three." Of the bees trained on "one," 72 percent flew to the "three" panel to the right, but of the bees trained on "five," 73 percent went to the "three" panel to the left. "That's exactly the concept of the mental number line," Giurfa says. "You align numbers based on your reference." If the test number was the same as the training number, the bees showed no preference for left or right.



This honeybee is being trained to recognize the concept of "three" by drinking sugar water from a micropipette placed in the middle of a panel with three black squares.

M. GIURFA

These experiments "make a very compelling case" for a mental number line in honeybees, says Felicity Muth, a biologist at the University of Texas at Austin. The study has "a number of controls that really rule out any of the alternative explanations I can think of."

Giurfa believes these results show that mental number lines, or at least some component of them, are present in creatures across the animal kingdom. But not everyone is convinced.

"The oversimplification of complex human concepts, such as that of 'number line,' must be avoided, since they severely distort the reality of the phenomena that make them possible," says Rafael Núñez, a cognitive scientist at the University of California, San Diego.

Núñez, who coauthored an article critical of the earlier results in chicks, thinks animal research should address why bees and chicks would have inborn mental number lines while some human groups, like those he's studied in Papua New Guinea, don't. Giurfa acknowledges that culture plays a role in explaining why not every adult naturally orders numbers from left to right (SN: 9/25/21, *p.* 8), but feels that the proof is there for a biological underpinning.

The study stops short of explaining why the brains of bees, chicks and human babies have all converged on the same left-to-right number ordering but does offer a possible answer — asymmetrical brains. All three have brains that process information differently on the left and right sides. "It might be an inherent property to these lateralized brain systems," Giurfa says.

A shared system for organizing numbers, if truly widespread, would highlight how surprisingly similar animal minds can be to our own. Though some cognitive powers seem to be uniquely human, Giurfa thinks there is danger in dismissing the abilities of animals.

"We are different from animals in some aspects," he says, "but we are very similar in others. Denying this similarity is not what will help us understand what we are." ■

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Forever Chemicals: HIDDEN THREATS

Growing evidence of danger from PFAS prompts new guidance for safe drinking water and consumer testing

By Melba Newsome

STEFANIA PELFINI, LA WAZIYA PHOTOGRAPHY/GETTY IMAGES PLUS

For decades, chemicals that make life easier — your eggs slide out of the frying pan, stains don't stick to your sofa, rain bounces off your jackets and boots — have been touted as game changers for our busy modern lives. "Better things for better living ... through chemistry," was the optimistic slogan coined by DuPont, the company that invented the widely used chemical coating Teflon.

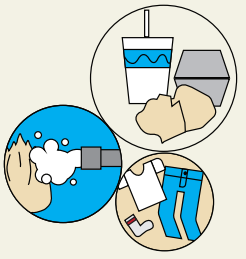
But this better living has come at a cost that is getting new attention. These chemicals — dubbed forever chemicals for their ability to last in the environment — are proving to have a lasting impact on human health. A growing body of research links the group of chemicals broadly known as PFAS, short for per- and polyfluoroalkyl substances, to conditions from unhealthy blood lipid levels to pregnancy complications to cancer.

Alarm about the health impacts of these chemicals has sparked a recent flurry of action from U.S. public health and regulatory officials. Warning that PFAS pose a greater health risk than previously thought, the U.S. Environmental Protection Agency in June dramatically lowered its recommended safe levels of the chemicals in drinking water.

"The updated advisory levels are based on new science, including more than 400 recent studies which indicate that negative health effects may occur at extremely low levels, much lower than previously understood," Radhika Fox, assistant administrator of the EPA's Office of Water, said in June at the Third National PFAS Conference, held in Wilmington, N.C.

Soon after, the National Academies of Sciences, Engineering and Medicine released the first clinical guidelines quantifying blood concentration levels of PFAS that could put someone's health at risk. The 300-page report urges clinicians to recommend regular blood tests for anyone exposed to high levels of the chemicals and to provide information on how to limit exposure, such as installing special filters known to reduce PFAS in drinking water.

In the United States alone, by one measure, the tally in medical care costs and lost productivity from PFAS exposure linked to five medical conditions adds up to at least $5.5 billion annually, researchers at New York University reported July 26 in *Exposure and Health*. Those conditions include low birth weight, childhood obesity, hypothyroidism in women, and kidney and testicular cancers. "We only looked at two of the more than 9,000 chemicals in the PFAS family, so we're just seeing the tip of an iceberg," says Leonardo Trasande, a pediatrician and environmental health expert at NYU Langone Health.



PFAS are found in many products, including:

- Firefighting foam
- Paint
- Sunscreen
- Makeup
- Dental floss
- Textiles
- Guitar strings
- Artificial turf
- Microwave popcorn bags
- Fast-food packaging
- Carpeting

Ubiquitous chemicals

Among those most at risk of exposure are firefighters: PFAS make protective gear more water resistant, and the chemicals are found in a widely used fire suppressant foam. But most people have some measurable level of PFAS in their bodies, according to the U.S. Centers for Disease Control and Prevention. Exposure typically comes from ingesting PFAS-contaminated drinking water or food grown in soil treated with fertilizers made from sewage contaminated with the chemicals (*SN: 11/24/18, p. 18*). An estimated 2,854 locations across the United States have PFAS contamination.

"People and communities have had significant exposure to these chemicals. If they can ID that they are in an area of significant exposure, they should seek testing through their usual source of care," says Ned Calonge, an epidemiologist at the Colorado School of Public Health in Aurora who chaired the committee that wrote the National Academies report. The committee linked PFAS exposure to a slightly different list of conditions than the NYU team, finding "sufficient evidence" linking PFAS to four conditions: poor antibody response to vaccination, abnormally high cholesterol levels, decreased infant and fetal growth, and kidney cancer. Evidence was "suggestive" for breast and testicular cancers, as well as thyroid problems and ulcerative colitis, an inflammatory bowel disease. The report calls for more research into the health effects of PFAS, noting gaps in evidence on everything from neurological issues to bone density. These chemicals have a wide range of impacts on multiple systems in the body, Calonge says. And they're "ubiquitous in the environment."

Newer, not safer

PFAS have been produced in the United States since the 1940s. Because they are good at repelling oil and water, holding up at high temperatures and reducing friction, the chemicals became useful for a vast array of products, including carpeting, upholstery, food packaging and even dental floss. Yet, relatively few

Health impacts A National Academies panel found sufficient and suggestive evidence that PFAS boost risk for several ailments.
* in adults, † in children

Sufficient evidence:	Suggestive evidence:
Poor antibody response to vaccination*†	Breast cancer*
Abnormally high cholesterol levels*†	Liver enzyme alterations*†
Decreased infant and fetal growth	Pregnancy-induced hypertension
Kidney cancer*	Testicular cancer*
	Thyroid disorders*
	Ulcerative colitis*

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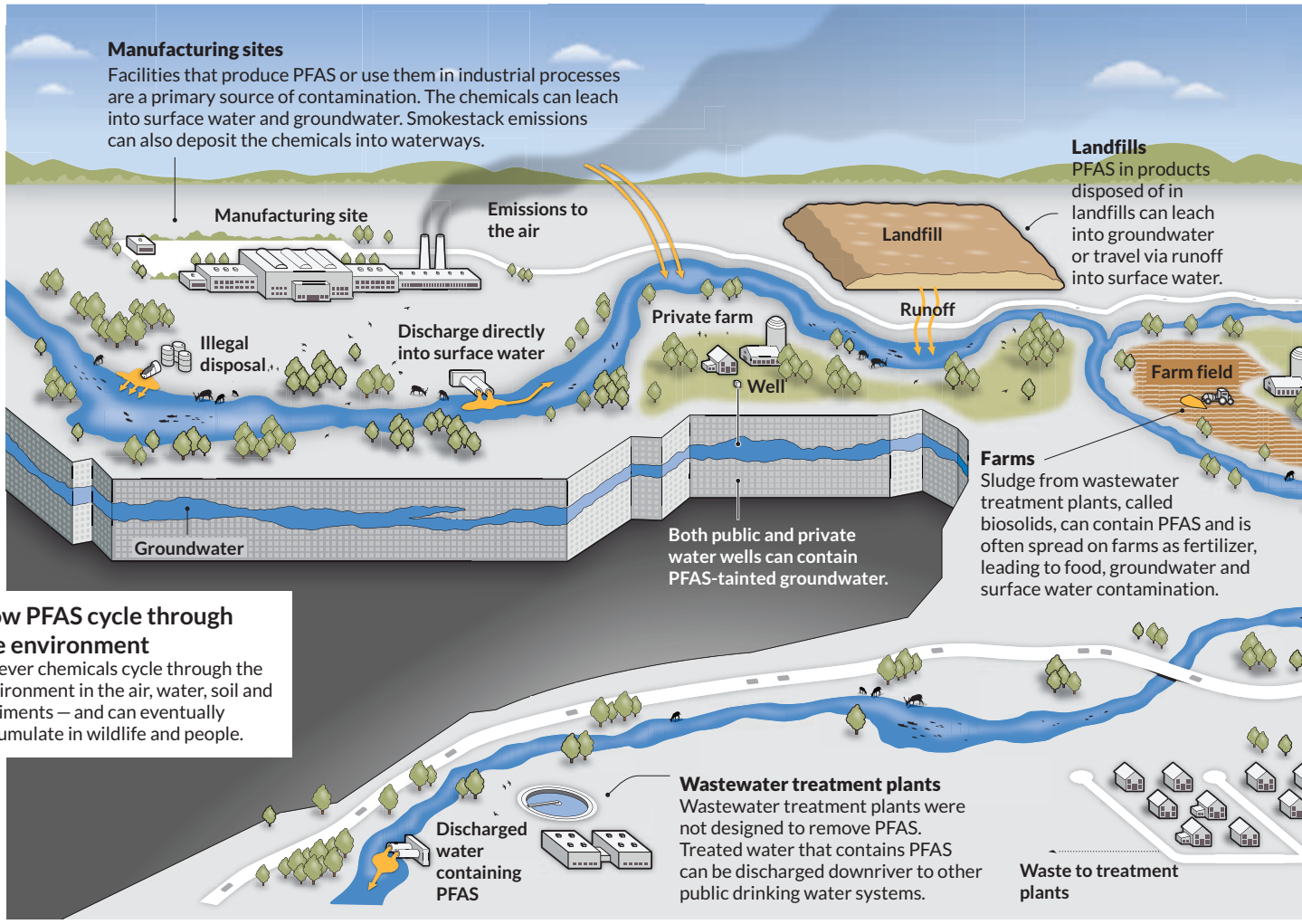


of the 9,000 or so versions of these synthetic chemicals have been studied for their toxicologic effects. Many PFAS are now recognized as endocrine disruptors, chemical compounds that interfere with the normal functioning of the endocrine, or hormonal, system. But PFAS have other effects that can boost cancer risk, such as weakened immunity, excessive cell growth and altered gene activity. One study found a greater than two-fold increase in kidney cancer risk between people with the highest versus lowest blood levels of one common PFAS called perfluorooctanoic acid, or PFOA, researchers reported in 2021 in the *Journal of the National Cancer Institute*.

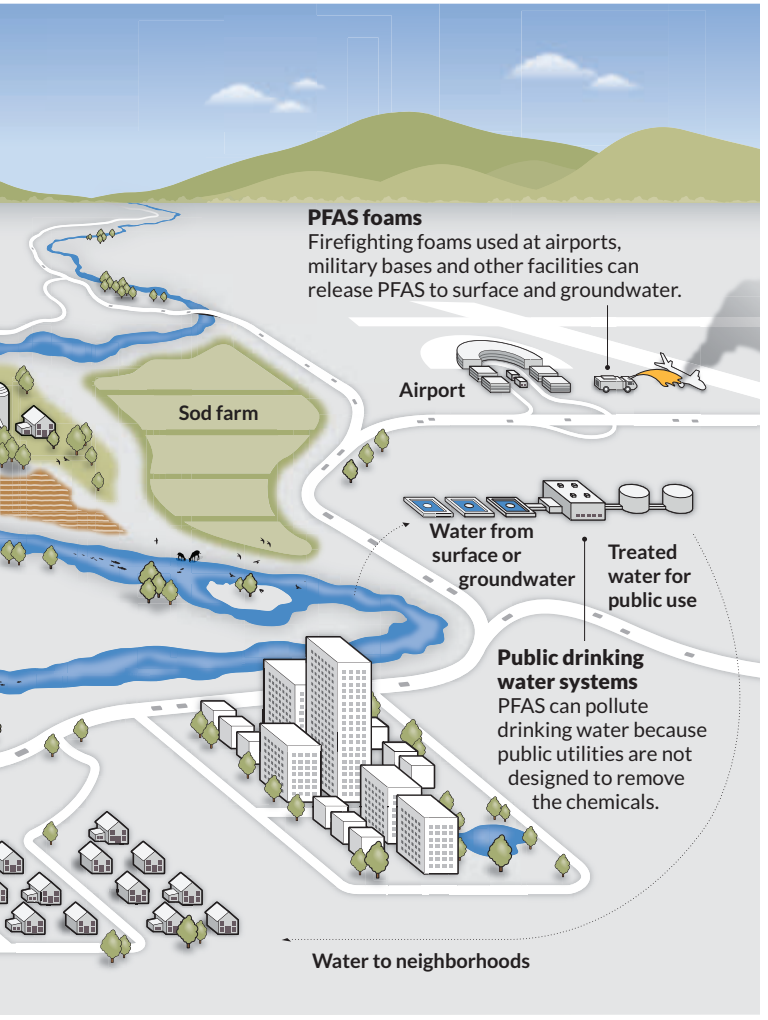
A newer generation of PFAS was assumed to be safer because the chemicals are less likely to accumulate in the body. But these newer compounds are structurally similar to the older ones and can be just as harmful to health as their cousins, Trasande says. These newer molecules "are increasingly being associated with diseases like gestational diabetes. We're just starting to see the bigger problem that might be at play."

The EPA's new drinking water advisory aims to tackle both old and new PFAS. It targets two of the earlier and most commonly found kinds of PFAS in the environment: PFOA and perfluorooctane sulfonic acid, or PFOS. The advisory reduces the level of drinking water contamination below which adverse health effects are not expected from 70 parts per trillion to 0.004 and 0.02 ppt, respectively. Those levels are based on routine exposure to them over a lifetime.

The EPA's health advisory also provided the first-ever recommendations on two of the newer kinds of PFAS: hexafluoropropylene oxide dimer acid and HFPO ammonium salt, collectively known as GenX chemicals, and perfluorobutane sulfonic acid, or PFBS. The agency set the drinking water safety threshold at 10 ppt for GenX chemicals and 2,000 ppt for PFBS. These newer chemicals have similar persistence in the environment, the agency states.

Consumers can ask their municipal water provider for data on PFAS testing in their area. Testing is becoming more common, and providers should be able to list which PFAS they test for. Private wells can be contaminated with PFAS if they are near manufacturers that produce or use the chemicals, as well as airfields where PFAS are used for firefighting, firefighting training areas and some waste disposal sites. People with private wells near one of these facilities can get their water

DAVID PUCKETT/NATIONAL WILDLIFE FEDERATION



tested. The EPA is giving grants to help underserved small and disadvantaged communities provide household water quality testing and comply with drinking water regulations.

PFAS price tag

Because there are limited available data on the health effects of the newer generation of chemicals, the NYU and National Academies reports focused on the impacts of older PFAS.

First, the NYU team examined PFAS chemicals in blood samples obtained from roughly 5,000 adults and children who participated in the U.S. National Health and Nutrition Examination Survey. Then, based on earlier studies linking PFAS to certain diseases and models that estimate medical costs and lost worker productivity for these illnesses, the team came up with its PFAS price tag.

Childhood obesity, the largest contributor to the overall economic toll of PFAS exposure, costs about $2.7 billion a year, the team estimates, followed by hypothyroidism in women at $1.26 billion. When the researchers considered other PFAS-linked diseases beyond the top five, such as endometriosis, obesity in adults and pneumonia in children, the estimated economic burden rose to as much as $63 billion annually.

The National Academies report focused in part on how to curb that toll by providing testing guidelines to clinicians to detect high levels of PFAS in the body and try to reduce exposure.

The report provides the first clinical guidelines on how to assess a person's disease risk. A person with a PFAS blood concentration of less than 2 nanograms per milliliter doesn't have to worry. But for patients with blood concentrations between 2 and 20 ng/mL, clinicians should screen for conditions like unhealthy levels of fat in the blood, which can lead to heart problems. Such screening is especially important for people more vulnerable to the effects of PFAS exposure, like children, pregnant people and those who are immunocompromised. For anyone who tests above 20 ng/mL, the report encourages routine screenings for some cancers, thyroid problems and ulcerative colitis.

"For almost 20 years, we've been able to measure PFAS in people's blood, but there was no guidance to say what [those measurements] mean," says National Academies report coauthor Jane Hoppin, who heads the Center for Human Health and the Environment at North Carolina State University in Raleigh. "For the first time, this actually sets some ranges, some guidance for what could be levels of concern, and what kinds of health follow-up might be appropriate."

She hopes that the recommendations will increase testing availability and make both doctors and patients more aware of these chemicals and their health risks. The report also encourages doctors to work with their patients to figure out where they are being exposed to PFAS and how to mitigate those risks, by cutting down on PFAS-containing products and filtering water.

Activated carbon filters, found in some countertop or pitcher filters, don't remove PFAS as completely as reverse osmosis filters, researchers at Duke University and North Carolina State reported in 2020. The National Academies report offers a link to NSF, a testing organization that offers technical details on which filters actually filter out PFAS.

Efforts like reducing PFAS in drinking water could help. While EPA's health advisories are recommendations and not enforceable, Trasande is pleased that the agency acted quickly, particularly on newer chemicals like GenX. But he argues that in light of what we already know and are continuing to learn about the disease burden caused by these chemicals, PFAS should undergo more testing before they are approved. Better yet, they should be regulated by class instead of taking what he calls a whack-a-mole approach.

"Our environmental policy still takes a wait-and-see approach that we should wait 20 to 30 years, which is the time that people take to develop diseases due to chemical exposures," he says. ■

Explore more

- Environmental Protection Agency. Questions and Answers: Drinking Water Health Advisories for PFOA, PFOS, GenX Chemicals and PFBS. bit.ly/EPA_foreverchemicals

Melba Newsome is a freelance writer based in Charlotte, N.C.

Louis Pasteur, who was born December 27, 1822, in Dole, France, believed in science and the scientific method — and employed them to great benefit for humankind.

Louis Pasteur's Long Legacy

The father of microbiology turns 200

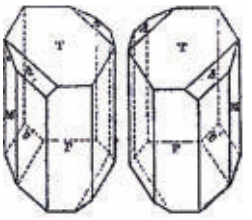
By Tom Siegfried

Great scientists become immortalized in various ways. Some through names for obscure units of measurement (à la Hertz, Faraday and Curie). Others in elements on the periodic table (Mendeleev, Seaborg, Bohr, among many others). A few become household names symbolizing genius—like Newton in centuries past and nowadays, Einstein. But only one has been honored on millions and millions of cartons of milk: the French chemist, biologist and evangelist for experimental science Louis Pasteur.

Pasteur was born 200 years ago this December, the most significant scientist birthday bicentennial since Charles Darwin's in 2009. And Pasteur ranked behind only Darwin among the most exceptional biological scientists of the 19th century. Pasteur not only made milk safe to drink, but also rescued the beer and wine industry. He established the germ theory of disease, saved the French silkworm population, confronted the scourges of anthrax and rabies, and transformed the curiosity of vaccination against smallpox into a general strategy for treating and preventing human diseases. He invented microbiology and established the foundations for immunology.

Had he been alive after 1901, when Nobel Prizes were first awarded, he would have deserved one every year for a decade. No other single scientist demonstrated more dramatically the benefit of science for humankind.

He was not, however, exactly a saint. A Pasteur biographer, Hilaire Cuny, called him "a mass of contradictions." Pasteur was ambitious and opportunistic, sometimes arrogant and narrow-minded, immodest, undiplomatic and uncompromising. In the scientific controversies he engaged in (and there were many), he was pugnacious and belligerent. He did not suffer criticism silently and was often acerbic in his responses. To his laboratory assistants, he was demanding, dictatorial and aloof. Despite his revolutionary spirit in pursuing science, in political and social matters, he was conformist and deferential to authority.



Pasteur found that two crystal forms of racemic acid are mirror images (his drawings shown), and so cancel out each other's light-twisting effects.

And yet he was a tireless worker, motivated by service to humankind, faithful to his family and unwaveringly honest. He was devoted to truth, and therefore also to science.

From art to science

In his youth, Pasteur did not especially excel as a student. His interests inclined toward art rather than science, and he did display exceptional skill at drawing and painting. But in light of career considerations (his father wanted him to be a scholar), Pasteur abandoned art for science and so applied to the prestigious École Normale Supérieure in Paris for advanced education. He finished 15th in the competitive entrance examination, good enough to secure admission. But not good enough for Pasteur. He spent another year on further studies emphasizing physical sciences and then took the École Normale exam again, finishing fourth. That was good enough, and he entered the school in 1843. There he earned his doctoral degree, in physics and chemistry, in 1847.

Among his special interests at the École Normale was crystallography. In particular he was drawn to investigate tartaric acid. It's a chemical found in grapes responsible for tartar, a potassium compound that collects on the surfaces of wine vats. Scientists had recently discovered that tartaric acid possesses the intriguing power of twisting light—that is, rotating the orientation of light waves' vibrations. In light that has been polarized (by passing it through certain crystals, filters or some sunglasses), the waves are all aligned in a single plane. Light passing through a tartaric acid solution along one plane emerges in a different plane.

Even more mysteriously, another acid (paratartaric acid, or racemic acid), with the exact same chemical composition as tartaric acid, did not twist light at all. Pasteur found that suspicious. He began a laborious study of the crystals of salts derived from the two acids. He discovered that racemic acid crystals could be sorted into two

OPPOSITE PAGE: MIKROMAN6/MOMENT/GETTY IMAGES; THIS PAGE: L. PASTEUR/ANNALES DE CHIMIE ET DE PHYSIQUE 1848

asymmetric mirror-image shapes, like pairs of right-handed and left-handed gloves. All the tartaric acid crystals, on the other hand, had shapes with identical asymmetry, analogous to gloves that were all right-handed.

Pasteur deduced that the asymmetry in the crystals reflected the asymmetric arrangement of atoms in their constituent molecules. Tartaric acid twisted light because of the asymmetry of its molecules, while in racemic acid, the two opposite shapes canceled out each other's twisting effects.

Pasteur built the rest of his career on this discovery. His research on tartaric acid and wine led eventually to profound realizations about the relationship between microbes and human disease. Before Pasteur, most experts asserted that fermentation was a natural nonbiological chemical process. Yeast, a necessary ingredient in the fermenting fluid, was supposedly a lifeless chemical acting as a catalyst. Pasteur's experiments showed yeast to be alive, a peculiar kind of "small plant" (now known to be a fungus) that caused fermentation by biological activity.

Pasteur demonstrated that, in the absence of air, yeast acquired oxygen from sugar, converting the sugar to alcohol in the process. "Fermentation by yeast," he wrote, is "the direct consequence of the processes of nutrition," a property of a "minute cellular plant … performing its respiratory functions." Or more succinctly, he proclaimed that "fermentation … is life without air." (Later scientists found that yeast accomplished fermentation by emitting enzymes that catalyzed the reaction.)

Pasteur also noticed that additional microorganisms present during fermentation could be responsible for the process going awry, a problem threatening the viability of French winemaking and beer brewing. He solved that problem by developing a method of heating that eliminated the bad microorganisms while preserving the quality of the beverages. This method, called "pasteurization," was later applied to milk, eliminating the threat of illness from drinking milk contaminated by virulent microorganisms. Pasteurization became standard public health practice in the 20th century.

Pasteur used the foreground double flask to demonstrate anaerobic fermentation. The flask in the back is full of barley water that Pasteur had pasteurized in 1860. It remained unfermented decades later.

COURTESY OF SCIENCE HISTORY INSTITUTE

Incorporating additional insights from studies of other forms of fermentation, Pasteur summarized his work on microbial life in a famous paper published in 1857. "This paper can truly be regarded as the beginning of scientific microbiology," wrote the distinguished microbiologist René Dubos, who called it "one of the most important landmarks of biochemical and biological sciences."

Spontaneous generation, not

Pasteur's investigations of the growth of microorganisms in fermentation collided with another prominent scientific issue: the possibility of spontaneous generation of life. Popular opinion even among many scientists held that microbial life self-generated under the proper conditions (spoiled meat, for example). Demonstrations by the 17th century Italian scientist Francesco Redi challenged that belief, but the case against spontaneous generation was not airtight.

In the early 1860s Pasteur undertook a series of experiments that should have left no doubt that spontaneous generation, under conditions encountered on Earth today, was an illusion. Yet he was nevertheless accosted by critics, such as the French biologist Charles-Philippe Robin, to whom he returned verbal fire. "We trust that the day will come when M. Robin will … acknowledge that he has been in error on the subject of the doctrine of spontaneous generation, which he continues to affirm, without adducing any direct proofs in support of it," Pasteur remarked.

It was his work on spontaneous generation that led Pasteur directly to the development of the germ theory of disease.

For centuries people had suspected that some diseases must be transmitted from person to person by close contact. But determining exactly how that happened seemed beyond the scope of scientific capabilities. Pasteur, having discerned the role of germs in fermentation, saw instantly that something similar to what made wine go bad might also harm human health.

After disproving spontaneous generation, he realized that there must exist "transmissible, contagious, infectious diseases of which the cause lies essentially and solely in the presence of microscopic organisms." For some diseases, at least, it was necessary to abandon "the idea of … an infectious element suddenly originating in the bodies of men or animals." Opinions to the contrary, he wrote, gave rise "to the gratuitous hypothesis of spontaneous generation" and were "fatal to medical progress."

His first foray into applying the germ theory of disease came during the late 1860s in response to a decline in French silk production because of diseases afflicting silkworms. After success in tackling the silkworms' maladies, he turned to anthrax, a terrible illness for cattle and humans alike. Many medical experts had long suspected that some form of bacteria

caused anthrax, but it was Pasteur's series of experiments that isolated the responsible microorganism, verifying the germ theory beyond doubt. (Similar work by Robert Koch in Germany around the same time provided further confirmation.)

Understanding anthrax's cause led to the search for a way to prevent it. In this case, a fortuitous delay in Pasteur's experiments with cholera in chickens produced a fortunate surprise. In the spring of 1879 he had planned to inject chickens with cholera bacteria he had cultured, but he didn't get around to it until after his summer vacation. When he injected his chickens in the fall, they unexpectedly failed to get sick. So Pasteur prepared a fresh bacterial culture and brought in a new batch of chickens.

When both the new chickens and the previous batch were given the fresh bacteria, the new ones all died, while nearly all of the original chickens still remained healthy. And so, Pasteur realized, the original culture had weakened in potency over the summer and was unable to cause disease, while the new, obviously potent culture did not harm the chickens previously exposed to the weaker culture. "These animals have been vaccinated," he declared.

Vaccination, of course, had been invented eight decades earlier, when British physician Edward Jenner protected people from smallpox by first exposing them to cowpox, a similar disease acquired from cows. (Vaccination comes from cowpox's medical name, vaccinia, from *vacca*, Latin for cow.) Pasteur realized that the chickens surprisingly displayed a similar instance of vaccination because he was aware of Jenner's discovery. "Chance favors the prepared mind," Pasteur was famous for saying.

Because of his work on the germ theory of disease, Pasteur's mind was prepared to grasp the key role of microbes in the prevention of smallpox, something Jenner could not have known. And Pasteur instantly saw that the specific idea of vaccination for smallpox could be generalized to other diseases. "Instead of depending on the chance finding of naturally occurring immunizing agents, as cowpox was for smallpox," Dubos observed, "it should be possible to produce vaccines at will in the laboratory."

Pasteur cultured the anthrax microbe and weakened it for tests in farm animals. Success in such tests not only affirmed the correctness of the germ theory of disease, but also allowed it to gain a foothold in devising new medical practices.

Later Pasteur confronted an even more difficult microscopic foe, the virus that causes rabies. He had begun intense experiments on rabies, a horrifying disease that's almost always fatal, caused usually by the bites of rabid dogs or other animals. His experiments failed to find any bacterial cause for rabies, leading him to realize that it must be the result of some agent too small to see with his microscope. He could not grow cultures in lab dishes of what he could not see. So instead he decided to grow the disease-causing agent in living tissue — the spinal cords of rabbits. He used dried-out strips of spinal cord from infected rabbits to vaccinate other animals that then survived rabies injections.

Pasteur (seated) poses with, among others, children treated with his rabies vaccine. By early 1886, more than 300 patients had received it.

Pasteur hesitated to test his rabies treatment on humans. Still, in 1885 when a mother brought to his lab a 9-year-old boy who had been badly bitten by a rabid dog, Pasteur agreed to administer the new vaccine. After a series of injections, the boy recovered fully. Soon more requests came for the rabies vaccine, and by early the next year over 300 rabies patients had received the vaccine and survived, with only one death among them.

Popularly hailed as a hero, Pasteur was also vilified by some hostile doctors, who considered him an uneducated interloper in medicine. Vaccine opponents complained that his vaccine was an untested method that might itself cause death. But of course, critics had also rejected Pasteur's view of fermentation, the germ theory of disease and his disproof of spontaneous generation.

Pasteur stood his ground and eventually prevailed (although he did not turn out to be right about everything). His attitude and legacy of accomplishments inspired 20th century scientists to develop vaccines for more than a dozen deadly diseases. Still more diseases succumbed to antibiotics,

The newspaper *Le Petit Journal* printed a reverential portrait of Pasteur on its illustrated supplement's cover after his death in 1895.

FROM TOP: SVINTAGE ARCHIVE/ALAMY STOCK PHOTO; PHOTOS.COM/GETTY IMAGES PLUS

This painting depicts French President Sadi Carnot helping Pasteur walk across the stage during a ceremony held at the Sorbonne in Paris in honor of Pasteur's 70th birthday.

following the discovery of penicillin by Alexander Fleming — who declared, "Without Pasteur I would have been nothing."

Even in Pasteur's own lifetime, thanks to his defeat of rabies, his public reputation was that of a genius.

Temples of wealth

As geniuses go, Pasteur was the opposite of Einstein. To get inspiration for his theories, Einstein imagined riding aside a light beam or daydreamed about falling off a ladder. Pasteur stuck to experiments. He typically initiated his experiments with a suspected result in mind, but he was scrupulous in verifying the conclusions he drew from them. Preconceived ideas, he said, can guide the experimenter's interrogation of nature but must be abandoned in light of contrary evidence. "The greatest derangement of the mind," he declared, "is to believe in something because one wishes it to be so."

So even when Pasteur was sure his view was correct, he insisted on absolute proof, conducting many experiments over and over with variations designed to rule out all but the true interpretation.

"If Pasteur was a genius, it was not through ethereal subtlety of mind," wrote Pasteur scholar Gerald Geison. Rather, he exhibited "clear-headedness, extraordinary experimental skill and tenacity — almost obstinacy — of purpose."

His tenacity, or obstinacy, helped him persevere through several personal tragedies, such as the deaths of three of his daughters, in 1859, 1865 and 1866. And then in 1868 he suffered a cerebral hemorrhage that left him paralyzed on his left side. But that did not slow his pace or impair continuing his investigations.

"Whatever the circumstances in which he had to work, he never submitted to them, but instead molded them to the demands of his imagination and his will," Dubos wrote. "He was probably the most dedicated servant that science ever had."

To the end of his life, Pasteur remained dedicated to science and the scientific method, stressing the importance of experimental science for the benefit of society. Laboratories are "sacred institutions," he asserted. "Demand that they be multiplied and adorned; they are the temples of wealth and of the future."

Three years before his death in 1895, Pasteur further extolled the value of science and asserted his optimism that the scientific spirit would prevail. In an address, delivered for him by his son, at a ceremony at the Sorbonne in Paris, he expressed his "invincible belief … that science and peace will triumph over ignorance and war, that nations will unite, not to destroy, but to build, and that the future will belong to those who will have done most for suffering humanity."

Two hundred years after his birth, ignorance and war remain perniciously prominent, as ineradicable as the microbes that continue to threaten public health, with the virus causing COVID-19 the latest conspicuous example. Vaccines, though, have substantially reduced the risks from COVID-19, extending the record of successful vaccines that have already tamed not only smallpox and rabies, but also polio, measles and a host of other once deadly maladies. Yet even though vaccines have saved countless millions of lives, some politicians and so-called scientists who deny or ignore overwhelming evidence continue to condemn vaccines as more dangerous than the diseases they prevent. True, some vaccines can induce bad reactions, even fatal in a few cases out of millions of vaccinations. But shunning vaccines today, as advocated in artificially amplified social media outrage, is like refusing to eat because some people choke to death on sandwiches.

Today, Pasteur would be vilified just as he was in his own time, probably by some people who don't even realize that they can safely drink milk because of him. Nobody knows exactly what Pasteur would say to these people now. But it's certain that he would stand up for truth and science, and would be damn sure to tell everybody to get vaccinated. ■

Explore more

- Institut Pasteur's Bicentenary Celebration: www.pasteur.fr/en/bicentenary-2022

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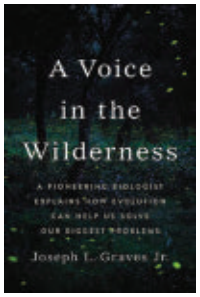

A Voice in the Wilderness
Joseph L. Graves Jr.
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BOOKSHELF

A pioneering Black biologist tells his story

It's both good and bad that the first Black American to earn a Ph.D. in evolutionary biology is not a long-ago hidden figure but a contemporary scientist. On the upside, there's no agonizing over papers no one saved, no stitching together other people's memoirs to guess what pioneering might have felt like. Instead, Joseph L. Graves Jr., who finished his degree in 1988, tells his story himself in *A Voice in the Wilderness*.

But evolutionary biology's first Black Ph.D. in 1988? That "first" came late even considering that the field took a while to declare itself a specialty. The Society for the Study of Evolution didn't form until 1946. Black biologists in other specialties had started cracking the glass ceiling of academic credentials as early as 1889.

Still, Black biologists struggled to get jobs befitting their credentials and talent. Even now, while nearly 14 percent of the U.S. population is Black, Black scientists make up only about 3 percent of the resident Ph.D.s working in a biological discipline.

Showing how racism narrows the gateways to science is a major theme in *A Voice in the Wilderness* as Graves draws on his own twisty, bruising path to becoming a "first." Yet he declares that the book isn't an autobiography. The book feels like a long, candid, free-flowing conversation. Graves mixes in bitter and sweet childhood memories, the lab challenges of coaxing insects to fly in place, quick math and science explainers, enthusiastic accounts of the scientific questions that kept drawing him to the field, vignettes from his political activism, his alienation from and return to Christianity, and some *Star Trek*.

Graves has already published on why Black evolutionary biologists are rare, lamenting the longtime lack of an inclusive culture and the few, often barely visible, role models. Also, evolutionary biology has baggage. He described in a 2001 book, *The Emperor's New Clothes*, a long whack-a-mole history of serial racist pseudoscience, such as polygeny, a 19th century idea that held that races had independent origins and were thus separate species. In the 20th century, the selective breeding notions of eugenics supposedly justified forced sterilizations and exterminations to purge unwanted traits as if people were livestock. Misuse of science continues, though Graves highlights a few heroes who have summoned science to fight the perversions.

Graves' own path was not easy. His parents were born in 1920s Virginia. His grandfather started the migration north after a tip that the Ku Klux Klan was about to target him. His moonshine was getting too competitive with white suppliers'.

"Both my parents grew up under the constant threat of the lynch rope should they in any way sass a white person," Graves writes. He was born in New Jersey in 1955. "Four months after I was born, young Emmett Till was lynched in Money, Mississippi, for supposedly doing just that."

Graves attended largely white-majority schools that didn't see his potential. His mother, Helen, was the advocate who won him his education. She fought back when his elementary school pushed to move him into "special education." In third grade, eye tests revealed he was nearsighted. He got glasses, and new possibilities dawned.

At another turning point, he convinced some kids playing chess to let him have a try. He lost badly, but found two chess books in the library that he devoured that night. "In hindsight, I credit chess with being the most important factor changing the trajectory of my life," he writes. He played on the school team and made lifelong friends.

His path through higher education got complicated. He went to Oberlin College in Ohio because its recruiting brochures had pictures of students who looked like him. The reality was tough. He and many other students struggled with freshman physics. Yet, as far as he could tell, he and the class's only other Black student were the only ones to get their final exams back marked, "You have no talent for physics, you should never take another physics class at this college." Graves avoided physics, but the other student went on to earn a physics Ph.D. at MIT.

While studying parasites for his master's degree, Graves discovered that his ability to spot weaknesses in current knowledge, which led him to overthink exam answers in his earlier school days, became a strength in research.

For his Ph.D., he wanted to go to Harvard University despite his experiences on campus visits. He recalls "European American students coming back and locking their offices or removing valuables from sight when I walked through the common area."

The National Science Foundation awarded him a fellowship in 1979, not just honoring his talent but offering schools the catnip of full funding for his tuition and support. "I suspect I am the only person in the history of the [fellowship] to be rejected for admission to a graduate program in the same year the award was made," he says. Harvard informed him that he was qualified but that no one could be found to advise him.

So he happily plunged into the intellectual fizz of the University of Michigan. Yet increasingly passionate political activism pulled him away. He organized efforts to stop Klan threats against Black Americans moving into Detroit suburbs. He went to the United Kingdom to stand arm in arm with the wives of striking miners as police charged them. Graves returned to academics and finished his Ph.D. in 1988 at Wayne State University in Detroit. His career took off as he worked on the evolutionary genetics of aging. Today, he's a professor at North Carolina A&T State University, a historically Black school.

In keeping with his activist past, Graves uses his expertise to fight racism that claims a basis in science. The book's title comes from the biblical phrase, "I am the voice of one calling in the wilderness, 'Make straight the way for the Lord.'" It has become a metaphor, Graves says, "for any perspective of great importance and truth that has been silenced to maintain the status quo." He is far from silenced. —*Susan Milius*

INSPIRING YOUNG ENVIRONMENTALISTS THROUGH ACTION

Austin Youth River Watch is a nonprofit organization creating safe places for teenagers in the Austin, Texas, area to learn about environmental science through hands-on experiences. In after-school and summer programs, students, known as River Watchers, collect and analyze water quality data, participate in environmental restoration projects and embark on outdoor adventures. Combining environmental education with youth development, the organization is working to give students the inspiration and tools to become active stewards of our planet.

This year, Austin Youth River Watch received a $4,000 STEM Action Grant from Society for Science, which assisted the organization with its operating costs, including stipends, transportation and nutrition needs for the River Watchers. The STEM Action Grant program supports community-driven organizations working to enhance the public's understanding of science and to increase participation of underrepresented populations in STEM (science, technology, engineering, and math) fields. The program has awarded $586,000 to 85 organizations since its founding in 2016.

SEPTEMBER 24, 2022

SOCIAL MEDIA

Zooming in on zombies

An award-winning photo captured a mind-controlling parasitic fungus erupting from a fly (below), **Richard Kemeny** reported in "Attack of a zombie fungus" (*SN: 9/24/22, p. 32*). Twitter user **@robgo84** remarked: "A fungus among us. So cool."

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Rings and rainbows

A team of scientists claim they've uncovered a thin ring of light called a photon ring around the first black hole to have its picture taken, the supermassive black hole in the galaxy M87. But skeptics aren't convinced, ***Emily Conover*** *reported in "Physicists dispute photon ring claim" (*SN: 9/24/22, p. 8*).*

Assuming that Earth and the photon ring are on the same plane, reader **James P. Rice** wondered why we see the light as a circle rather than a straight line.

"The photon ring is a little like a rainbow," physics writer **James R. Riordon** says. "It's an optical effect, not a physical ring." Rainbows are caused by the way raindrops affect paths of light. A person can see a rainbow in the rain in front of them as long as the sun is behind them. But where the rainbow appears to the observer changes depending on where that person stands relative to the sun.

In a similar way, a photon ring is caused by a black hole's influence on paths of light, **Riordon** says. A photon ring will appear as a circular ring around a black hole no matter which direction you look at the black hole from. "You can't be in the plane of a photon ring any more than you can walk to the end of a rainbow," he says.

JUST WONDERING

Science News *readers often ask questions that are unrelated to our journalism but are fascinating nonetheless. We're indulging our nerdy impulses to try to answer those questions.*

Reader **Marc Sapir** asked if light from the early solar system could bend and come back to us during space travel so that we might someday see past Earth events.

"Everything bends light a little bit," says **Sam Gralla**, a physicist at the University of Arizona in Tucson. But for light to come back all the way to us, it would have to bend a lot.

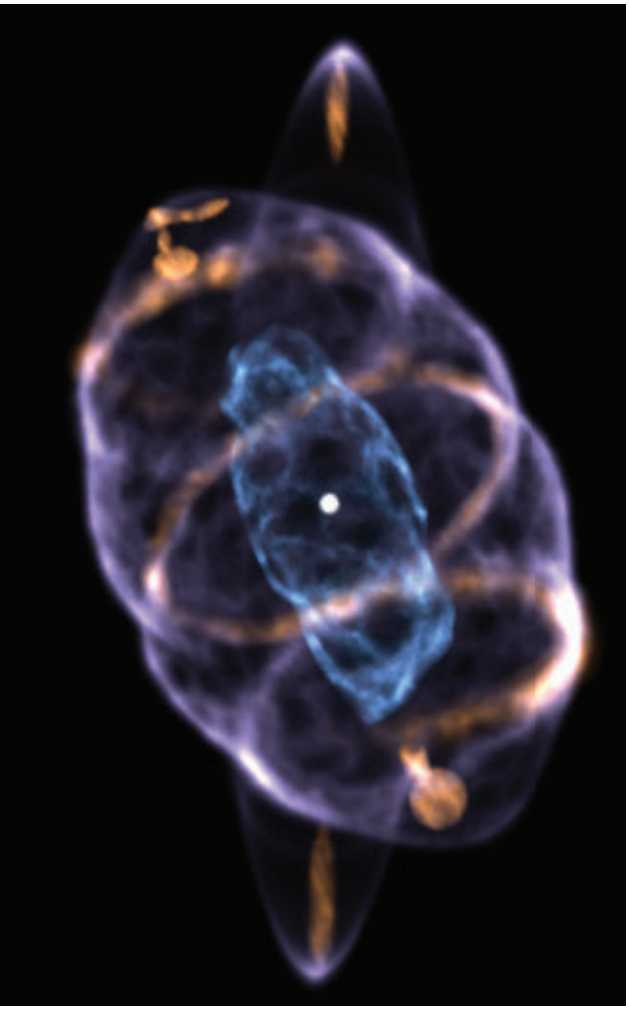
Our sun, for instance, "bends light by a little less than one one-thousandth of a degree, so it won't help us see our own past," **Gralla** says. If, hypothetically, the sun collapsed to a black hole of the same mass, "then it could bend light all the way around, which would be pretty cool," he says. "But only a very small fraction of emitted light gets bent so much, so we'd have to have amazing telescopes to see it." Even if we did have such telescopes, humans and other life on Earth would not survive without the sun's light, **Gralla** says. And alas, our sun is destined to become a red giant when it dies, not a black hole.

Some light from our early solar system also could reach Sagittarius A*, the black hole at the Milky Way's center. "Sgr A* can bend light a lot," **Gralla** says. "But unless the light is emitted very near it, only a tiny fraction is actually bent." For light from our solar system to return to us, it would have to approach Sgr A* at precisely the right direction, he says. "The proverbial needle in a haystack."

"Still, it's fun to think that aliens near black holes might be looking at themselves in the 'black hole mirror' at this very minute," **Gralla** says.

Send your science questions to feedback@sciencenews.org.

ROBERTO GARCÍA-ROA



The Cat's Eye nebula in 3-D

Roughly 3,000 light-years from Earth sits one of the most complex and least understood nebulae, a landscape of gas and dust left in the wake of a star's death throes. A new computer visualization (top left) reveals the 3-D structure of the Cat's Eye nebula and how not one, but two dying stars sculpted it.

Based on images from the Hubble Space Telescope, the reconstruction reveals three gas rings (orange). Two of those rings, at opposing ends of the nebula, probably were formed by a twirling duo of long-lost jets of charged gas launched from a pair of dying stars (shown as one white dot) in the center, Ryan Clairmont and colleagues report in the October *Monthly Notices of the Royal Astronomical Society*.

Two other jets pierce an outer shell of gas (purple) launched outward in the final gasps of one of the stars. The central ring is caused by gas lighting up as it runs into denser material encircling the nebula. A later wind from at least one of the moribund stars probably carved an inner shell of gas (blue).

"I realized there hasn't been a comprehensive study of the structure of the nebula since the early '90s," says Clairmont, an undergraduate student at Stanford University. Last year, while a high school student in San Diego, he reached out to two astrophysicists at a scientific imaging company called Ilumbra who had written software to reconstruct the 3-D composition of astronomical objects.

The trio combined Hubble images (one shown, top right) with ground-based observations of light in several wavelengths, which revealed the motions of the nebula's gas. Figuring out which parts were moving toward and away from Earth helped reveal the 3-D structure.

The symmetry and unfinished nature of the two outer rings suggest that they are the remains of two opposing, spinning plasma jets launched from the heart of the nebula, then snuffed out before they could complete a full circle. Such jets are usually formed through an interaction between two stars orbiting one another, says Ilumbra partner Wolfgang Steffen, who is based in Kaiserslautern, Germany.

The work won Clairmont a prize at the 2021 Regeneron International Science and Engineering Fair, an annual competition run by the Society for Science, which publishes *Science News*. — *Lisa Grossman*

VISUALIZATION: R. CLAIRMONT; IMAGE: NASA, ESA, HEIC AND THE HUBBLE HERITAGE TEAM/STSCI/AURA

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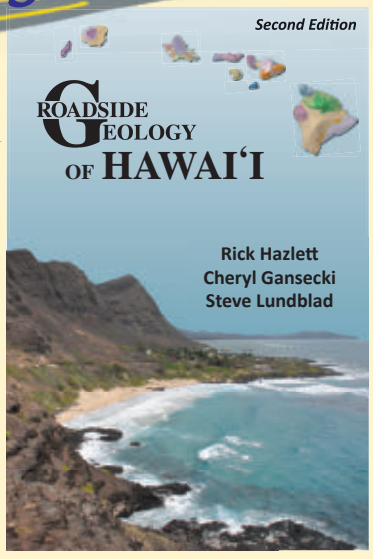

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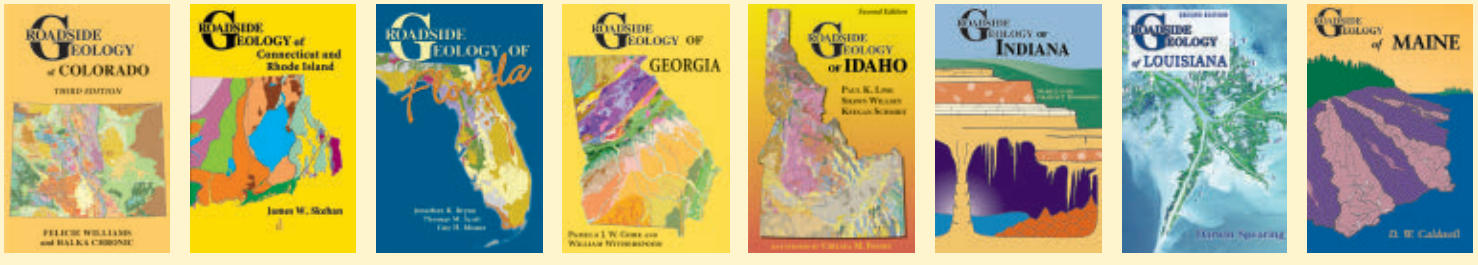

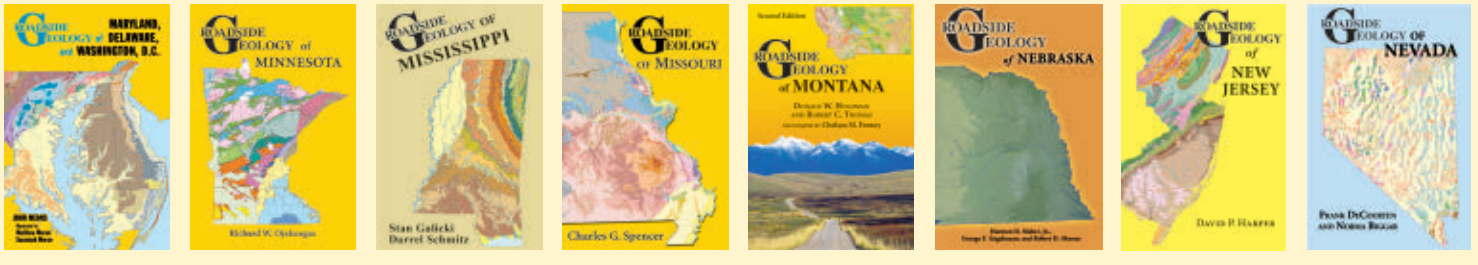

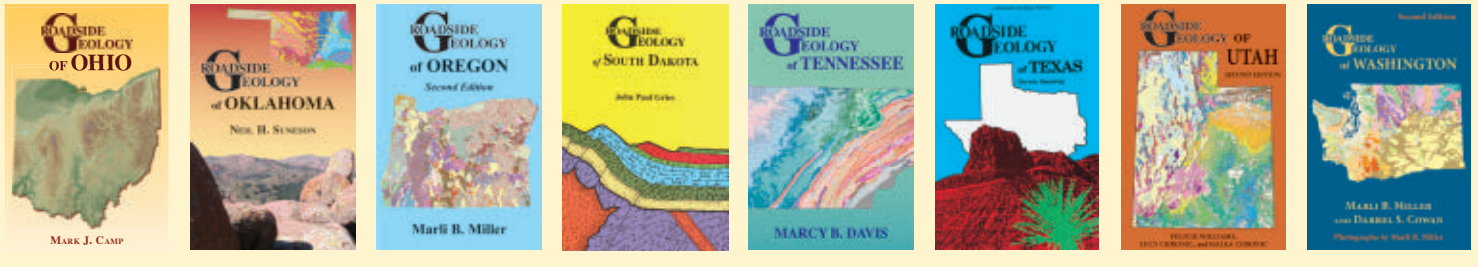

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