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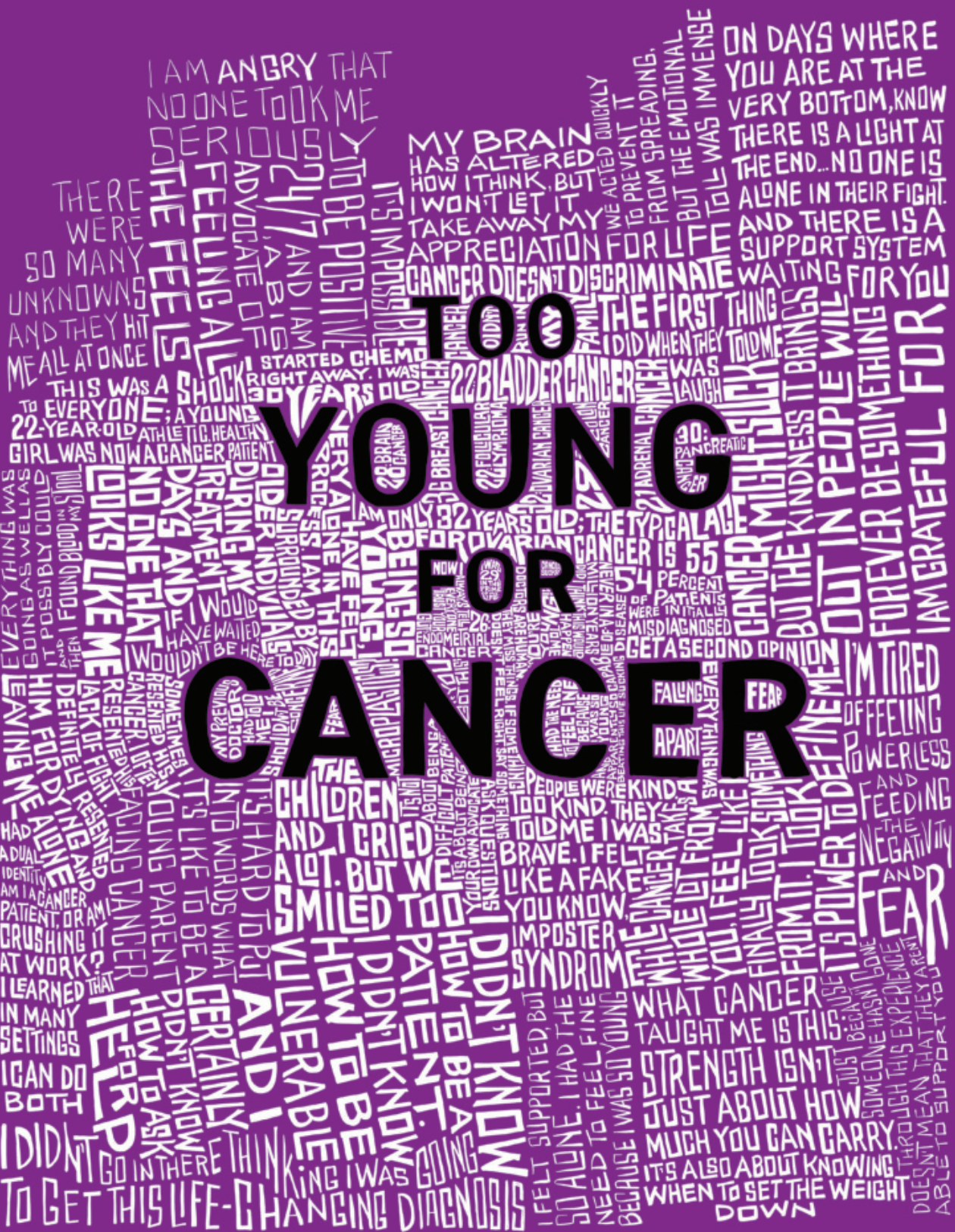

Thermo Fisher Scientific
Junior Innovators Challenge | A program of Society for Science

CONGRATULATIONS to our TOP 300 Junior Innovators

Thermo Fisher Scientific salutes the nearly 2,000 competitors who entered the 2025 Thermo Fisher JIC. Congratulations to our Top 300 Junior Innovators and good luck to the 30 who will join us as finalists in Washington, D.C. this October!

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About Thermo Fisher JIC

The Thermo Fisher Scientific Junior Innovators Challenge, a program of Society for Science, is the nation's premier science and engineering research competition in the United States, created to inspire sixth, seventh and eighth grade students to pursue their personal passion for STEM subjects into high school and beyond.

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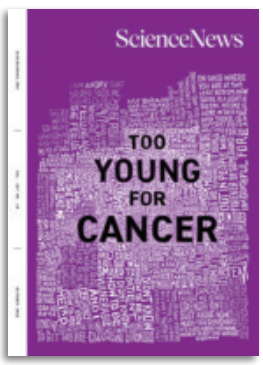

On the Cover

Illustration by John Mavroudis

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FROM TOP: HARVARD PLATE STACKS/CENTER FOR ASTROPHYSICS | HARVARD & SMITHSONIAN; OLLIE HIRST

Features

Curiosities

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When cancer targets the young

Cancer is usually a curse of time. In the United States, the vast majority of cancer diagnoses are in people over age 50. Our bodies' cells accumulate DNA damage over time, and older immune systems are not as good at making repairs. At the same time, decades of interaction with sunlight, tobacco products, alcohol, carcinogenic chemicals and other risk factors also take their toll.

But in recent years, cancer has been increasingly attacking younger adults. Global incidence rates of several types of cancer are rising in people in their 20s, 30s and 40s, many with no family history of the disease. Scientists don't know why diagnoses are soaring in people under age 50, and they are racing to find out. But as freelance journalist Fred Schwaller reports in this issue, identifying how risk factors like diet or environmental exposures could be at fault is notoriously difficult because there are so many potential influences at play (Page 38).

For one, cancers in young adults may advance much more quickly than they do in older people, belying the assumption that healthy young bodies would excel at eradicating malignant cells.

What's more, cancer screening recommendations in many countries aren't currently designed to detect the disease in younger people. Young adult patients often say their concerns that something wasn't right are dismissed by doctors who say they are "too young to have cancer," even when they repeatedly voice their concerns. And that can lead to delayed diagnosis and treatment.

In this issue, we also explore a glimmer of hope for people who get cancer as very young children. Harsh treatments like radiation and chemotherapy can damage immature egg cells and cells that make sperm, making it impossible for some people who had cancer in childhood to have biological children. Teenage and adult patients may be able to freeze eggs or sperm, but children who haven't gone through puberty don't have those options. Senior writer Meghan Rosen reports on emerging research intended to help make that possible, including a conversation with the first childhood cancer survivor to have testicular stem cells transplanted back into his body (Page 46).

Parents of children with cancer are increasingly considering these options for both boys and girls. And while scientists say the work is still in its infancy, they hope more childhood cancer survivors will one day have the option to thrive as parents.

Nancy Shute
Editor in Chief
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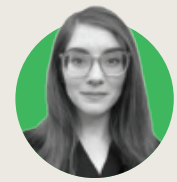
FRED SCHWALLER

FREELANCE JOURNALIST

● CANCER DIAGNOSES in people younger than 50 years old are on the rise globally. But why? In this issue's cover story, Fred Schwaller investigates the potential drivers of the surge, explains how these cancers can be more aggressive and lays out what to do when a young person suspects cancer (Page 38). Schwaller, who's in his 30s, says he "never took the idea of getting cancer seriously" before speaking with cancer survivors and researchers. Reporting the story made him more aware of the various warning signs and how to self-screen for potential illness. "The best advice I heard from cancer survivors was know your body," he says. Young people can reduce the risks of getting cancer by maintaining a healthy diet, exercising and receiving the HPV vaccine. Now, he says, "I feel well-armed to push my case with doctors if anything serious does pop up."

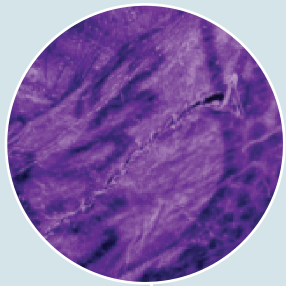


Meghan Rosen
Childhood cancer research and treatments have been advancing steadily. This positive trend has allowed researchers to think more about survivors' futures and quality of life, including preserving their ability to have children (Page 46). To understand the state of the field and what it means to everyone involved, senior writer Meghan Rosen spoke with a childhood cancer survivor and a survivor's parent. "Their stories could offer hope to other parents whose children have been diagnosed with cancer — to know that there may be options for preserving their children's fertility," she says.

Matthew Hutson
With the advancement of artificial intelligence, some people worry that it will develop into a sentient being full of emotions. In this issue, freelance journalist Matthew Hutson reports on a study investigating if AI can "feel" guilt (Page 14). "The guilt in the AI agents is much different from the guilt we feel, so for now we don't need to worry about imposing anguish on them," Hutson says. "But it shows that future AIs might have something closer to human emotions, with or without consciousness." Fear not, though, Hutson says, as this means the AIs might become more predictable and follow human values.

Erin Garcia de Jesús
As a *Science News* staff writer who often covers biomedicine, Erin Garcia de Jesús has reported on a number of out-of-the-box vaccine delivery methods. But now, she writes about a truly unique approach: providing immunization to mice via dental floss (Page 22). Garcia de Jesús, a trained microbiologist, has never done anything as wild as flossing mice teeth. But she once delivered RNA into live mosquitoes by blowing liquid samples into their bodies. Called mouth-pipetting, this method is an antiquated technique that "every chemistry safety class tells you not to do," says Garcia de Jesús, "but we were doing it with genetic material, so it was fine."

CLOCKWISE FROM TOP LEFT: FRANZISKA POTHOU; SOCIETY FOR SCIENCE; M. HUTSON; SOCIETY FOR SCIENCE



FADED MEANING
Infrared images show burial cuts stitched across the woman's tattoos — signs they weren't central to funeral rites. Once she died, the elaborate ink may have lost its meaning to those preparing her body.

CAT TATS
The right forearm ink depicts two striped tigers and a spotted leopard interlocked with two stags. A modern artist has filled in some of the faded details in this reconstruction.

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BATTLING BEASTS The left forearm sports a tattoo (partially reconstructed) of what looks to be a griffinlike creature attacking a hooved, antlered animal. The rough execution suggests a novice artist.

HANDY ART The woman's hands bear simple, striking tattoos (reconstructions shown): a proud rooster, a cross and a fishlike ornament on the left hand, a floral design on the right.

ARCHAEOLOGY

THIS ANCIENT SIBERIAN ICE MUMMY HAD A TALENTED TATTOOIST

By Celina Zhao

● Some tattoos do age well. More than two millennia ago, a woman sat for inking sessions that left her with sick sleeves — arms etched with scenes of prowling tigers, lanky stags and even a griffinlike creature, researchers report in *Antiquity*.

Differences in style suggest either two tattoo artists — one skilled, the other still learning — or the early and late stages of a single artist's career, the scientists say.

Skin decays rapidly, but Siberian permafrost preserved several bodies from the Pazyryk culture, nomadic horse riders of the Eurasian steppes. This inked woman, who died at 50 and is shown in a 3-D model, was among them.

Invisible to the naked eye, the tattoos were revealed with infrared photography. Probably made using several pointed instruments, the ancient tats are "a fascinating look into the past of a talented practitioner," says study coauthor Gino Caspari of the Max Planck Institute of Geoanthropology in Jena, Germany, "and a great addition to the prehistory of a craft that is important for people around the world today."

MODEL: M. VAVULIN, SKETCHES: D. RIDAY


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This bronze military diploma discharged warship sailors in ancient Rome. A new AI tool may help historians study such fragmented texts (see Page 19).

News

HUMANS

A child's biological sex may not always be a 50–50 chance

By Jake Buehler

● Some people may be predisposed to having children of just one sex.

The chances of having a male or female child across whole populations may resemble a coin flip. But for many individuals — especially those who have their first child later in life — the odds might be skewed toward one outcome, researchers report in *Science Advances*.

The probability of conceiving and birthing a male or female child is theoretically about 50–50. This is because, at least initially, equal proportions of sperm cells carry X and Y sex chromosomes. These chromosomes are a major — though certainly not the only — factor determining sexual development in humans.

↑ **Having multiple children of the same biological sex, as shown in this family, may be linked to a person's maternal age being higher when they first start having children.**

But reproductive epidemiologist Jorge Chavarro and his colleagues were interested in the frequent cases of people having multiple children of a single sex.

The team compiled data on the pregnancies and births of over 58,000 people from 1956 to 2015. The data came from the Nurses' Health Study, an ongoing series of epidemiological studies analyzing hundreds of thousands of

JACKSON GIBBS

pregnancies and births since the mid-20th century. Around a third of families had siblings all of the same sex. Of those, more than expected had three, four or five kids — assuming a standard coin flip probability of male or female children.

Each individual family may have a "unique probability" of having babies of a specific sex, says Chavarro, of the Harvard T.H. Chan School of Public Health in Boston. However, that probability varies from family to family across the whole population, he says. So it mostly balances out to a 50–50 chance at that larger scale.

Families susceptible to birthing one sex may continue having children until they eventually have a child of the other sex. Some families may also cease having children after two if they have a male and a female. But when the analyses accounted for this, the team still found clustering of sexes within families, particularly for people who were older at the birth of their first child.

Higher maternal age may increase the likelihood of single-sex sibling sets due to biological factors related to reproductive aging. For example, the vaginal environment may become a bit more acidic with age during the reproductive years. And that may favor sperm carrying an X chromosome, the team says. X sperm are slightly larger than Y sperm and may have more buffering chemicals for surviving the acidic surroundings.

Another factor could be the fact that the length of the menstrual cycle phase that prepares an egg for release from the ovary shortens over time. That may create conditions in the cervical mucus or oviduct fluid that favor the survival of sperm carrying a Y chromosome.

The ultimate impact on the skew toward one sex or another may vary depending on what biological factors are most dominant for that individual as they age.

Chavarro and his colleagues also analyzed genetic data from a subset of study participants and found two gene variants associated with having children of just one sex — one for all male and one for all female. These gene variants aren't known to be associated with reproductive traits, so their influence remains mysterious for now.

Nicola Barban, a demographer at the University of Bologna in Italy, says the study provides valuable insights, but more work is needed. "This research underscores that investigating biological factors alone is insufficient to fully explain reproductive patterns."

But Brendan Zietsch, a behavioral geneticist at the University of Queensland in Brisbane, Australia, isn't convinced by the findings of skewed sex ratios. "We previously showed in a much larger sample, comprising the entire Swedish population born after 1931, that there is no tendency for individual families to have [just] boys or girls."

Zietsch says studies claiming genetic associations with offspring sex ratios need replication in another sample. Chavarro would also like to see this approach replicated in another population. Ninety-five percent of the study's participants were white and predominantly from the United States. Paternal information could also be crucial; it's possible the partner's paternal age is causing the skew and not maternal age, since partners tend to be fairly close in age.

The study is the "first draft of biological explanation," Chavarro says, with many avenues ready to explore. ✖

61 percent

The probability of having another boy in families with three boys

58 percent

The probability of having another girl in families with three girls

ARTIFICIAL INTELLIGENCE

Can AI ‘feel’ guilt?

By Matthew Hutson

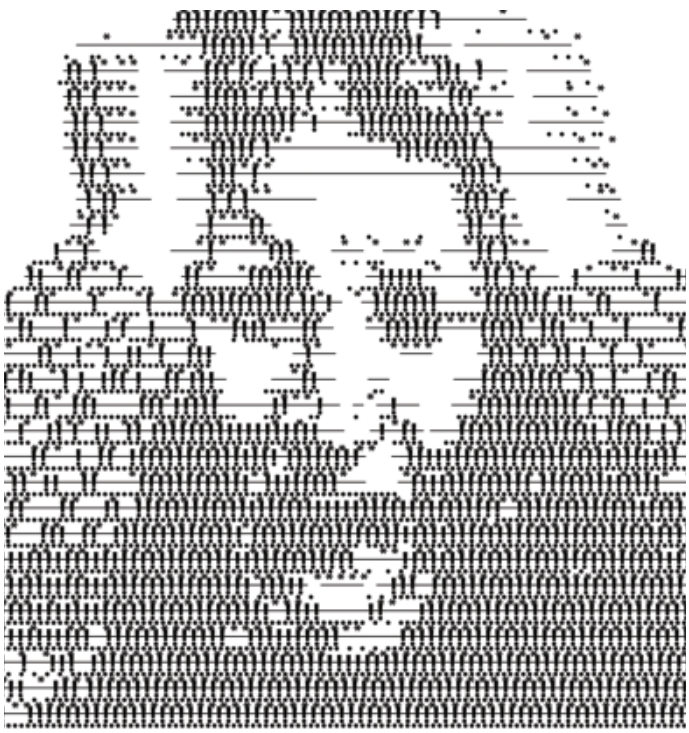
● **Some sci-fi scenarios depict robots** as cold-hearted clankers eager to manipulate human stooges. But that’s not the only possible path for artificial intelligence.

Humans have evolved emotions like anger, sadness and gratitude to help us think, interact and build mutual trust. Advanced AI might do the same. In populations of simple software agents (like characters in “The Sims” but much, much simpler), having “guilt” can be a stable strategy that benefits them and increases cooperation, researchers report in *Journal of the Royal Society Interface*.

Emotions are not just subjective feelings but bundles of cognitive biases, physiological responses and behavioral tendencies. When we harm someone, we often feel compelled to pay a penance, perhaps as a signal to others that we won’t offend again. This drive for self-punishment can be called guilt, and it’s how the researchers programmed it into their agents. The question was whether those that had it would be outcompeted by those that didn’t, say Theodor Cimpeanu, a computer scientist at the University of Stirling in Scotland, and colleagues.

The agents played a two-player game with their neighbors called the iterated prisoner’s dilemma. The game has roots in game theory, a mathematical framework for analyzing multiple decision makers’ choices based on their preferences and individual strategies. On each turn, each player “cooperates” (plays nice) or “defects” (acts selfishly). In the short term, you win the most points by defecting. But that tends to make your partner start defecting, so everyone is better off cooperating in the long run. The AI agents couldn’t feel guilt as humans do, but experienced it as a penalty that nudged them to cooperate after selfish behavior.

The researchers ran several simulations with different settings and social network structures. In each, the 900 players were each assigned one of six strategies defining their tendency to defect and to feel and respond to guilt. In one strategy, nicknamed DGCS for technical reasons, the agent was made to “feel” guilty after defecting by having to give up points until it cooperated again. Critically, the AI agent lost points only if it received information that its partner was also paying a guilt price after defecting. This prevented the agent from giving in when its partner behaved selfishly, thus enforcing cooperation in others. (In the real world, seeing guilt in others can be tricky, but sincere apologies are a good sign.)



← **Research based on game theory suggests if we program artificial intelligence agents with a sense of guilt, they could behave more cooperatively, much like humans do.**

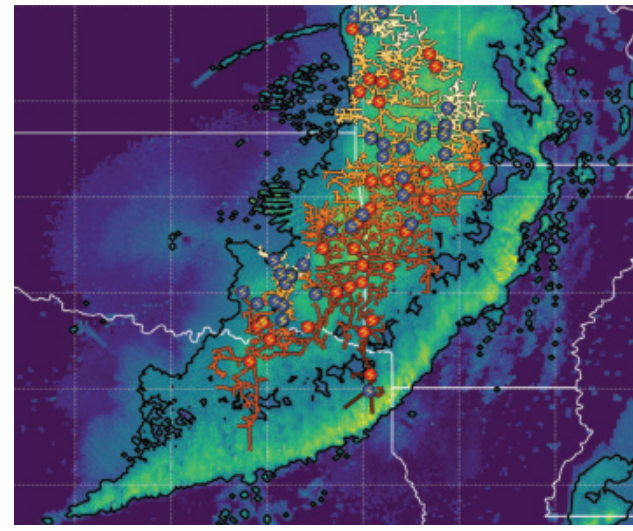
MELVIN GALAPON

The simulations didn't model how guiltlike behavior might first emerge — only whether it could survive and spread once introduced. After each turn, agents could copy a neighbor's strategy, with a probability of imitation based on neighbors' cumulative score. In many scenarios — particularly when guilt was relatively low-cost and agents interacted with only their neighbors — DGCS became the dominant strategy, and most interactions became cooperative, the researchers found.

We may want to program such pro-social responses into AIs. "Maybe it's easier to trust when you have a feeling that the agent also thinks in the same way that you think," Cimpeanu says. We may also witness emotions — at least the functional aspects, even if not the conscious ones — emerge on their own in groups of AIs if they can mutate or self-program, he says.

But there are caveats, says Sarita Rosenstock, a philosopher at the University of Melbourne in Australia who was not involved in the work but has used game theory to study guilt's evolution in humans. First, simulations embody many assumptions, so one can't draw strong conclusions from a single study. But this paper contributes "an exploration of the possibility space," highlighting areas where guilt is and is not sustainable, she says.

Second, it's hard to map simulations like these to the real world. What counts as a verifiable cost for an AI, besides paying actual money from a coffer? If you talk to a present-day chatbot, Rosenstock says, "it's basically free for it to say I'm sorry." With no transparency into its innards, an AI might feign remorse, only to trespass again. ✖



MICHAEL PETERSON/GTRI

↗ This composite image includes data from 160 National Weather Service radars that scanned the skies at multiple elevations to detect lightning in October 2017.

CLIMATE

A MIDWEST 'MEGAFLASH' IS THE LONGEST LIGHTNING ON RECORD

BY CAROLYN GRAMLING

A massive bolt of lightning that lit up the sky from Dallas to Kansas City, Mo., on October 22, 2017 is officially the longest single flash ever recorded.

A reanalysis of satellite data collected during the storm revealed that this megaflash spanned 829 kilometers and lasted 7.39 seconds, says Michael Peterson, an applied physicist at Georgia Tech in Atlanta. A study describing the event was published in the *Bulletin of the American Meteorological Society*.

Megaflashes are relatively rare, happening in only about 1 in 1,000 thunderstorms across the Americas. But any given one can pack a punch, Peterson says. They're long, complex discharges of electricity that don't just shunt energy from cloud to cloud, but from cloud to ground as well. While typical lightning strikes the ground for mere microseconds, these massive bolts do so for up to 100 milliseconds, potentially infusing that intense energy into a tree or other target. That can also make them powerful triggers for wildfires.

The 2017 cloud-to-cloud record-breaker spawned from a massive thunderstorm system that swept the CONT. ON PAGE 16

CONT. FROM PAGE 15 central United States. It sparked at least 116 cloud-to-ground spikes along its length.

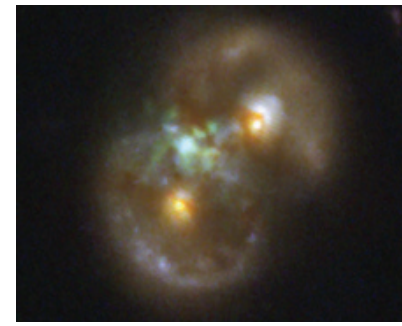
Megaflash hot spots include the U.S. Midwest and southeastern South America. The previous record-holder spanned 768 kilometers across parts of the southern U.S. and the Gulf of Mexico in 2020. A 709-kilometer-long bolt over parts of Brazil and Argentina still holds the record for longest duration, at 17 seconds.

Researchers hope that satellites in geostationary orbit watching such hot spots will help uncover why these flashes occur.

"They have the same ingredients as ordinary lightning, but with a twist," Peterson says. The convective heart of thunderstorms can contain many rain and ice particles, which are sent aloft to different heights due to updrafts. Each particle can carry a charge, and when they collide, the charge transfers, forming lightning.

There's a limit to how high these particles can rise: Thunderstorm cells don't tend to kick them up higher than 11 kilometers, the upper boundary of Earth's troposphere, or lowest atmospheric layer. "When they can't go up anymore, they go out," creating the potential for an epic flash, Peterson says. "There are these massive, horizontally large, charged layers that are vertically as thin as a sheet of paper. And these layers are key ingredients for megaflashes."

Understanding how giant bolts of lightning form is an active area of research, he adds. "A single strike can potentially impact a lot of people. It's the most impactful kind of lightning we have on Earth," Peterson says. "It's the kind of lightning we want to get a good handle on to keep people safe." ✖



ASTRONOMY

Two colliding galaxies may have birthed this black hole

By McKenzie Prillaman

● **A supermassive black hole** may have emerged from the wreckage of an epic galactic smashup, researchers report in *Astrophysical Journal Letters*. Astronomer Pieter van Dokkum of Yale University and colleagues spotted an odd galaxy in data from the James Webb Space Telescope. The object resembles two slightly overlapping rings with dots at the center of each, inspiring the name Infinity galaxy and suggesting it was once two separate galaxies that collided.

Observations from other telescopes revealed signs of an actively growing black hole with the mass of 1 million suns. The team expected to find black holes in the dots within the rings, which were the centers of the previous two galaxies. But surprisingly, the black hole turned out to be in the region in between the two dots.

The team suspects that the black hole was born from a messy galactic meetup. As the galaxies encountered one another, their gases slammed together, creating a big, dense clump that became a black hole instead of several smaller clumps that typically form stars.

Researchers aren't sure how supermassive black holes form. They may come from smaller black holes merging over time. A more controversial idea suggests that these giants form in one go from singular gas clouds following dramatic events.

That may be what happened in the Infinity galaxy, van Dokkum says. Computer simulations could verify if that scenario is possible. ✖

↑ **An active supermassive black hole (central light blue dot) may have been born from a galactic collision.**

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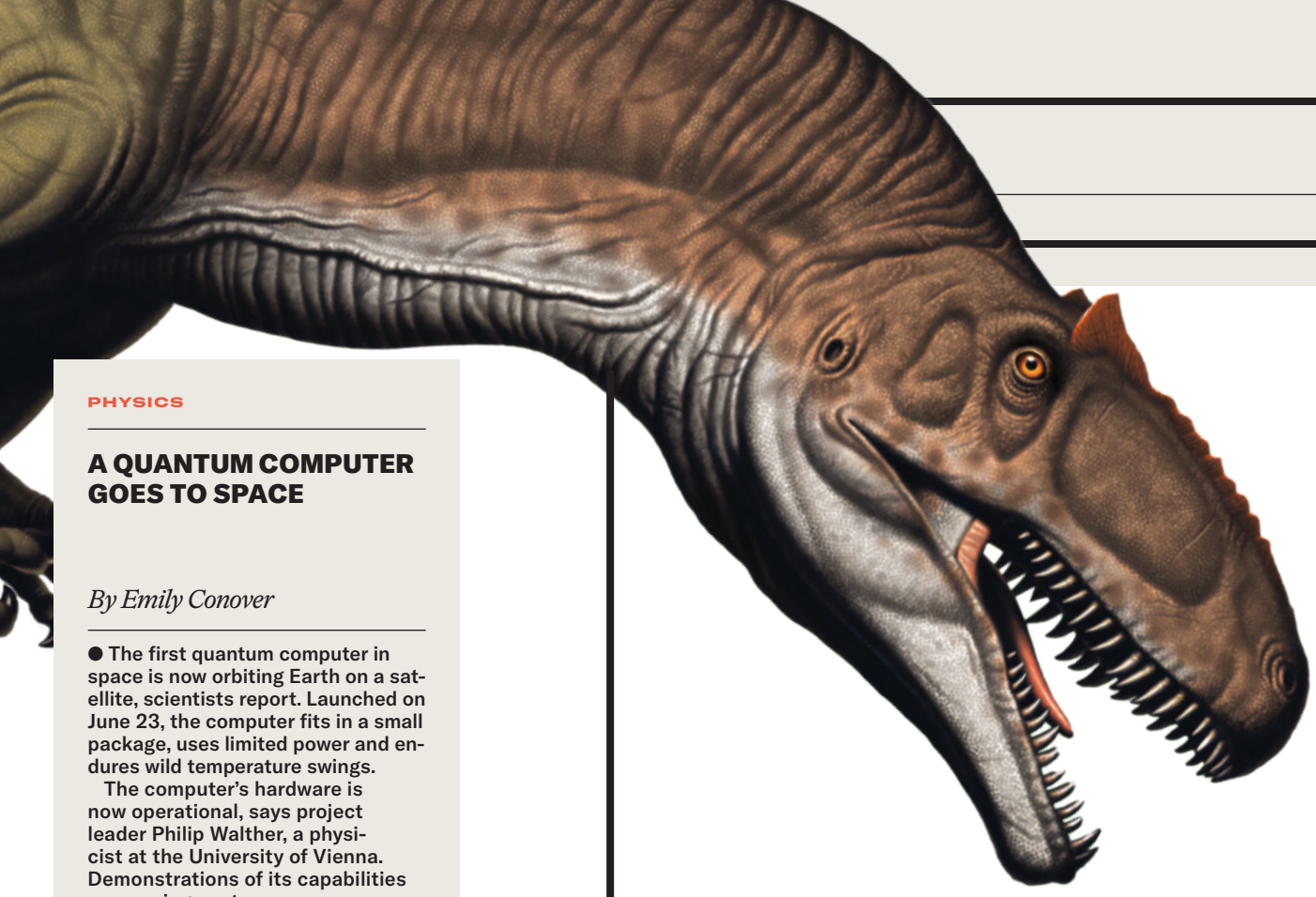

PHYSICS

A QUANTUM COMPUTER GOES TO SPACE

By Emily Conover

● The first quantum computer in space is now orbiting Earth on a satellite, scientists report. Launched on June 23, the computer fits in a small package, uses limited power and endures wild temperature swings.

The computer's hardware is now operational, says project leader Philip Walther, a physicist at the University of Vienna. Demonstrations of its capabilities are coming next.

Satellites often contain onboard computers that perform various calculations. For example, a satellite might process and enhance images on the fly. But energy is at a premium on satellites. Quantum computers could be useful if they can perform calculations more efficiently than standard computers.

The new device is a photonic quantum computer, meaning it calculates using particles of light called photons. Such computers are typically built in highly controlled laboratory conditions and sprawl across tables that are meters long, using energy-hungry lasers and electronics. The new quantum computer fills a volume of just 3 liters and uses only about 10 watts of power — similar to a typical LED light bulb.

Scientists have previously deployed satellites designed for quantum communication. Those satellites can transmit and receive photons to enable ultrasecure messaging across large distances. In the future, such quantum communication networks may also demand quantum computers in orbit, Walther says.

Space-based quantum computers could also allow tests of fundamental physics principles in a new environment, Walther says. "Being the first here also means we have the duty and privilege to investigate if things operate in the way as we'd be used to on the ground." ✖

PALEONTOLOGY

Dinosaur teeth reveal some picky eaters

By Tom Metcalfe

● **Some dinosaurs were fussy eaters.** Certain herbivorous dinosaurs preferred specific parts of plants, challenging long-standing assumptions about their diets, a study of fossilized dino teeth shows. The analysis of calcium isotopes in 150-million-year-old tooth enamel reveals that diet may have depended less on the size of dinosaurs and more on the nutritional value and texture of their food, researchers report in *Palaeogeography, Palaeoclimatology, Palaeoecology*.

"My big takeaway is that the herbivores had different diets, and it is likely that the parts of a plant that these animals eat [were] a more significant driver than height," says Liam Norris, a paleontologist at the Texas Science & Natural History Museum in Austin. "If they are eating softer parts like leaves versus eating twigs or maybe bark," preference may have outweighed convenience, he says.

Norris and colleagues compared calcium isotope levels in dinosaur enamel with the levels in enamel from modern herbivores. The team found that the towering sauropod *Camarasaurus* — from the Late Jurassic period, between about 164 million and 145 million years ago, long thought to feed primarily from treetops — ate more woody plants

BOB WALTERS AND TESS KISSINGER, NATIONAL PARK SERVICE

← An analysis of tooth enamel from dinosaurs that roamed the western United States about 150 million years ago, including *Allosaurus* (left), suggests that different species ate varied parts of plants or animals to coexist.

and twigs than expected. But the smaller *Camptosaurus* preferred softer plant parts such as leaves and buds.

This finding goes against common wisdom that large dinosaurs had the pick of what they ate.

Norris' team also measured calcium isotope levels in the teeth of two meat eaters and compared them with modern carnivorous animals. The results suggest that the crocodile-like *Eutretauranosuchus* ate mostly fish, and the fierce theropod *Allosaurus* dined mostly on the flesh of other dinosaurs — but not as much on their bones, as did the later theropod *Tyrannosaurus rex*, which lived between 68 million and 66 million years ago.

The researchers used samples from the Carnegie Quarry, a famous fossil site in Utah's Dinosaur National Monument. Some of the teeth had already been removed and classified by earlier researchers, but others Norris and colleagues sampled directly from the quarry wall itself.

"People have been looking at dinosaur teeth for many decades, and this is a nice new method for looking at the same kind of problem," says dinosaur expert Paul Barrett of the Natural History Museum in London, who was not involved in the study. The study establishes the measurement of calcium isotopes in dinosaur tooth enamel as a valid scientific inquiry. "This is nice confirmation that these kinds of chemical signatures are preserved in the teeth for so long." ✖

ARCHAEOLOGY

AI REVEALS SUBTLE CLUES IN FAMOUS ROMAN TEXT

BY TOM METCALFE

An artificial intelligence system has revealed fresh details about one of the most famous Latin inscriptions: the *Res Gestae Divi Augusti*, once inscribed on two bronze pillars in Rome and in copies throughout the Roman Empire.

Researchers used an AI system called Aeneas to analyze the supposedly autobiographical inscription, which translates to "Deeds of the Divine Augustus." When compared with other Latin texts, the RGDA inscription, as it is known, shares subtle language parallels with Roman legal documents and reflects "imperial political discourse," or messaging focused on maintaining imperial power — an insight not previously noted by human historians, researchers report in *Nature*.

Aeneas uses a software structure known as a generative neural network to search for parallels of a text within a unique database of Latin inscriptions. The system helps human experts "interpret, attribute and restore fragmentary Latin texts" using a combination of textual and visual analysis, says study coauthor Thea Sommerschield, a historian at the University of Nottingham in England.

The study found that epigraphers — historians who study inscriptions — were significantly more accurate and faster when using the Aeneas system to help with key tasks, such as determining the likely age and location of an inscription.

In the case of the *Res Gestae Divi Augusti*, Aeneas identified similarities between the inscription and other Roman texts written between 10 B.C. and 1 B.C., as well as inscriptions written between A.D. 10 and A.D. 20 — around the time of the Roman Emperor Augustus' death in A.D. 14.

This pattern of two likely date ranges reflects disagreements among human experts about when the RGDA inscription was composed, Sommerschield says. "The way that it has modeled this scholarly debate was really an exciting result for us."

Historians Jackie Baines and Edward Ross, both at the University of Reading in England, say in an email that AI systems such as Aeneas are invaluable for freeing up human experts' time. AI "allows researchers to spend ... more time drawing connections across the ancient world." ✖

PLANTS

Potatoes have their roots in ancient tomatoes

By Javier Barbuzano

● **The potato came from a surprising mashup.**

The starchy vegetable emerged around 9 million years ago in the Andes mountains — a result of natural interbreeding between an ancient tomato plant and potato-like species. This ancient cross gave rise to tubers, the underground buds that can produce new plants, which were inherited across the entire potato lineage, researchers report in *Cell*.

The cultivated potato (*Solanum tuberosum*) is one of the world's most important staple crops. To peel away the mystery of the potato's origin, botanist Sandra Knapp and colleagues analyzed the genomes of dozens of cultivated potato varieties and their wild relatives. Scientists knew cultivated potatoes were related to South American tuberless plants called *Solanum etuberosum*, which physically resemble potato plants but can't form tubers. Genetics show that potatoes are also related to tomatoes. But scientists thought the plants were like cousins.

Instead, every potato species possessed a mixed genetic composition, with about half of its genetic information from the tomato lineage and half from the tuberless potato lineage. This consistent signature suggests potatoes originated as a single hybrid crossing between these two groups, says Knapp, of the Natural History Museum in London.

A gene called *SP6A*, a master switch for tuber initiation, came from the tomato side. Another gene called *IT1*, essential for the growth of the underground stems that form tubers, came from *S. etuberosum*. Experiments confirmed that without the *IT1* gene, tubers were extremely small. Without the *SP6A* gene, no tubers formed at all.

"How the conjunction of these genes led to [potato plants] making potatoes isn't fully explained in this paper," says plant biologist Salomé Prat at the Centre for Research in Agricultural Genomics in Barcelona, who was not involved in the new work. Just showing that these genes were inherited after the hybridization might not be enough to show that tubers appeared right away.

Even so, the capacity to form new, complex organs after hybridization shows that hybrid speciation is a powerful driver for evolution. New hybrids are often sterile due to genetic incompatibilities. But the tubers, which store water and nutrients, can sprout new plants from the ground if left buried, no pollination or seeds needed. That can buy time to re-evolve sexual reproduction.

Most of the wild potato species that emerged as the Andes grew are inedible. But thousands of years ago, the Indigenous inhabitants of the mountains discovered a tasty, wild potato species and derived varieties from it. Spanish explorers later brought several of these varieties to Europe, leading to the potato's global spread as a staple food.

More recent human selection for traits such as high yield or pathogen resistance has inadvertently narrowed cultivated potatoes' genetic variability, making them vulnerable to extreme heat, flooding and other environmental factors.

Identifying the potato's genetic ancestors opens new avenues to make it more resilient. Scientists can now seek lost beneficial traits and reintroduce them through breeding or genetic engineering, building more robust and adaptable potato varieties, Knapp says. ✖

Scientists thought potatoes and tomatoes were cousins. Turns out they were more closely related. ↙

FROM LEFT: LIU KAIYOU/MOMENT/GETTY IMAGES; JOANNA MCCARTHY/THE IMAGE BANK/GETTY IMAGES

Urgent: Special Summer Driving Notice

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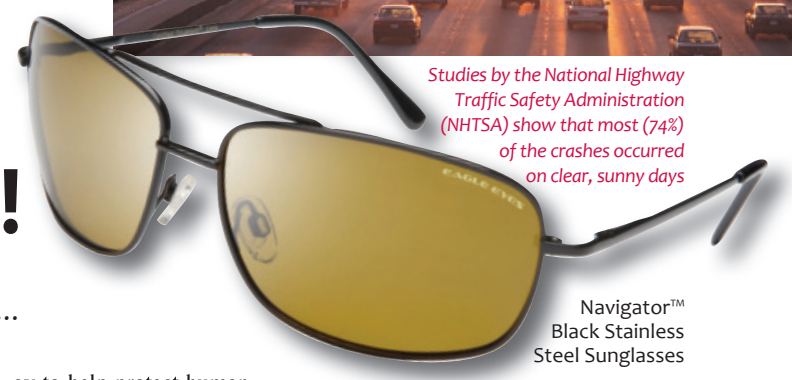

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HEALTH & MEDICINE

VACCINES COULD ONE DAY BE DELIVERED BY DENTAL FLOSS

BY ERIN GARCIA DE JESÚS

Rohan Ingrole needed to floss a mouse's teeth.

The intent wasn't to help mice get a clean bill of health at the dentist. Each bit of store-bought floss was coated with dead influenza viruses, or lab-made bits and pieces of them. Ingrole, a bioengineer at Texas Tech University in Lubbock, wanted to vaccinate the animals, giving them protection against flu through their gums.

Vaccines that target the moist tissues that line the mouth or nose aim to build up immune defenses in the parts of the body that pathogens tend to invade, says Harvinder Gill, a bioengineer at North Carolina State University in Raleigh. Influenza virus, for instance, typically enters the body through the nose before making its way toward the lungs.

Protecting mucous membranes from infectious diseases isn't always a simple task. Because these mucosal tissues come into direct contact with the air around us, as well as things like fingers that can pick up pathogens from surfaces, their cells are tightly packed to help keep pathogens out. This can also prevent vaccines targeting places like the mouth from permeating the body and prompting an immune response.

Researchers have previously designed vaccine candidates that target the mouth's leakier tissues — where cells aren't quite as close together — in the forms of cheek patches or liquid drops under the tongue. While reading a paper on dental structure, Gill learned about the junctional epithelium, a leaky collection of cells at the base of a small pocket where gums attach to teeth.

But that pocket is a tough target because it sits below the gumline. "We needed something more precise [than a drop of liquid]," Gill says. "And then we thought 'Oh, hey, we already have floss.... Why don't we just use [floss] to also deposit the vaccines into this location?"

But no one had flossed a mouse before, Ingrole says, and the peculiar task posed some challenges. As Ingrole applied gentle force to move the floss back and forth, he inadvertently tugged the animals' jaws down and the floss slipped out. Using the ring of a key chain to provide support to the mouse jaw "turned out to be a game changer."

Even with a support tool, it's a two-person job to floss a mouse. One person holds the sleeping mouse upright by the scruff of its neck. That person also pops the mouse's head through a key ring, allowing the animal's lower jaw to hang open and rest against the ring's edge. The second person then plays dental hygienist, swooping in with an influenza vaccine–coated piece of floss.

With each swipe back and forth, the floss delivers a vaccine through the gum's junctional epithelium, Ingrole, Gill and colleagues report in *Nature Biomedical Engineering*.

The team found that floss coated with four different types of vaccines sparked immune defenses in mice. Mice vaccinated against influenza were more likely to survive flu infections than unvaccinated mice, even when they had access to food and water immediately after flossing.

What's more, protection against the disease from one of the four vaccine types was similar to that from a vaccine given through the nose. But noses have a direct connection to the brain, Gill says. Safety tests of any new nasal CONT. ON PAGE 24

↖ A pair of researchers gently floss a mouse's bottom incisors, delivering a vaccine that could help protect the animal against influenza.

PAUL STONUM

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CONT. FROM PAGE 22 vaccines need to address the risk of neurological side effects. Material introduced to the gums lowers that risk because the gum-targeting vaccines aren't likely to make it to the brain.

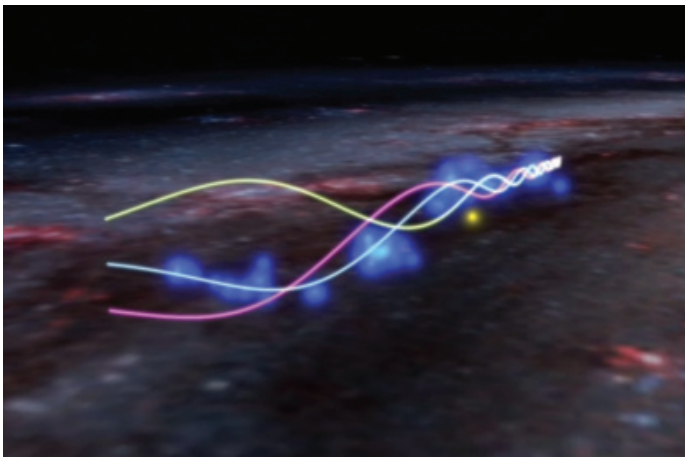
"It's very clever; I like the strategy," says Stephanie Langel, a viral immunologist at Case Western Reserve University in Cleveland who was not involved in the work. But analyses of the kinds of antibodies that the mice developed suggest that while the intranasal and floss vaccines both trigger immune defenses in the blood, the intranasal vaccine may be better than the floss vaccine at protecting mucosal linings, such as those in the nose.

That could mean that although both vaccination methods are good at preventing severe disease and death in mice, intranasal vaccines might be better at blocking transmission, Langel says.

The technology still needs some work before it makes it into people. In an early test, a one-handed floss pick coated in a vaccine-free fluorescent dye deposited roughly 60 percent of the dose into the gum pockets of 27 people. Now, Gill says, the goal is to develop new tools to make it easier to floss and ensure people get a consistent dose.

If floss vaccines prove effective, that could provide a needle-free way to vaccinate, Gill says. If people are comfortable flossing their teeth with a vaccine on their own, "it has the potential to be self-administrable."

Self-administration could be huge during a pandemic, Ingrole says. During the COVID-19 pandemic, scores of health care workers were diverted toward vaccination efforts. "Imagine if you had this vaccine that could just get delivered at your doorstep," he says. "You no longer have to go stand in line for hours." ✖



↗ The Radcliffe Wave (illustrated) is a gaseous supercloud that wiggles above and below the plane of the flat Milky Way. Astronomers have now found seven similar clouds.

RALF KONIETZKA, ALYSSA GOODMAN, WORLDWIDE TELESCOPE

ASTRONOMY

Seven superclouds sit just beyond the solar system

By McKenzie Prillaman

● **Astronomers have found** a nearby septet of superclouds. These giant strings of gas — five of which were previously unknown — sit nearly parallel to each other, and most of them undulate up and down in a wave pattern, researchers report in a paper at arXiv.org.

"We finally [know] the interstellar cloud structure near us," says independent astrophysicist Bruce Elmegreen, based in Katonah, N.Y. "It's always been hard to see what is very local" to the solar system, because structures tend to blur together with most observation techniques.

Additionally, the superclouds, which may have formed from material shed by the Milky Way's spiral arms, house most of the local stellar nurseries and probably gave rise to them. The gaseous behemoths could help researchers trace the hierarchy of structures that lead to star formation, says Elmegreen, a pioneer of supercloud research who was not involved in the study.

One of the seven is a nearby supercloud dubbed the Radcliffe Wave, reported in 2020. It comes within some 400 light-years of the solar system, and wiggles above and below the disk of the galaxy for thousands of light-years.

Building on that work, astrophysicist Lilly Kormann of the University of Vienna and colleagues examined a 3-D map of interstellar dust within some 50 million square light-years of the sun. The map was created using data from the Gaia spacecraft

and published in 2024. Within that dust, "you see by eye some large-scale structures," Kormann says. But she didn't know exactly what they were.

Kormann turned the dust map into one showing the density of hydrogen, which fills up most of the space between stars. Searching for denser regions revealed 40 small clouds whose locations and orientations hinted that some were connected. After linking them up, the team identified seven long superclouds — including the Radcliffe Wave and another previously found one called the Split — lying nearly parallel to each other along the disk of the galaxy. All but the Split zigzag up and down, showing the shape is a common feature.

The seven superclouds range in length from about 3,000 to 8,000 light-years and have masses roughly 800,000 to 3.5 million times that of the sun. They're probably even bigger than that, Kormann says, because the huge strings of gas may extend beyond the map's edges.

Moreover, most of the known nearby stellar nurseries reside within the superclouds, particularly along their central axes. The arrangement suggests that superclouds are the "mothers" of smaller, denser clouds that collapse and produce stars, says astrophysicist João Alves of the University of Vienna.

Alves, Kormann and their colleagues are still figuring out why the superclouds weave up and down, how they spur star-birthing clouds and how they regulate their average densities — which closely match one another despite variation in the amount of material packed into any given stretch. "It's just opening a lot of doors," Alves says.

Elmegreen agrees. "There's a huge picture waiting to be discovered." ✖

ASTRONOMY

THIS STAR MAY BE BETELGEUSE'S SHY BUDDY

BY MARA JOHNSON-GROH

Astronomers may have finally found a long-sought companion hidden cozied up to Betelgeuse, a bright red star in the constellation Orion. This close-orbiting small star, first postulated over a century ago, matches some predictions and adds another piece to the puzzle of the mysterious supergiant star.

New images, taken with the 8.1-meter-wide Gemini North telescope in Hawaii and published in *Astrophysical Journal Letters*, show the companion only faintly. Astronomers agree that the discovery, while exciting, is not definitive.

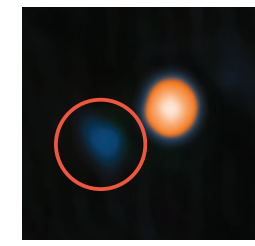
"I think at this point it's quite tough to say whether or not the detection is believable," says Sarah Blunt, an astrophysicist at the University of California, Santa Cruz who was not involved with the study. "We'll have to wait and see if the companion can be confirmed with more instruments."

The companion appears to orbit the supergiant at a distance just four times that between Earth and the sun, putting the companion within Betelgeuse's expansive outer atmosphere — a perilous spot for a small star.

"The companion will have drag in its orbit," says Steve Howell, an astronomer at NASA's Ames Research Center in Mountain View, Calif. As a result, it will be sucked into Betelgeuse within 10,000 years, Howell and colleagues found.

The companion star probably formed at the same time as Betelgeuse, nearly 10 million years ago. But the companion grew more slowly than the fast-aging supergiant because of its smaller mass (around 1.6 times that of the sun). A supergiant star paired with a small companion hasn't been seen before, Howell says, so it's impossible to say how common they are.

The next chance to observe the purported star will be in November 2027, when the companion is farthest from Betelgeuse as seen from Earth. ✖



→ New images may show a tiny companion (blue with red circle) to the supergiant star Betelgeuse (orange).

INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA; IMAGE PROCESSING: M. ZAMANI/NSF NOIRLAB

HEALTH & MEDICINE

HOW MANY STEPS A DAY DO YOU REALLY NEED TO TAKE?

BY SKYLER WARE

Walking just 7,000 steps per day may lower a person's risk of certain health issues, according to a new study.

"While the 10,000-step goal is widely known, it lacks a solid evidence base," says Borja del Pozo Cruz, a physical activity epidemiologist at Universidad Europea de Madrid. "A target around 7,000 steps is more achievable for many and still provides substantial health benefits."

To understand how walking might impact a range of health conditions, del Pozo Cruz and colleagues analyzed data from 57 studies examining the relationships between daily step count and various health outcomes. Compared with people who walked only 2,000 steps per day, those who took 7,000 steps were 47 percent less likely to die from any cause within several years, the team reports in the *Lancet Public Health*.

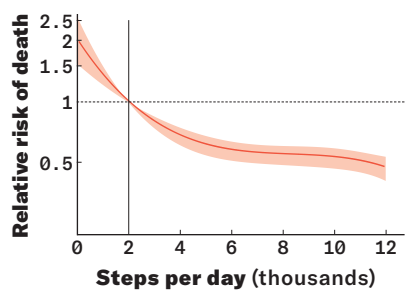
Hitting 7,000 steps was also linked with a 25 percent lower risk of cardiovascular disease, a 37 percent lower risk of dying from cancer and a 38 percent lower risk of dementia. The risk dropped further for people who walked more, but by a smaller amount.

Even a small increase in steps per day was associated with lower health risks: 4,000 steps were linked to a 36 percent lower risk of death, compared with 2,000 steps.

The study didn't capture how other factors, such as age, lifestyle or existing health conditions, might affect the recommended step count. Larger, longer-term studies could bolster the conclusions.

Still, even small changes in physical activity may boost overall health. "Every step counts," del Pozo Cruz says. ✖

WALKING FOR LONGEVITY



Walking reduced the relative risk of death in study participants; compared with a baseline of 2,000 steps per day (vertical solid line), walking 7,000 steps a day reduced death risk by 47 percent. Walking more than that provided only minor gains.

HEALTH & MEDICINE

SEEING SICK FACES MAY PRIME THE IMMUNE SYSTEM

By Simon Makin

● Our immune systems may respond to merely seeing someone who looks sick.

A study in *Nature Neuroscience* found that participants who saw sick-looking faces in virtual reality showed changes in brain activity related to personal space and threat detection.

Immunologist Camilla Jandus at the University of Geneva and colleagues had 248 participants watch humanlike faces approach in virtual reality. Some faces displayed clear signs of sickness, while others appeared fearful or neutral. Those who saw sick-looking avatars reacted faster to their face being touched, suggesting a state of high alert. Brain imaging revealed that regions responsible for monitoring personal space reacted differently to sick faces compared with neutral or fearful ones.

Most striking, blood tests revealed that participants who saw sick faces showed increased activity of innate lymphoid cells, one of the immune system's first responders.

"This is a completely new level of immune activation I wouldn't have expected ... without entry of a pathogen into the body," Jandus says. ✖

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ANIMALS

The mystery of melting sea stars may finally be solved

By Siddhant Pusdekar

● **A mysterious disease** has been turning sea stars into goo since 2013. Now, there's a leading suspect behind the killings: a bacterium called *Vibrio pectenicida*, researchers report in *Nature Ecology & Evolution*. Identifying the killer could help scientists protect both captive and wild populations of sea stars.

The disease, known as sea star wasting disease, is characterized by twisted arms, lesions and rapid death. One of the worst hit species is the sunflower sea star (*Pycnopodia helianthoides*), which lost almost 91 percent of its population — over 5 billion individuals — to repeated outbreaks in 2015, 2018 and 2023. This decline has consequences for ocean ecosystems, as sunflower sea stars are predators that keep sea urchin populations in check. In their absence, sea urchins have mowed down kelp forests, which absorb atmospheric CO_2 and support fish, otters, sea lions and other animals.

↖ This cookie sea star found near Calvert Island, British Columbia, in 2019 shows how sea star wasting disease "melts" the animal's flesh.

GRANT CALLEGARI/HAKAI INSTITUTE

Identifying a pathogen responsible for wasting brings hope for *P. helianthoides*, says Ian Hewson, a marine ecologist at Cornell University. The study may be good news for rearing sunflower sea stars in captivity, "because you can treat them with antibiotics [that] would target that specific bacteria."

In 2014, Hewson was part of a team that thought they had identified the pathogen responsible for deteriorating sea star populations. But the researchers couldn't replicate their initial findings. Without knowing the identity of the sea star killer, protecting these creatures from the disease has been challenging, even in zoos and aquariums where sea stars are bred for potential restoration in the wild.

To identify the killer, marine disease ecologist Alyssa-Lois Gehman of the Hakai Institute in British Columbia and colleagues brought healthy-looking wild and captive-bred *P. helianthoides* to the U.S. Geological Survey Station in Marrowstone, Wash., where they quarantined the sea stars for two weeks to ensure they showed no signs of wasting.

Then, the team dunked 50 sea stars in a tank where a wasting sea star had been, let them live with sick sea stars or injected them with diseased coelomic fluid, which is "essentially sea star blood," Gehman says. All methods proved fatal: 92 percent of the once-healthy sea stars died within an average of about 12 days.

Next, the team looked for what spread the disease. Like humans,

sea stars teem with bacteria, viruses and other microorganisms. The researchers analyzed the coelomic fluid of both healthy and sick sea stars for foreign genetic material.

At a team meeting in January 2024, Melanie Prentice, a marine ecologist at the Hakai Institute, presented genetic sequencing results that compared the microbial makeup of healthy and sick sea star coelomic fluid. Of the over 55,000 bacteria identified in sea star blood, one stood out — *V. pectenicida*. While some healthy sea stars also had *V. pectenicida*, it was in much smaller amounts.

To confirm the role of *V. pectenicida*, the researchers grew the bacteria in petri dishes and injected them into six healthy sea stars. Seven days later, all six were dead.

Hewson says that this was the strongest part of the study. But he is not convinced *V. pectenicida* is the smoking gun. In his previous attempts to look for a pathogen, *V. pectenicida* did not consistently turn up in wasting sea stars.

This discrepancy could be because previous studies looked for pathogens amid a hodgepodge of sea star tissues, Gehman says, while the current study focused on isolated coelomic fluid, where the contrast between healthy and sick sea stars is clearest.

Hewson disagrees. Sea stars can get sick for multiple reasons, but they "can only show us ... in so many ways," he says. Disparate observations of wasting in different sea star species could have unrelated underlying causes. Still, this work could benefit sunflower sea stars.

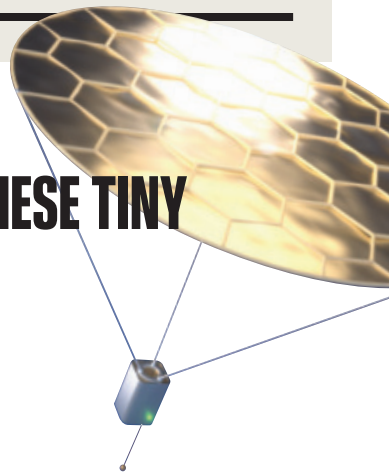
Gehman is now working on rapid diagnostic kits — like the ones used for COVID-19 — so researchers can detect and treat *V. pectenicida* outbreaks in the field and act quickly. ✖

B. C. SCHAFER *ET AL*/*NATURE* 2025

PHYSICS

SUNLIGHT KEEPS THESE TINY AIRCRAFT ALOFT

BY EMILY CONOVER



↗ Lightweight aircraft could fly in Earth's mesosphere. The devices could carry payloads (illustrated) for weather measurements or communications networks.

Earth's mesosphere is a "no-fly zone." The air in this layer of the upper atmosphere is too thin to support traditional aircraft. But new, lightweight devices could defy that rule, requiring only sunlight to keep them aloft on high.

The technology is based on photophoresis, the flow of gas generated around an object when light shines on it. This effect is particularly strong at low pressures, as in the mesosphere, which sits 50 to 85 kilometers above Earth's surface. Aircraft designed to harness this principle levitated in laboratory conditions that mimicked the mesosphere, physicist Benjamin Schafer and colleagues report in *Nature*. The technique could help scientists unlock the secrets of the mesosphere, which is so poorly understood it's known as the "ignorosphere."

The fliers are just a centimeter wide and weigh less than a milligram. Cradling one in your hand feels like holding nothing, says Schafer, of Harvard University and Rarefied Technologies, a startup in Albuquerque, N.M. developing the technology. An errant sigh could send it sailing from your palm. "If you sneeze, you might as well say goodbye."

The design consists of two thin layers of material stacked atop one another, perforated by channels that allow gas flow — like two slices of Swiss cheese. The top layer is transparent, while the bottom layer absorbs sunlight. This produces a temperature difference that sends gas streaming from the top of the device to the bottom, generating an upward force.

Similar mesosphere surfers have been studied previously, but the new devices generate the largest lift forces for their weight of any tested so far, Schafer says. The researchers estimate that a device with a 3-centimeter radius could hold a 10-milligram payload that could make simple measurements and communicate with the ground.

The devices could provide data on wind speeds, temperatures and pressures in the mesosphere. Or the craft could explore an even more challenging environment: the thin atmosphere of Mars. ✖

GENETICS

This snail may hold a secret to human eye regeneration

By Tina Hesman Saey

● **Freshwater golden apple snails** (*Pomacea canaliculata*) from South America can completely regrow a functional eye within months of having one amputated, researchers report in *Nature Communications*.

This finding is exciting because apple snails have camera-like eyes similar to those of humans. Understanding how the snails re-create or repair their eyes might lead to therapies to heal people's eye injuries or reverse diseases such as macular degeneration.

These snails are among the most invasive species in the world. That got developmental biologist Alice Accorsi thinking: Why are they so resilient and able to thrive in new environments? Accorsi, now at the University of California, Davis and colleagues at the Stowers Institute for Medical Research in Kansas City, Mo. used the molecular scissors called CRISPR/Cas9 to genetically disable certain key genes involved in eye development and established lineages of snails carrying those mutations. Those are big steps toward making snails laboratory stand-ins for studying human eye development. Developing such model organisms can take decades, but Accorsi accomplished the feat in just a few years.

When Accorsi snipped off a snail's eye, it grew back in just under a month. Humans don't regrow damaged eye parts and certainly not a whole eye. Even a transplanted eye has not yet been successfully wired to a recipient's brain.

Besides the structural similarity of human and snail eyes, both species use some of the same genes to form eyes. In particular, snails, like humans, need the *PAX6* gene to grow eyes, Accorsi found. Snails in which she disabled that gene didn't develop eyes. Other body parts developed normally, but the eyeless snails rested on their backs in the bottom of the tank and were unable to right themselves, crawl around or find food. They didn't move, even if the researchers flipped them over. But the snails grew to adulthood when the researchers hand-fed them leftover organic lettuce from the institute's salad bar. That inability to forage suggests *PAX6* may also be important for brain development.

Discovering the basis of eye regeneration in snails won't lead to immediate cures for people, says Henry Klassen, an ophthalmologist and stem cell researcher at the University of California, Irvine, who wasn't involved in the work. But knowing that it is possible to regenerate eyes can be "like a beacon of light," he says. "You can at least start asking questions like, 'Where's the hang-up? How far along the similar path do things go [in humans]?'" ✖

↑ **Golden apple snails can regrow their eyes, a trick that might one day help heal human eye injuries and diseases.**

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Nathalie Brandes • Photographs by Paul Brandes

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VOL. 207 NO. 10 | OCTOBER 2025

THE HEALTH CHECKUP

BRAINS DON'T ALL ACT THEIR AGE

BY LAURA SANDERS

Amid the petty drama of internet arguments, one never fails to entertain me: Do millennials actually look younger than their age? Sunscreen, vaping, hair parting choices and Botox for people who don't have wrinkles are used as evidence for and against this generational Dorian Graying. I can't and won't adjudicate this debate. But I can shift the conversation away from TikTok and inward to the brain.

Brain age isn't a new concept, especially for people trying to make money. For decades, people have sold books, apps, IV drips and supplements promising to keep brains spry, often with little or no scientific evidence.

But lately, scientists have been building evidence that a metric called brain age holds promise for understanding how the healthy brain ages. Even more tantalizingly, they're uncovering hints about what might affect that number.

First, a caveat: There's no single way to measure and calculate brain age. Scans of entire brains, measurements of gray matter thickness, the size of some brain structures and many other measurements have all been used to calculate brain age, often with sophisticated machine learning analyses. One attempt, published in *Nature* in 2022, examined scans of over 100,000 brains, from fetal to centenarian. Those were used to produce "essentially growth charts, similar to height and weight [curves] for babies," but instead with gray and white matter changes in the brain, says coauthor Katharine Dunlop, a cognitive neuroscientist at the University of Toronto.

Those growth charts displayed the collective ways that brains change over time; they also hint at a relationship between diseases such as Alzheimer's and advanced brain age, which can result in a gap between someone's brain age and their chronological age. On average, some brain regions shrink as we age, and research suggests these changes come earlier with Alzheimer's. Schizophrenia, depression and anxiety have also been linked to older-than-expected brain age.

"There's a lot of unexplored territory here," Dunlop says, including the details of how premature brain aging happens. Genetics, early life events, stress, inflammation and other innumerable variables may all contribute; a single measurement can't explain why a person's brain is the way it is.

"Our bodies are complex," Dunlop notes. She thinks of a brain age measurement a bit like a thermometer. The simple tool produces a single metric — temperature — that marks illness. A thermometer can't pinpoint a fever's cause, but the tool still comes in handy. The same concept holds true for brain age; a simple score could help identify who is at risk, and who might benefit from interventions early.

Those brain age interventions are not the puzzles and tricks pushed online. Instead, our brains benefit from basic healthy habits, evidence suggests: Exercise, don't smoke, eat a healthy diet and keep socially active. This stodgy but powerful advice is also reinforced by a two-year study of people at risk of dementia published this summer in *JAMA*.

Neuroscientist Laura Han of Amsterdam UMC studies people with depression, a condition linked to a larger brain age gap. Han and her colleagues found that lifestyle factors may influence brain age — for better and for worse — in people with depression. Smoking and a high body mass index were associated with an older-than-expected brain age, while education was associated with a more accurate brain age. These results were recently described in a preprint on bioRxiv.org. Han and her colleagues are now examining a structured running program's effect on depression and brain age.

For now, brain age is not a clinical tool that doctors use regularly, though they may one day. Don't let this stress you out. No matter how you part your hair, underneath it all, your brain is a powerful, adaptable and mysterious wonder. ✖

ANIMALS

THIS DESERT BEETLE RUNS TO COOL OFF

By Rohini Subrahmanyam

● The African black beetle *Onymacris plana* runs fast for its tiny size. That speed may cool the animals down. Their temperatures drop after a sprint, even in intense sunlight, researchers report in the *Journal of Experimental Biology.*

The cooling "takes them into a safety zone that guarantees their survival," says Carole Roberts, formerly a physiologist at the Gobabeb Namib Research Institute in Walvis Bay, Namibia. She and her colleagues studied the beetles nearly 40 years ago. But because no one had looked at this behavior since then, the team decided to go ahead and publish their findings.

Roberts' team inserted a device that converts temperature differences to electrical voltages into beetles' thoraxes and attached it to a fishing rod (below). After their sprints, the beetles' temperature dropped by about 1.5 degrees Celsius, the researchers found.

In the lab, the team found that under moderate temperature, no ambient wind and high radiation, the beetles cooled by almost 13 degrees, the max cooling under controlled conditions.

"How many pedestrian animals do you need to find ... to know that animals can cool by running?" Mitchell says. "Just one." ✖

ANIMALS

A dog's taste for TV may depend on its temperament

By Bethany Brookshire

● **Maybe your Pomeranian** is a little too into *The Secret Lives of Mormon Wives*. Your pit bull *says* he likes mixed martial arts, but really, he's curled up in a onesie on the couch for *The Bachelor*. Some dogs pay attention to the television, but what they get out of it may depend on the individual dog's personality, researchers report in *Scientific Reports*.

While some owners leave the TV on to keep their pooch company, comparative psychologist Jeffrey Katz wondered

ROBERT NEUBECKER

about channels devoted to content for dogs — offering soothing music, videos of dogs and other animals and even exposure to scary things like vacuum cleaners and doorbells. "I've seen them watch TVs or look at TVs. But do we really know what they're extracting from it?" asks Katz, of Auburn University in Alabama.

Dogs can see moving images on modern TVs, Katz says. "They don't see the same thing we see, but that doesn't mean it's not similar," he says. They have a faster flicker-fusion rate, which determines how quickly images need to flicker past to be perceived as continuous video. Original cathode-ray tube sets had a slow flicker-fusion frequency, which means dogs would have seen flashing still images instead of smooth film. "It's not an issue anymore," Katz says. "These new LED screens, it's fused together at a much higher resolution rate." Dogs also have dichromatic color vision — they have only two kinds of color-sensitive cone cells in their eyes, while most humans have three.

To find out how dogs might perceive TV, Katz and his colleagues sent surveys out via Facebook and email lists, receiving responses from 453 U.S. dog owners about which TV objects and sounds their dogs responded to, and whether they barked, wagged, followed or growled.

Owners reported that their pups showed at least some interest in animals on the screen, with 45 percent responding to images or sounds of other dogs. Factors such as breed group, age or sex didn't seem to matter in how dogs responded, but personality did. Owners reported that more excitable dogs tended to follow moving objects on the screen — especially animals. Study coauthor Lane Montgomery, a cognitive and behavioral scientist at Auburn, observed this behavior in her own dog, a 3-year-old Catahoula leopard dog named Jax. "He is especially a fan of dog shows," she says. Jax — and other dogs in the study — even look behind the TV to see where an offscreen object or animal "went."

More fearful dogs, however, responded negatively to sounds like doorbells or doors opening. "I think a lot of times we think, 'Oh, TV is going to be enriching,'" says Seana Dowling-Guyer, an animal behaviorist at Tufts University in North Grafton, Mass., who was not involved in the study. "But the reality is sometimes it's too much, it's overstimulating."

Dogs might also respond to TV because their owners do, she says. Reports from dog owners don't necessarily account for what the human is doing. Labradors might love to cheer on a football game just because you do.

Dowling-Guyer says that before turning on the TV, "people really should know their pets and know their personality." Maybe your schnauzer loves true crime and your collie likes *Survivor* — but a more anxious pup might benefit from peace and quiet. ✖

↖ **How dogs respond to TV may depend on their personality.**

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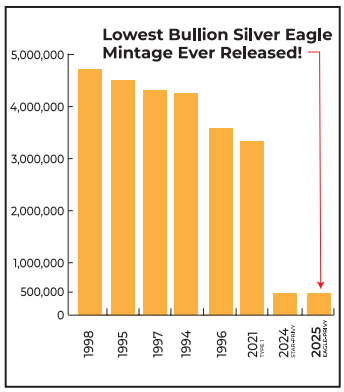

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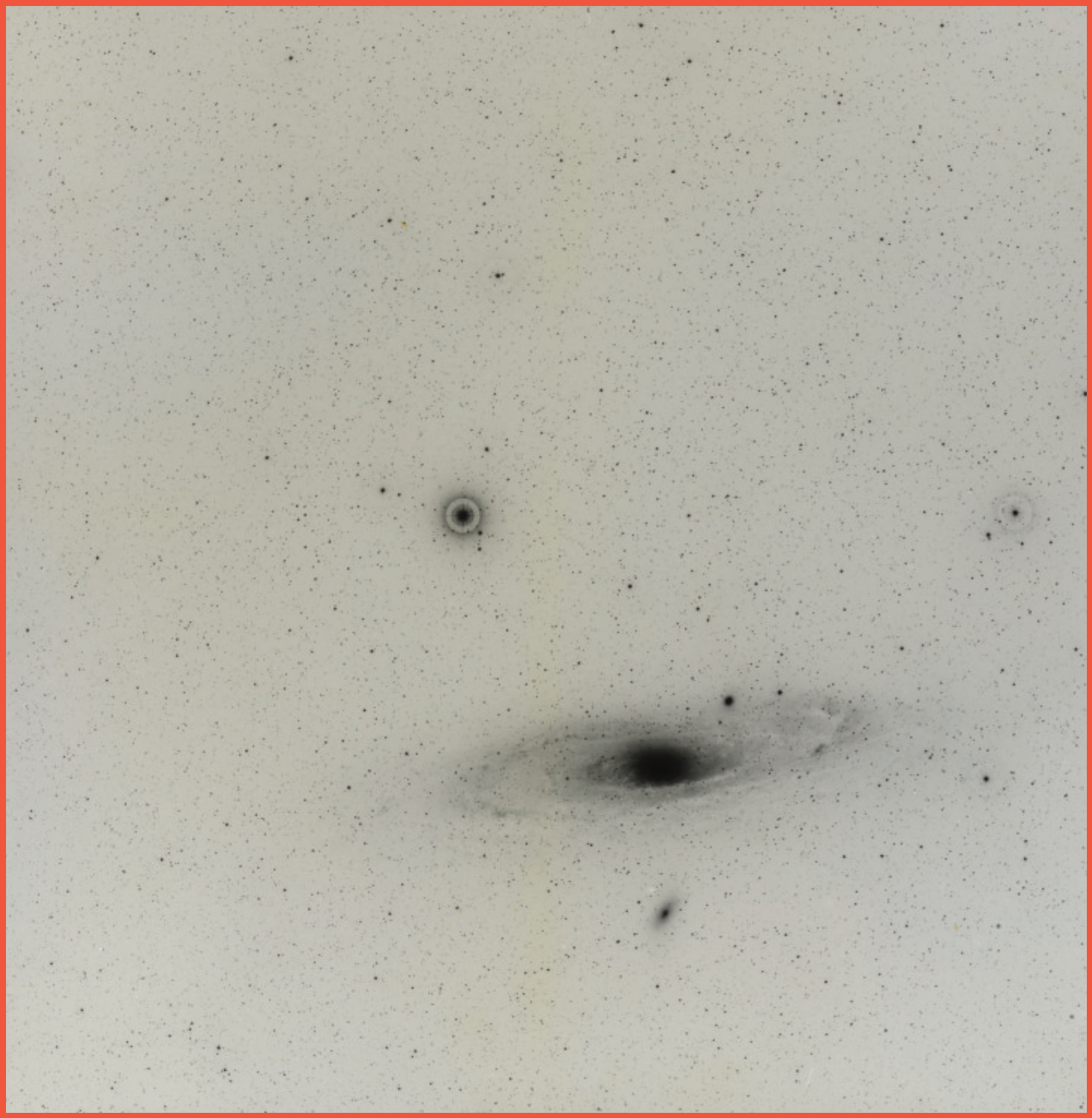

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ASTRONOMY

CAPTURING THE COSMOS IN GLASS

● Until the mid-1800s, the only way for astronomers to depict their observations was to draw what they saw. But advancements in photography allowed observers to better record images of the sky. One method was to use glass plates coated with light-sensitive materials. Skywatchers would place the plates under a telescope. Then they would wait while photons that had flown light-years slithered through the telescope and left their marks. These plates, including this 1945 one of the Andromeda galaxy, aided many discoveries (see Page 52). — *Karen Kwon*

Why are so many young people getting cancer?

Diagnoses before age 50 have been increasing rapidly. Scientists don't know why, but they have a few suspects

By Fred Schwaller

Ryan Decembrino knew something was seriously wrong.

When he began experiencing constant abdominal pain five years ago, the 29-year-old in Philadelphia went to the doctor. At that doctor's insistence, Decembrino underwent a colonoscopy, which found a dozen polyps, but the other doctor who oversaw the scan "wasn't very concerned because cancer didn't run in my family," Decembrino recalls. He was due to come back in three years for a follow-up.

But two years later, the pain got so severe he insisted the doctors take it seriously. A colonoscopy found a tumor in his colon. He went in for surgery and chemotherapy right away. "If I would have waited until my three-year follow-up, I wouldn't be here today," he says.

Now, Decembrino advocates for cancer awareness. "We have to get the word out," he says. "Cancer can happen to anyone."

Cancer is typically a disease of older people. In the United States, about 88 percent of cancer cases are among those over 50. Of the roughly 2 million people in the country diagnosed with cancer annually, less than 100,000 people are between 15 and 39. But since the 1990s, rates of early onset cancer — diagnosed before the age of 50 — have been rapidly increasing globally.

One major study found that the global incidence of early onset cancer increased by 79 percent between 1990 and 2019, while deaths rose by 28 percent. Another study, published in the *Lancet Public Health* last year, found that the incidence of 17 cancers in the United States has risen steadily among young men and women, particularly among those born after 1990. The steepest rises were seen in cancers of the small intestine and pancreas, says study coauthor Hyuna Sung, a cancer epidemiologist at the American Cancer Society in Atlanta.

Lack of historical data in many countries makes it difficult to pinpoint when these trends really began, Sung says. But people born after the 1980s are four times more likely to be diagnosed with rectal cancer than those born around 1950. Compared with 2019, the global incidence of early onset cancers is projected to rise by 31 percent by 2030, and deaths will go up by 21 percent. Millennials and Gen Zers will carry disproportionate cancer risks with them as they age, "potentially slowing decades of progress against cancer," Sung says.

The data reflect what oncologist Alok Khorana sees in his practice at the Cleveland Clinic. Older adults still make up a majority of cancer cases, but Khorana is seeing more otherwise healthy young people without family histories of cancer. "It's a question we're all asking," he says. "Why are we seeing more and more younger people in our clinics, and why are they … presenting

PREVIOUS SPREAD: TIM ROBBERTS/STONE/GETTY IMAGES PLUS; SIDI A. BENCHERIF, THOMAS FERRANTE/WYSS INSTITUTE AT HARVARD UNIV.; ADAPTED BY T. TIBBITTS

[cancers] at more advanced stages?"

Scientists are researching those questions, but don't yet know the answers. Better cancer surveillance and screening methods don't fully explain this rise, Sung says. It can't account for "this kind of broad, across-age effect of rapid and concentrated increases observed in certain cancers among younger adults."

The leading hypothesis is that young people have been exposed to certain environmental and lifestyle factors that weren't prevalent before the 1990s. While some older people have been exposed to the same risks, researchers suspect that bioaccumulation of these factors from an early age exacerbates the risks of early onset cancer. Potential factors include changes to the gut microbiome and rising exposures to antibiotics, microplastics and "forever" chemicals known collectively as PFAS. Researchers are also investigating links between cancer and the spread of the Western diet and rising obesity rates.

"But if there had been one risk factor, we would have identified it by this point," says Sonia Kupfer, a gastroenterologist and cancer expert at the University of Chicago Medical Center. It "makes you think that it's probably a combination of a number of different factors."

↑ Ryan Decembrino (right) was in his mid-20s when doctors found a tumor in his colon. After experiencing initial disbelief that he could have cancer due to his age, Decembrino became an awareness advocate.

COURTESY OF R. DECEMBRINO

How diet may be linked to cancer

Some epidemiological evidence points to obesity being a key risk factor for early onset cancers. An analysis of 21 cancers in 25- to 49-year-olds between 2000 and 2012 found global increases in colon, rectal, pancreatic and kidney cancers may be partly explained by increases in excess body weight. But the link between obesity and cancer isn't clear-cut: One U.S.-based study did not show an association between obesity rates and the development of early onset colorectal cancer between 1995 and 2015.

Rather than obesity itself being the problem, Khorana thinks certain aspects of modern diets, particularly the Western diet, might be the key cause. He points to a high intake of ultraprocessed foods, sugar and red meat. "The more components of the Western diet, the greater the risk of early onset colorectal cancer," he says. A 2022 review study in *Frontiers in Nutrition* linked a diet high in fat, deep-fried foods, refined foods and sugary drinks and desserts with higher rates of colorectal cancer in young people. On the other hand, a protective effect was observed for people who eat healthy diets of more fruits and vegetables.

So far, scientists haven't been able to pin down how any individual dietary component might spur cancer.

So far, scientists haven't been able to pin down how any individual dietary component might spur cancer. But lab studies are beginning to show how sugar, saturated fat, high-fructose corn syrup and other ingredients might influence the growth of colorectal tumors. A 2022 study in mice, for example, found that high-fat diets alter the body's gut microbiome and metabolism in ways that increase the chances of cancer-related gene

mutations popping up when cells divide. Whether this happens in humans is unknown.

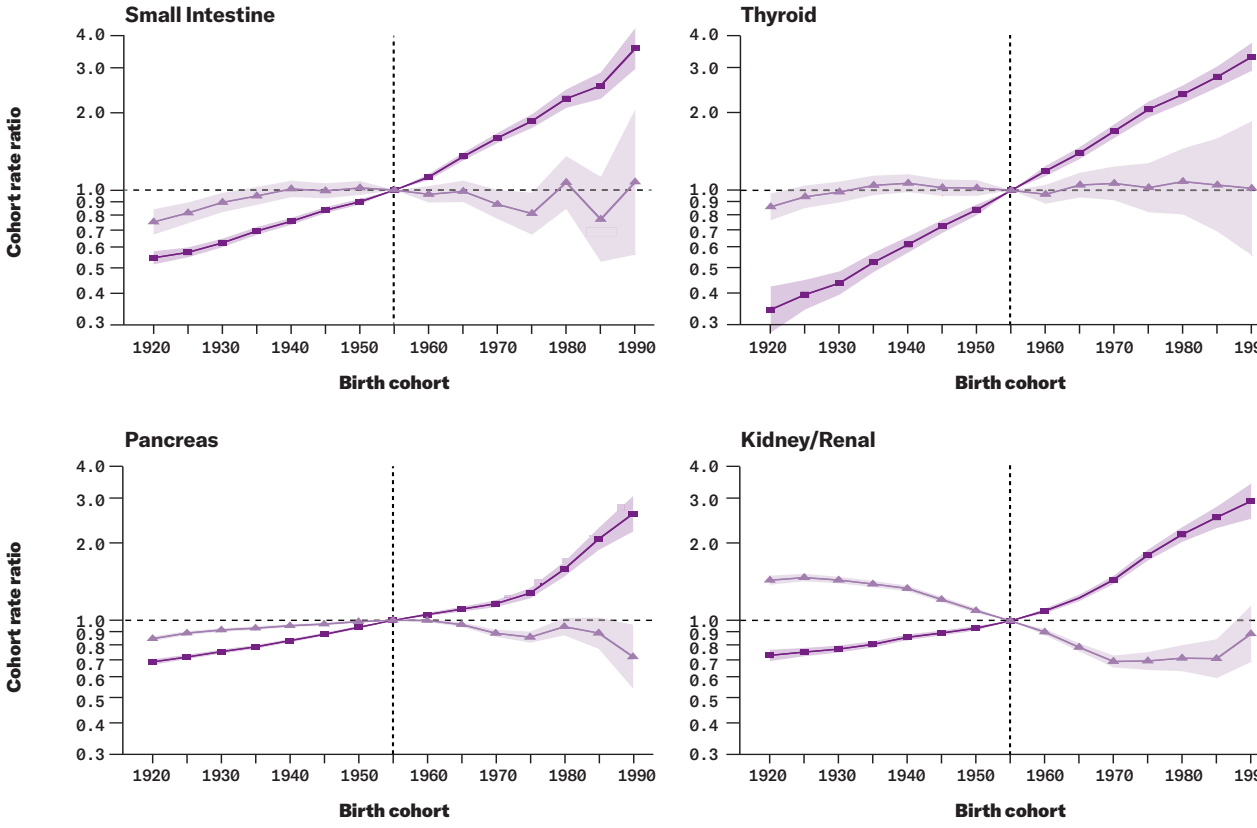
It's hard to pin down how diet influences cancer, Khorana says, because "there are too many factors to capture in studies."

More than just a coincidence?

Another area of interest is in certain materials that have become more commonly used over the last decades. These include environmental chemicals as well as microplastics that now permeate the environment, including the air we breathe, and that have even been found in the human body. Per- and polyfluoroalkyl substances, PFAS for short, are found in a range of products that people come in contact with, such as textiles and food packaging. PFAS are "suspected" to be linked to cancers at all ages, Sung says. Several studies have found associations between PFAS in drinking water, air and work environments with cancers in different organs. However, studies are yet to specifically investigate the link between PFAS and the rise in early onset cancers.

Similarly, the evidence that microplastics cause early onset cancers is "weak but increasing," says Frank Frizelle, a colorectal surgeon at the University of

CANCER RATES RISING AMONG THE YOUNG



Using data from millions of U.S. patients, scientists examined cancer diagnoses and related deaths recorded from 2000 to 2019. After grouping patients into birth cohorts based on the year they were born, they calculated the relative rate of cancer among people in certain age groups versus those born in 1955, the midpoint of their dataset. They found that rates of 17 cancers have increased steadily, especially among younger groups. The steepest increases involve intestinal and pancreatic cancers, diseases traditionally seen in older populations.

H. SUNG *ET AL/LANCET PUBLIC HEALTH* 2024, ADAPTED BY T. TIBBITTS

"Cancer can happen to anyone."

"If I would have waited until my three-year follow-up, I wouldn't be here today."

"We have to get the word out."

— Ryan Decembrino, 29, colon cancer

Otago in New Zealand. Global plastic production increased from around 120 million metric tons in 1990 to over 460 million tons in 2023, which coincides with the rising incidence of early onset cancer. When plastics degrade, they create micro- and nanoplastics that can be ingested and inhaled. Microplastics have been found in the majority of organs in the body, and in cancer tumors "in higher levels than normal tissue, but it is just an association for now and not cause and effect," Frizelle says.

These plastic particles, defined as being less than 5 millimeters across, are inert, Frizelle says, but it's possible they ferry viruses or bacteria that can cause cancer into our bodies. For instance, human papillomavirus, or HPV, has been linked to cervical and throat cancers. Other researchers question whether microplastics really are inert. How mammalian cells respond to plastic is not well understood. Laboratory studies in mice indicate microplastics can cause inflammation, a well-known promoter of cancer. But the lab studies to date have not looked at the health effects of years of microplastics accumulating in rodents, which makes it hard to glean much insight into how they might cause early onset cancers in humans.

Factors in the gut

Colorectal cancer is now the leading cause of cancer death in American men under 50 and the second leading cause for women. The incidence of early onset colorectal cancers has also risen in 27 of 50 countries and territories analyzed in a study published in January. The steep rise, particularly in those under the age of 40, has led to a lot of research, making colorectal cancer among the better studied early onset cancers and at the leading edge of understanding causes.

Given the link between gut health and gut microbes, it's perhaps not surprising that scientists suspect diet, microplastics and environmental chemicals may promote early onset colorectal cancer by influencing the gut microbiome, the ecosystem of bacteria and other microbes that live in the intestines. Observational studies point to environmental exposures and dietary changes since the 1990s that allow certain species of gut bacteria to dominate the bowels. Several species — including *Fusobacterium*, *E. faecalis*, colibactin-producing *E. coli*, *S. gallolyticus* and *B. fragilis* — have been linked with cancer in different parts of the digestive tract. Now researchers are zeroing in on how these harmful bacteria might trigger early onset cancer.

A study published in April in *Nature* put the blame on a certain bacterial toxin. Researchers studied colon cells from 981 patients with colorectal cancer in 11 countries. A certain pattern of cancer-causing genetic mutations was more than three times as common in early onset cases than in later onset ones. The researchers found that this pattern coincided with childhood exposure to colibactin.

"These mutation patterns are a kind of historical record in the genome, and they point to early life exposure to colibactin as a driving force behind early onset disease," says Ludmil Alexandrov, a computational biologist at the University of California, San Diego who led the study. If someone acquires these mutations as a child, they could be decades ahead of schedule for developing colorectal cancer, getting it at age 40 instead of 60, he says.

Alberto Bardelli, a molecular geneticist at the University of Torino and the AIRC Institute of Molecular Oncology, Milan, says the study shows a "beautiful correlation" between the mutational signature of colibactin and early onset colorectal cancers. But, he says, we need to understand the causes and mechanisms of early onset colorectal cancer. It's possible the food children eat, as well as their lifestyles and immune systems, could give rise to colibactin-producing *E. coli* toxins, but it's not well understood. What's more, colibactin exposure explains perhaps only 15 percent of early onset cases, according to previous studies, which means many more mechanisms are yet to be discovered.

Do early onset tumors grow more quickly?

A complete understanding of the causes of early onset cancers won't

come any time soon, so scientists are also working to come up with better ways to diagnose cancers in young people much earlier.

One reason younger people tend to be diagnosed with cancer at a late stage is because early-onset tumors might progress more quickly than tumors in older adults.

Bardelli is one of several scientists who hypothesize that early onset cancers might not follow the same timeline of progression as typical cancers. Scientists have mapped the molecular alterations that typically cause colorectal cancer — evidence indicates it takes five to 15 years for tumors to develop, invade and metastasize. But Bardelli has started to look into the pace of growth in early onset colorectal cancers, and they seem to advance much faster, perhaps in one to two years. If true, it could make the typical five- to seven-year screening gaps much less effective for younger people, he says.

Bardelli is trying to develop ways to determine how long a tumor has been growing. By studying tumor age in lots of people with early onset cancer, doctors would be able to figure out how often to screen for it and know which tumors are "born to be bad" — are fast-developing and require aggressive treatment.

Other researchers are trying to find ways to identify people likely to develop early onset cancers, then send them for screenings. The idea is to use other kinds of tools besides symptoms to create risk prediction models. If someone has unexplained anemia or weight loss, these are warning signs, says Kupfer, the gastroenterologist at the University of Chicago.

However, she says, these attempts are "aspirational" because scientists haven't yet identified the biological causes of early onset cancers, or how to score the risk factors we know. There is low-hanging fruit, she says, like trying to identify cases based on family history, but "we do a really bad job of identifying those people, and so we wait often until a cancer develops in the family until someone says, 'Oh, wait a second.'"

Listen to your body

Because research into early onset cancer is still in its infancy, medical experts don't yet have specific recommendations for how young adults can reduce their risks of developing most cancers. Getting vaccinated against HPV can help reduce the risks of cervical and throat cancers, and there is some evidence that the hepatitis B vaccines help prevent liver cancer. Aside from that, the best advice is to follow the basics of a healthy lifestyle: eating a balanced diet, exercising and limiting alcohol, smoking and sun exposure.

Decembrino says being aware of the signs of cancer and knowing your own body is the best thing you can do. But because early onset cancer is still not the norm, many young adults describe a grave challenge: being taken seriously by doctors. Samantha-Rose Evans,

"My previous doctors had told me I shouldn't be concerned ..."

— Samantha-Rose Evans, 26, endometrial cancer

"If anything worries you ... get it checked."

— Rosalind Holden, 38, uterine cancer

an administrator in Lincolnshire, England, was diagnosed and treated for endometrial cancer at the age of 26 only because her then-fiancé encouraged her to seek medical help about her irregular periods. "My previous doctors had told me I shouldn't be concerned," she says.

One survey in the U.K., Australia and New Zealand found that young people with colorectal cancer perceived doctors to not suspect cancer because of their age, which contributed to delays in treatment. A common issue is misdiagnosis of cancer-related symptoms as more benign health issues. In a U.S. survey of nearly 900 people with early onset colorectal cancer, 54 percent of patients were initially misdiagnosed, usually with hemorrhoids. "Thirty-six percent of patients saw three or more doctors before receiving a diagnosis of colorectal cancer," says Michael Sapienza, CEO of the nonprofit Colorectal Cancer Alliance in Washington, D.C., which led the survey.

Rosalind Holden, 38, assistant principal of a school in London, had to be "an absolute pain in the arse" to her doctors two years ago to get rapid medical attention for uterine cancer, which has an average age at diagnosis of 60. "If anything worries you, especially women's health like heavy periods, get it checked," she says. The hysterectomy to treat her cancer stopped her family planning in its tracks. "If I had gone to the doctor sooner, would the treatment have been different so it wouldn't have impacted my ability to have another child?"

The success story buried in the gloomy data is that scientists have made tremendous strides reducing overall cancer mortality. Improved screening and treatment methods have dramatically lowered cancer rates in older populations for many cancers, Khorana says.

Austria and Italy have already been screening populations in their 40s for colorectal cancer. A 2019 study shows both nations bucking the trend for rising colorectal cancer rates in people aged 40 to 49, though not for those under 40. In the United States, the American Cancer Society recommended lowering the screening age for bowel cancers from 50 to 45 in 2018, but it's too soon to know if this helped catch cancers at younger ages.

Spreading awareness among both the general population and physicians is vital for catching cancers early, says Kupfer. The most useful advocacy has been around making people aware of their symptoms, she says, so they know that rectal bleeding might not be hemorrhoids but colorectal cancer.

In the three weeks following the Colorectal Cancer Alliance's LEAD FROM BEHIND screening awareness campaign featuring Ryan Reynolds, "appointments for colonoscopies increased by 36 percent," Sapienza says, according to the digital health care marketplace Zocdoc. The Alliance State of Screening Survey revealed that 57 percent of Americans are unaware that colonoscopies can prevent colorectal cancer by removing precancerous polyps. "If they knew this, 98 percent reported they would be more likely to undergo the screening," Sapienza says.

Evans, Holden and Decembrino all say one of the challenges dealing with cancer is the difficulty finding stories from people closer to their age. That's why they're all involved in support programs for young people going through cancer.

"Cancer sucks," Decembrino says. "The only way I got through it was by having great people around me. I'm part of a buddy program now, but thankfully I haven't needed to be called up yet." ✖

79
percent
Increased incidence of early onset cancer globally between 1990 and 2019

28
percent
Rise in deaths due to early onset cancer globally between 1990 and 2019

54
percent
U.S. patients with early onset colorectal cancer who were initially misdiagnosed

57
percent
Americans unaware that colonoscopies can prevent colorectal cancer

Fred Schwaller is a science writer and editor based in Berlin.

Helping childhood cancer survivors preserve hope for fertility

Saving reproductive tissue from kids treated for cancer before adolescence could give them a chance at having biological children later in life. **By Meghan Rosen**

On the morning of Jaiwen Hsu's stem cell transplant in November 2023, the atmosphere in the hospital felt electric. Doctors had never before tried what they were going to attempt with someone like Hsu.

There was this building buzz, he says, a sense of anticipation mingled with hope. The procedure wasn't like surgeries Hsu had had in the past, some 15 to 20 since being diagnosed with bone cancer at age 11. Those surgeries were often large-scale, scary operations that ended with him waking in pain.

But this morning, at UPMC Magee-Womens Hospital in Pittsburgh, "no one was scared," Hsu says. "It was just excitement."

In 2011, doctors had snipped a piece of tissue from Hsu's prepubescent testicles. They chilled a suspension of his cells and stored them in liquid nitrogen, a process called testicular tissue cryopreservation. The goal was to save Hsu's fertility.

At the time, he had just begun an intense regimen of chemotherapy to treat a tumor growing in his femur. Though chemo could save his life, the toxic treatment would likely damage his sperm-making cells — unless his doctors could preserve them.

ILLUSTRATION BY MANOCKI

Freezing sperm — the standard option to preserve a man's fertility — isn't possible for boys who haven't gone through puberty. But freezing testicular tissue might offer a work-around. One day, after Hsu had grown up, doctors could reimplant his cells into his body, giving him the potential to conceive.

At 24 years old, Hsu was ready. Doctors put him under anesthesia, injected his preteen cells into one of his testicles and woke him about 20 minutes later. "It was completely pain-free," Hsu says. He was driving back home before lunchtime.

Hsu is the first childhood cancer survivor in the world to have his testicular cells injected back into his testes, reproductive scientist Kyle Orwig and his team reported in March in a preprint posted at medRxiv.org. Though it may take years before doctors know if the procedure worked, efforts like this represent a concerted focus on improving young cancer patients' quality of life. There are even projects in the works to help people who survived cancers more pervasive than Hsu's, like leukemia.

It's not enough to just treat patients' cancer, says Tyler Ketterl, an oncologist at Seattle Children's Hospital. He wants his patients to live long, healthy, fulfilling lives. That means looking to the future, to the decades they have ahead of them, and the families they may one day build. "We don't want you just to survive," he tells patients. "We want you to thrive."

Transplants like Hsu's will likely be increasingly common, says Orwig, of the University of Pittsburgh School of Medicine. Worldwide, more than 3,000 boys under age 18 have had their testicular tissue frozen. Most of them haven't yet reclaimed their tissue. But "it's exactly the time for it to start happening," Orwig says.

And an influx of women who've had ovarian tissue frozen as young girls may be coming, too, says Veronica Gomez-Lobo, an obstetrician-gynecologist at the National Institute of Child Health and Human Development in Bethesda, Md. "In the next 10 years, we're going to see a tsunami of these patients starting to come back for their tissue."

← As a child, Jaiwen Hsu had testicular cells frozen to try and preserve his fertility after cancer treatment. Doctors have now implanted those cells back into his body.

JAIWEN HSU

Looking beyond survival

Not long ago, a childhood cancer diagnosis was often a death sentence. From 1975 through 1979, nearly 5 in 100,000 children died from the disease. Since then, the number has been more than cut in half. From 2010 through 2019, cancer was the cause of death for roughly 2 kids per 100,000, researchers reported this year. That's thanks largely to improvements in treatment.

Today, a child diagnosed with cancer has an 85 percent chance of surviving five years or more, according to the American Cancer Society. Physicians and scientists are now thinking more about what comes next for these children. And there are a lot of them. In the United States alone, the number of childhood cancer survivors could reach nearly 600,000 by 2040, scientists estimate. Treatments like chemotherapy and radiation may have saved their lives, but they can also cause lasting harm to the body.

Childhood cancer survivors seem to age faster, for one. They tend to experience age-related health conditions like heart attacks and strokes nearly 20 years earlier than the general population, scientists reported in March in *JAMA Oncology*. And scientists have long known that highly toxic cancer therapies can wipe out egg cells and cells that make sperm. For girls, a lack of healthy eggs means not just infertility, but also the need to use hormone replacement therapy to start puberty like their peers.

When a patient faces the sometimes rocky aftermath of childhood cancer treatment, the knowledge that they may be able to have biological kids one day can be a lifeline.

It "plays an important role in coping," Ketterl said in November at the 2024 Oncofertility Consortium meeting in Detroit. "We hear this over and over again."

↑ Charlie Stenson, shown with her parents, had an ovary removed and frozen when she was 3 years old.

Hope for female patients

Charlie Stenson had one of her ovaries removed when she was just 3 years old.

In 2023, her surgeon slipped the organ out of her body via a small incision in her abdomen. Later, scientists peeled off the outer layer of the ovary like the skin of a grape, sliced it into strips and then deep-froze the tissue. The process is called ovarian tissue cryopreservation, and until 2019, it was considered an experimental treatment.

For young patients like Charlie, whose cancer had spread from its original site in her tailbone to her liver, the choice to freeze reproductive tissue can be tough. "It wasn't an easy decision, because you're removing part of your kid's body," says Charlie's mother, Emily Stenson. But "we knew that this would be giving her the best chance of having a family in the future." Just a few years ago, Charlie might not have had the option.

In 2006, reproductive biologist Teresa Woodruff coined the term oncofertility to describe a field that merges cancer care with reproductive health care. In the late '90s, she saw an adolescent male cancer patient on his way to bank sperm before treatment. She asked the team at her cancer center how they preserved fertility for female patients. They just need to focus on surviving, the team told her.

Woodruff, of Michigan State University in East Lansing, calls that her "lightning bolt moment." As a reproductive scientist, she says, "I knew that was wrong."

Since then, scientists around the world have taken steps to make things right for their young female patients. Today, experts estimate that more than 200 babies worldwide have been born to women who relied on frozen ovarian tissue. But the vast majority had their tissues frozen as women or teenagers, not as young girls like Charlie. Scientists don't know if ovarian tissue from toddlers and infants will have the same success. "We're going to see how well this works," Gomez-Lobo says.

The situation is even more uncertain for young boys. No baby has yet been born of a father who's had cryopreserved testicular tissue. But Hsu remains hopeful.

"Despite everything I've been through," he says, "I still might be able to have kids in a few years."

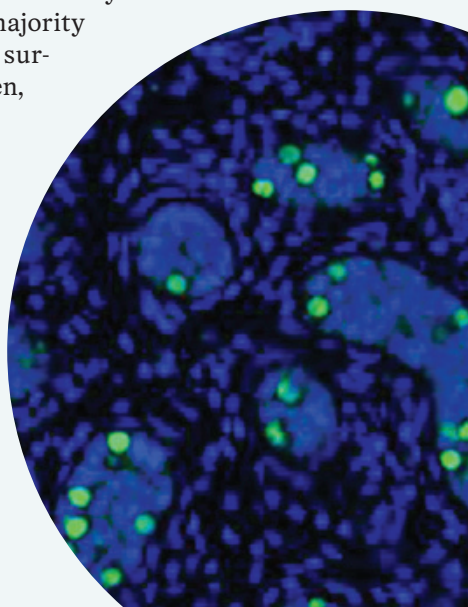
Watching and waiting

Every six months, Hsu will give Orwig's team a semen sample and get an ultrasound to see if he's begun producing sperm.

The testicular cells transplanted into Hsu's body contained stem cells with the potential to make sperm. But even if they one day achieve that, Hsu's tissue may not produce enough sperm for it to appear in his ejaculate. "It's theoretically possible," Orwig says, but not realistic. Instead, he thinks the cells may eventually form small pockets of sperm in the testes that a doctor could later surgically extract.

It could take a while. "There's no rush," Hsu says. But burning like an ember in the back of his mind is the pressure of being the first childhood cancer survivor to undergo this procedure. "I hope this works," he says. "I hope I have the opportunity to start a family."

Hsu is not alone. The majority of male childhood cancer survivors want to have children, according to a 2023 survey of more than 1,300 survivors. Compared with their siblings, though, that desire is five times as likely to go unfulfilled. Stem cell transplants like the one Hsu had might change that. And scientists are now testing transplanting whole chunks of testicular



In this microscopy image of Hsu's testicular tissue, green dots represent a protein found in sperm stem cells, suggesting the cells have the potential to create sperm. →

EMILY STENSON; A.C. ZIELEN *ET AL*/MEDARXIV 2025

tissue, rather than solely stem cells.

In 2024, about a year after Hsu's transplant, a group in Belgium performed the first transplant of frozen testicular tissue fragments, 16 years after a man had undergone treatment for childhood cancer. These intact tissue fragments may contain more sperm stem cells than cell suspensions do, providing more chances for sperm production. The technique is still considered experimental. But Orwig's team has seen success in monkeys.

Most recently, Orwig and colleagues welcomed a newborn macaque named Tiger to the world. Tiger's father had had testicular tissue removed and frozen, just like thousands of human cancer survivors. To mimic cancer treatment, Orwig's team used chemotherapy and radiation to wipe out the monkey's sperm-producing cells. Later, they transplanted the frozen tissue back into his body. The tissue "developed fine and made sperm," which the team used for in vitro fertilization, Orwig says. Tiger was born to a surrogate mother in October 2024, the team reported at the Oncofertility Consortium meeting.

There's still much to learn, though, and reason for caution, he says — like ensuring doctors transplanting frozen tissue don't accidentally reintroduce cancer back into a survivor's body. That is "the worst thing we could do," Orwig says.

Zapping or trapping rogue cells

For bone cancer that's caught early and confined to one area, like Hsu's, the risk of cancer cells sneaking into the testicular tissue is low. Doctors aren't too worried frozen reproductive tissue is carrying cancerous hitchhikers.

Other cancers aren't so stationary. They can meander throughout the body, riding the currents of the bloodstream. Leukemia cells, for instance, can infiltrate all sorts of tissues and organs, including the ovaries and testes.

Transplanting tissues from patients who had leukemia can risk reintroducing malignant cells back into patients' bodies. One potential way to avoid that is collecting tissue only after doctors can no longer detect leukemia in the blood — but before the reproductive tissue is too badly damaged. Two experimental strategies might also help. Researchers could obliterate leukemia cells in frozen tissue before transplantation, or they could confine the cells inside in a jellylike jail.

At the tissue bank in Université Catholique de Louvain in Brussels, about 11 percent of people who've stored their frozen tissues are patients with leukemia, says reproduction researcher Christiani Amorim.

Those patients froze their tissues in the hope that scientists like Amorim and her graduate students would figure out a plan. "What can I do?" patients have asked Amorim. "Have you found a solution for me?" Other patients have tracked her down on the internet, sharing their stories and asking for help. "Every time I receive an email like this, I tell my students, 'We need to hurry!' "

Amorim is working on ways to purge leukemia cells from ovarian tissues. One approach relies on light-sensitive molecules to kill cancer. Scientists could add these molecules to ovarian tissue before a transplant, then shine a laser to switch them on. The molecules then produce chemicals called reactive oxygen species, which tend to kill off cancer cells, not healthy ones.

In human ovarian tissue spiked with leukemia cells in the lab, this strategy, called photodynamic therapy, successfully eradicated cancer cells, Amorim's team reported in *Human Reproduction Open* in 2023. The researchers are now testing other light-sensitive molecules, including one activated by LED light, Amorim reported at the Oncofertility Consortium meeting. Amorim hopes that the therapy will be available within a decade. But first,

Tiger the macaque was born to a father that had testicular tissue cryopreserved and later reimplanted. Scientists used sperm from this tissue for in vitro fertilization. ↓

ORWIG LAB/ONCOFERTILITY 2024

scientists have to prove that it doesn't affect the quality of the eggs or any potential offspring, she says.

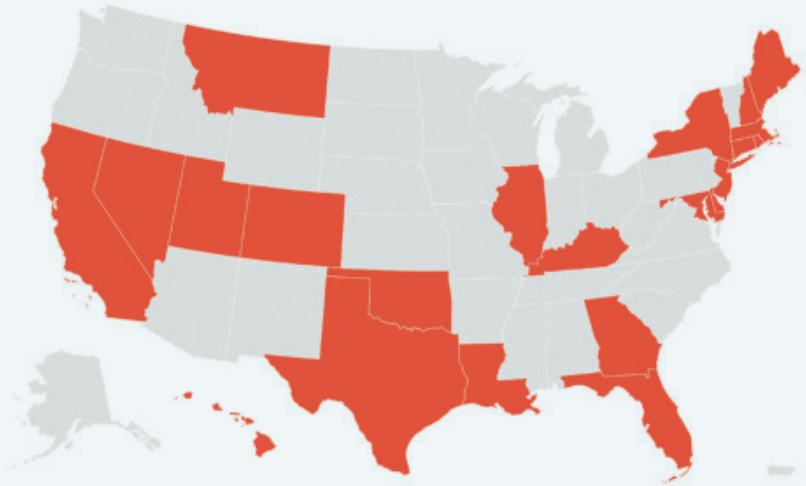
At the University of Michigan in Ann Arbor, biomaterials scientist Ariella Shikanov is trying to protect patients from rogue cancer cells using a different approach. Her team has created a squishy capsule that surrounds chunks of ovarian tissue before transplantation. It's like Jell-O, she says. Hormones, nutrients and oxygen can pass through, but cells can't go in or out.

That would trap any potential cancer cells inside the jelly bubble. For leukemia survivors looking to get pregnant, Shikanov envisions placing their cryopreserved ovarian tissue into a capsule, transplanting it into their body and then letting the tissue develop until eggs have matured. At that point, doctors could remove the capsule to retrieve eggs for IVF.

The capsule technique could also help young cancer survivors go through puberty. A recent transplantation experiment in mice showed that encapsulated human ovarian tissue functioned like normal, pumping out estrogen in regular cycles, Shikanov's team reported in a paper posted in March at bioRxiv.org. Such a capsule strategy could one day give young survivors an option beyond hormone replacement therapy, which doesn't mimic the changing hormone levels girls' bodies experience over time, Shikanov says. She's planning a similar study in monkeys and is preparing to apply to the U.S. Food and Drug Administration for a clinical trial.

Developing technologies like these and other efforts to manage reproductive health in a cancer setting still have a long road to travel. "We have miles to go before we're done," Woodruff says. One issue: making sure cancer patients know the options available to them — and can afford them.

States where insurers are mandated to cover fertility preservation procedures for cancer patients



↑ Only about 20 states mandate fertility preservation coverage for patients with cancer.

Who gets access?

Though doctors can cryopreserve sperm, eggs, embryos and ovarian and testicular tissue, these options often aren't shared with people who have cancer. Only about half of patients reported discussing fertility preservation options before treatment, researchers reported in *JAMA Network Open* in 2024.

Even fully informed patients can face barriers trying to access fertility preservation care. Cost is a big one. Charlie Stenson's family pays over $400 per year to store her ovarian tissue. Insurance doesn't cover it. Thirty years of cryopreservation equals more than $12,000.

Today, only about 20 states require insurance companies to provide some kind of fertility preservation coverage. And because testicular tissue freezing is still considered experimental, that "means largely that patients are paying out of pocket," Orwig says.

He thinks that's unacceptable. Insurance covers many other therapies for side effects of cancer treatments, Orwig says. Because infertility can also be a side effect, why would we not cover fertility preservation, too, he asks. "We need to figure out a way to make it affordable to anybody who needs it," Orwig says.

Emily Stenson is grateful to be able to give Charlie, now 6 years old, a chance at future fertility. As a survivor of Stage 4 cancer, she's been through a lot. Charlie, who Stenson describes as a thoughtful and fun little girl who loves to dance, has lived through high-dose chemotherapy, more than 15 surgeries and the removal of a cancerous tailbone.

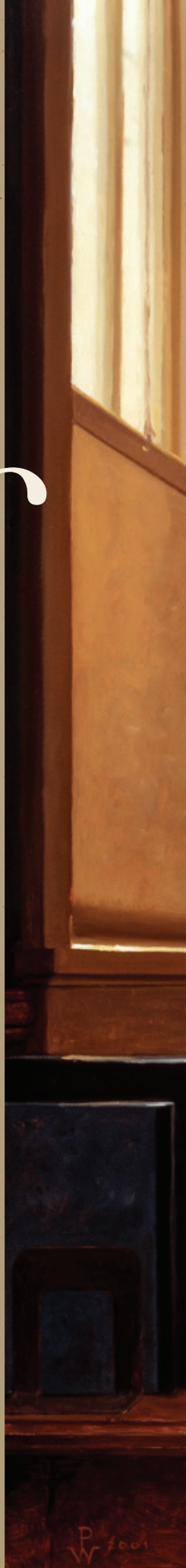
Hsu is also thankful that his family was able to get him fertility preservation care. Though the outcome of his stem cell transplant remains unknown, that doesn't keep him up at night, he says. "If it works, that's fantastic," he says. And if it doesn't, there's still good that can come of it. Orwig's team can learn from Hsu's experience to advance the technology. "It is definitely very cool to know I'm helping the field progress," he says. ✖

Star Stuff

A century ago, Cecilia Payne-Gaposchkin revealed what stars are made of and laid the foundation for modern astronomy

BY ELISE CUTTS

Astronomy is the oldest science, and the sky is among our first laboratories. Long before the written word, people erected stone circles to frame the first dawn rays of the summer solstice, etched lunar calendars in bone and wove the planets into their myths. Eventually, we learned to measure the heavens, and in the 16th century the Copernican revolution rewrote our world's place within them. But for all the long millennia that men of science had peered up at the heavens, it was a woman who would be the first to truly know the stars.



PORTRAIT BY PATRICIA WATWOOD

Cecilia Payne-Gaposchkin was just 25 years old when she discovered what stars are made of: hydrogen, helium and just a dash of nearly every other element. Her finding in 1925 was among the first successful attempts to apply the nascent field of quantum physics to observations of stars, and it was immediately controversial. At the time, astronomers believed that stars were essentially just hot Earths — incandescent orbs

HARVARD PLATE STACKS/CENTER FOR ASTROPHYSICS | HARVARD & SMITHSONIAN

↑ In 1925, women at Harvard University worked as "astronomical computers," studying glass photographic plates with images of stars. Cecelia Payne-Gaposhkin sits at the drafting table.

of iron, silicon and the other heavy elements that constitute our rocky world. Payne-Gaposchkin, a young woman astronomer, was asking her senior colleagues to throw out everything they thought they'd known about stars and write the universe anew.

It took a while. But, eventually, they did.

"You can't overstate the impact," says astronomer David Charbonneau of Harvard University. By revealing the stuff of the stars, Payne-Gaposchkin paved the way for understanding how stars form and evolve, where chemical elements come from and even how the universe began. "That has revolutionized our picture of the cosmos."

AMID THE QUANTUM REVOLUTION

Payne-Gaposchkin was born in 1900 in England, the same year that Max Planck caught a first glimpse of the quantum world through his work on how hot objects emit light. Gregor Mendel's previously obscure laws of inheritance had been rediscovered and a new field, genetics, was starting to take shape. Thanks to breakthroughs in sanitation and medicine, child mortality was in unprecedented decline: Between 1900 and 1950 in Britain, it would fall from 23 percent to just 3.7 percent. And scientists had finally convinced themselves that the universe was made of atoms — something one could still respectably dispute up until around the time of Payne-Gaposchkin's birth.

It must have seemed to her that there was nothing nature could conceal from a curious mind. "At a very early age," Payne-Gaposchkin recalled in her 1979 autobiography *The Dyer's Hand*, "I made up my mind to do research, and was seized with panic at the thought that everything might be found out before I was old enough to begin!"

There was, of course, no need for panic. When Payne-Gaposchkin arrived at the University of Cambridge in 1919, physicists were still coming to grips with the basic structure and behavior of atoms, especially how they interact with light.

Centuries earlier, scientists had realized that light streaming through a prism smears out into a rainbow, what Isaac Newton dubbed a "spectrum." In the early 1800s, English scientist William Hyde Wollaston used a prism to smear sunlight into a spectrum. This revealed a gappy rainbow, interrupted with mysterious blank lines that no one had noticed before. In the mid-1800s, German scientists Robert Bunsen and Gustav Kirchhoff realized that these lines, which appear in the spectra not just of stars but of anything that sheds light, were the spectral fingerprints of specific chemical elements.

These gaps in spectra arise from the quantum nature of atoms. In an atom, negatively charged electrons occupy regions of space around the nucleus called orbitals. The energies of electrons in different orbitals are "quantized," meaning they can only have specific, discrete values, like rungs on a ladder. To move up a step, electrons must absorb a photon, or a quantum packet of light, with exactly the right amount of energy. They can only ever climb from rung to rung — and never into the gaps between rungs.

Light's wavelength corresponds to its energy; redder light is less energetic than violet light. And the electrons in different chemical elements have different energy levels — the "rungs" on their orbital energy ladders sit at different heights. So, different elements absorb photons of different wavelengths. This allows scientists to read off spectral gaps like a kind of chemical barcode.

When Payne-Gaposchkin arrived at Cambridge, there was perhaps no better place in the world to study atomic physics. At the Cavendish Laboratory — a pioneering experimental physics laboratory — Payne-Gaposchkin learned from giants like J.J. Thomson, who discovered the electron, and Ernest Rutherford, a pioneer of nuclear physics. When Niels Bohr visited the lab to share his new quantum understanding of the hydrogen atom, with electrons zipping about the nucleus in discrete orbitals, he showed that this schema could be used to predict the spectral lines of hydrogen. Payne-Gaposchkin was a ready convert to the quantum revolution he evangelized. A few short years later, that revolution would be her way to the stars.

THE ATOMIC WORLD MEETS THE STARS

First, though, she needed a job. For bright young Englishwomen in the 1920s, there was generally only one professional path, and it led to the schoolhouse. But an ocean away, in another Cambridge, there was a place for her at the Harvard Observatory in Massachusetts. It had for decades employed women as "astronomical computers." With support from a fellowship for woman astronomers at Harvard, Payne-Gaposchkin had a chance to conduct research at the observatory for a year. That year would turn into two, and then into a lifetime. But Payne-Gaposchkin couldn't have known it when she boarded a ship in 1923 to start a new life in the United States.

For Franciele Kruczkiewicz, an astrochemist at Leiden University in the Netherlands, this part of Payne-Gaposchkin's story strikes a nerve. "I related to Cecilia," she says. "I left Brazil to go to Europe, where I could also follow my dreams." Having Payne-Gaposchkin as a role model made her feel less alone.

Beginning in the 1880s, the Harvard Observatory produced an enormous collection of astronomical data in the form of glass plates. These flat surfaces were coated with light-sensitive chemicals and used to photograph the sky. But more interesting to Payne-Gaposchkin, they were also used to collect stellar spectra.

In the decades before Payne-Gaposchkin arrived at Harvard, the woman computers had carefully annotated a lot of that spectral data. One computer, Annie Jump Cannon, had even devised a system for grouping stars into classes based on their spectral features that is still used today. Astronomers thought those classes corresponded to stars of different compositions. But there was another possibility that Payne-Gaposchkin, with her training in atomic physics and access to Harvard's glass plates, was in a unique position to test.

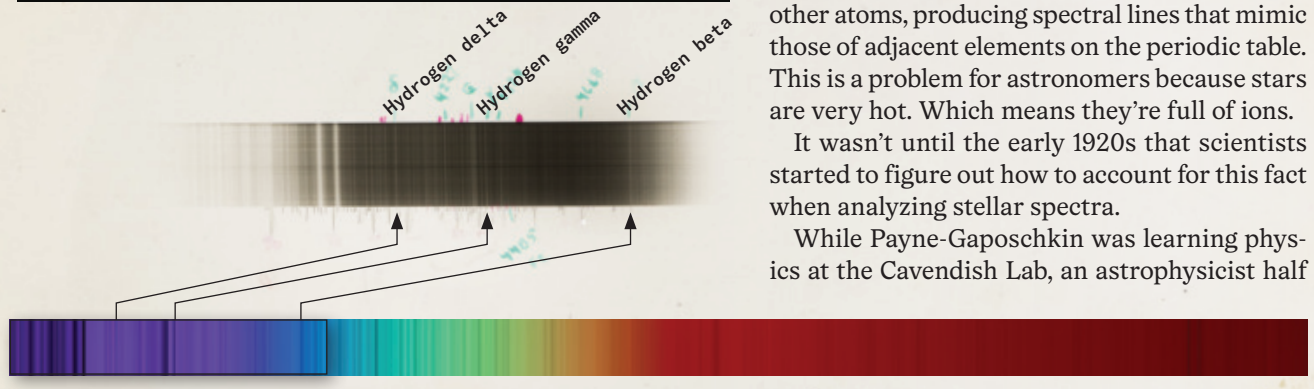
At high temperatures, atoms ionize; their electrons absorb enough energy to break free of the nucleus' hold and zip away. Ions masquerade as other atoms, producing spectral lines that mimic those of adjacent elements on the periodic table. This is a problem for astronomers because stars are very hot. Which means they're full of ions.

It wasn't until the early 1920s that scientists started to figure out how to account for this fact when analyzing stellar spectra.

While Payne-Gaposchkin was learning physics at the Cavendish Lab, an astrophysicist half

GAPS IN STELLAR SPECTRA

A refractor paired with a telescope spreads incoming starlight by wavelength, producing a spectrum. By capturing spectra on glass plates, astronomers at the turn of the 20th century could study compositions of stars. This black-and-white spectrum of the star Capella is one that Cecilia Payne-Gaposchkin frequently used. The spectrum was labeled, likely by Payne-Gaposchkin, with hydrogen's energy "gaps." Those gaps match the ones in a modern, full-color spectrum from the same class of star as Capella.



G-class stellar spectra

FROM TOP: PLATE C05256/HARVARD PLATE STACKS/CENTER FOR ASTROPHYSICS | HARVARD & SMITHSONIAN; IAU OAE/SDSS/NIALL DEACON

a world away in India named Meghnad Saha devised a formula relating the temperature and pressure of a gas to the fraction of atoms that had lost electrons and become ions. It was the key to connecting the properties of gaps in stellar spectra to the actual physical conditions — and compositions — of stars. Saha's formula was improved by astrophysicist Edward Arthur Milne and mathematician Ralph Fowler, both at the University of Cambridge. But neither Saha, Milne nor Fowler had applied the ionization equations to real observations of stars. Shortly before Payne-Gaposchkin departed for Harvard, Milne told her that if he were in her shoes, he'd use the Harvard glass plates to take Saha's work from theory to practice.

In her first two busy years at Harvard, that's exactly what she did. Using Saha's theory of thermal ionization, Payne-Gaposchkin showed that Cannon's spectral classes reflected differences mainly in the temperatures of stars, not their compositions. But Payne-Gaposchkin wasn't done. She turned Saha's equation around to take a star's spectrum and temperature and then determine the relative abundances of the elements and ions that made it up. According to her calculations, published in her now-legendary Ph.D. thesis in 1925, hydrogen and helium absolutely dominate the compositions of stars.

The simplest atoms were the stuff of the universe.

THE LASTING LEGACY

Much has been written about how Payne-Gaposchkin's work met opposition and how another scientist, a man named Henry Norris Russell, received credit for the same finding after he independently came to the same conclusions a few years later. Kruczkiewicz says she learned about Payne-Gaposchkin's discovery without learning about her — Kruczkiewicz first heard about Payne-Gaposchkin from a TV show, not a textbook. Emma Chapman, an astrophysicist at the University of Nottingham in England, likewise says she found out about Payne-Gaposchkin's contributions to astronomy only while tracing the history of astrophysics for her 2021 book *First Light*.

Despite her work's impact, Cecilia Payne-Gaposchkin (pictured at Harvard College Observatory) had not received adequate appreciation for decades. ↓

But Payne-Gaposchkin is starting to get the recognition she deserves, Charbonneau says. Today, her work on the compositions of stars — and later, on variable stars and the structures of galaxies — is widely recognized as having laid the foundation for modern astrophysics. Kruczkiewicz, who studies the composition of interstellar clouds using methods related to those Payne-Gaposchkin pioneered 100 years ago, sees her work as one of the foundation stones of not just astrophysics, but also astrochemistry.

"I say that she's one of the first astrochemists because she was the one that found out the composition of the universe," she says. Chapman studies the very first stars, which coalesced out of the hydrogen and helium left over from the Big Bang. This pursuit owes a serious debt to Payne-Gaposchkin's realization that the universe abounds in light elements.

"She was critical in us starting to understand what a star was and how it was different from the ground underneath our feet, from planet Earth," Chapman says.

Payne-Gaposchkin's discovery stands alongside the discovery of the cosmic microwave background — the afterglow of the Big Bang — and the first exoplanets as a major milestone in astrophysics, says Charbonneau, who chairs the astronomy department that Payne-Gaposchkin's Ph.D. thesis effectively established. The scientists behind those other discoveries won Nobel Prizes. Payne-Gaposchkin did not. It is impossible not to wonder if things might have been different had she been a man.

Payne-Gaposchkin ultimately was the first woman promoted to full professor at Harvard and chair of the astronomy department. As she would later reflect: "The truth will prevail in the end. Nonsense will fall of its own weight, by a sort of intellectual law of gravitation." ✖

Elise Cutts is a freelance science journalist based in Austria.

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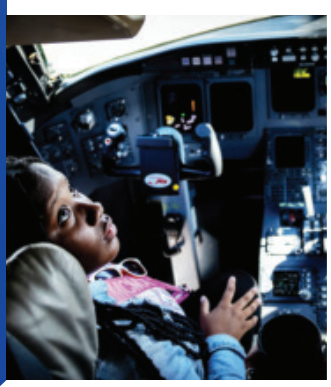


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Abstract

The Fundamentals First Fund, an ETF, is part owner of approximately 100 publicly traded worthy companies, and it owns publicly traded debt. These worldwide companies are vital, important, useful, or just plain nice to have around, and most have been pursuing their business course for decades. We individually select these companies with care and in a manner as to spread our risk so that no single company event can cause more than a bruise. Mason Capital has managed money this way for more than three decades. If you are more specifically interested in who we are, how we do it, and how you might participate, read on.

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Curiosities

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SPACE

DROPPING IN ON DISTANT WORLDS

● Humans have long dreamed of space travel. An early example traces to the second century, when the Syrian–Greek writer Lucian of Samosata wrote of a boat blasted to the moon. Recent discoveries may have put other moons on sightseers' bucket lists. Enceladus, which orbits Saturn, hosts icy geysers that inspired this poster, part of a series by NASA's Jet Propulsion Laboratory. But Enceladus and other distant worlds have thin atmospheres, so new technologies would be needed to be able to leave helmets back home (see Page 66). —*McKenzie Prillaman*

Media and cultural historian Alice Lovejoy unveils how some of the film industry's biggest players moonlighted in arms manufacturing in the 20th century and helped create history's most devastating weapon.

FILM'S BIG ROLE IN THE MANHATTAN PROJECT

By Anna Demming

TALES OF MILITANT CHEMISTRY | *Alice Lovejoy*
Univ. of California Press | $27.95

Despite the digitalization of pictures and movies, some cinephiles and moviemakers still favor film. For instance, Christopher Nolan's 2023 blockbuster *Oppenheimer*, a thriller about the theoretical physicist who oversaw the Manhattan Project to develop the first atomic bomb, was shot on Kodak's 70 millimeter film. But few of that movie's fans know what a significant role Kodak itself played in the Manhattan Project. In *Tales of Militant Chemistry*, media and cultural historian Alice Lovejoy unveils how some of the film industry's biggest players moonlighted in arms manufacturing in the 20th century and helped create history's most devastating weapon.

Lovejoy begins her story with Kodak's journey from a Rochester, N.Y.–based start-up producing cameras and glass plates in 1883 into a global chemical giant by the 1920s. Playing a strong supporting role in the narrative is Agfa, a film production company in Wolfen, Germany, and Kodak's main competitor. The companies manufactured materials for a breadth of products, including synthetic fibers, plastic toys and pesticides. But their most well-known was photographic film.

In the early 1900s, film was typically made of cellulose nitrate, a highly flammable material created by soaking cotton in nitric acid. The film's lethal hazards were compounded by the noxious fumes released should it catch fire. These fumes were similar to the poison gas used in World War I — so much so that Agfa's filmmaking factories were well-placed to produce poison gas in abundance for Germany in the Great War.

By the 1920s, Kodak had begun selling a safer, nonflammable film made from cellulose acetate. But nitrate film remained widely used because, until Kodak had refined and optimized the process, acetate film was more expensive and difficult to produce. Fortunately for Kodak, cellulose acetate became profitable as demand for the material, which was useful as a weatherproof coating for airplanes, skyrocketed during WWI.

Kodak's capacity to produce acetate en masse led to a lucrative side hustle for its subsidiary Tennessee Eastman — producing research department explosive, or RDX, in WWII. Creating RDX, used widely by both the Allied and Axis powers, required acetic acid, from which acetate is derived. The company churned out 570 tons of RDX a day by the end of the war.

Tennessee Eastman's chemical engineering expertise also made it the U.S. government's top choice to produce a different substance — fissionable uranium for the Manhattan Project. The company set up the Y-12 plant in Oak Ridge, Tenn., which

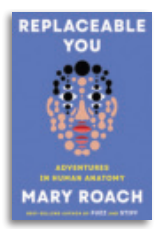
used big electromagnets to separate fissionable uranium from its heavier, nonfissionable counterpart. The fissionable uranium was sent to Los Alamos, N.M., to produce atomic bombs.

Chemistry enthusiasts may feel left wanting of details on the chemical and nuclear reactions in the book. Still, Lovejoy's tale is rife with intrigue and twists worthy of the silver screen. We meet Kodak cofounder George Eastman, who set his sights "on work instead of school" at 8 years old after his father died. We get to know Aleksandra Lawrik, who was displaced from Ukraine and forced to do toxic work in one of Agfa's factories after Germany invaded the Soviet Union in WWII. Lovejoy deftly weaves a cornucopia of strands in politics, economics, history, biography and technology, illustrating how fascinating and frightening the world of industrial chemistry can be. ✖

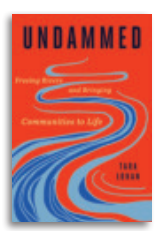
OTHER BOOKS ON THE SHELF

HOW TO SAVE THE AMAZON | *Dom Phillips*
Chelsea Green | $27.95
In 2022, a British journalist was brutally murdered in the Amazon while researching strategies to protect the rainforest and the people who inhabit it. In this posthumous book, a team of journalists and activists come together to interpret his field notes and complete his work.

V IS FOR VENOM | *Kathryn Harkup*
Bloomsbury Sigma | $28
If you're a fan of Agatha Christie's crime fiction novels, this book is for you. In this compelling tome, a chemist-turned-author investigates 14 poisons from Christie's iconic murder mysteries and examines the real-life chemistry and history behind the lethal substances.



REPLACEABLE YOU | *Mary Roach*
W.W. Norton & Company | $28.99
The human body comes with no warranty, which is why researchers have sought ways to restore ailing body parts for centuries. Explore some of science's remarkable advances in prosthetics and organ transplantation, from kidney printers to a stem cell "hair nursery" in San Diego.



UNDAMMED | *Tara Lohan*
Island Press | $32
An environmental journalist chronicles a growing movement to demolish unnecessary dams across the United States. Reviving free-flowing rivers can improve water quality, enhance public safety, boost dwindling fish populations and restore the rights of Indigenous communities, proponents argue. ✖

Supporting Educators, Inspiring Young Scientists

Natasha Rabinowitz, a veteran science educator in Phenix City, Ala., is passionate about expanding her students' access to hands-on STEM experiences. "All students should have the opportunity to explore science in ways that spark their curiosity and inspire innovation," she says. As a recipient of a 2025 STEM Research Grant from Society for Science, Rabinowitz is excited to bring new tools and real-world research opportunities into her classroom.

Society for Science's STEM Research Grants program provides support to U.S. middle school and high school teachers engaging their students in authentic scientific research. Each grantee receives either $1,000 in preselected research kits or up to $5,000 in funding to purchase other specialized STEM equipment.

Each STEM kit includes three Arduino Starter Kits, two PocketLab Voyagers, a Leaf Pack Stream Ecology Kit, a Soil Test Kit and a Garden Kit. These materials enable educators to introduce their students to hands-on, inquiry-based projects focused on electronics programming, data collection, aquatic macroinvertebrates and soil analysis, respectively.

Now in her 14th year of teaching, Rabinowitz has seen the impact these kits have had in her classroom. "I believe in bringing science to life for my students and challenging them to think beyond the textbook," she says. "These materials have given them the opportunity to explore the world around them via live data collection and analysis."

Since the program's launch, Society for Science has distributed more than 9,200 research kits and $943,000 in funding to 721 educators, helping ensure that students nationwide can explore their curiosity, learn new skills and conduct their own scientific research.

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According to Bennet, in lieu of becoming a science teacher, donating to Society for Science is one of the best ways to help cultivate scientific thinking in future generations. Through science, we can understand the world and improve lives. That is why Bennet gives to the Society through his donor advised fund at Vanguard Charitable.

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SCIENCE & SOCIETY

NOBEL PRIZES HONOR GREAT DISCOVERIES — BUT LEAVE MUCH OF SCIENCE UNSEEN

BY BETHANY BROOKSHIRE

Katalin Karikó thought the call was a joke. It was 3 a.m. on October 2, 2023. Her husband answered the phone. As someone in building maintenance, "he quite frequently gets calls for fixing this and that," Karikó says. But this time, he handed it over. "It is for you," he said. Only half awake, she heard someone calling from Sweden to congratulate her: Karikó, a biochemist at the University of Pennsylvania, had won a Nobel Prize in physiology or medicine for her work on mRNA, a discovery that propelled the rapid development of COVID-19 vaccines.

With that prize — the biggest in science, along with Nobels for chemistry and physics — she joined an elite group, all of whom received a message in early October letting them know they're now part of the most celebrated circle in science.

The Nobel Prize is an honor known the world over, but one that spotlights only narrow slices of science and very few scientists within them. Many fields of science don't fit into the prize categories at all. What's more, since only three people can share a prize, the hundreds of others who may have worked on a discovery end up being unrecognized for their prize-winning work.

Who gets celebrated — and who doesn't — has much to do with the parameters of the prize, the history of science and how the two combine to create their own kind of bias.

The Olympics of science

The prizes are named for Alfred Nobel, a Swedish chemist in the 1800s who invented dynamite and later used his fortune to establish the awards.

Nobel probably didn't intend for the prize to become the Olympics of science, says Marshall Lichtman, a physician at the University of Rochester Medical Center in New York who wrote a 2017 article on Alfred Nobel and the Nobel Prize. "What he was hoping to do, I think, was to provide [the winners] with a prize that would allow them to continue this exceptional work."

First awarded in 1901, the Nobels quickly became famous. At the time, there weren't other big prizes like it for scientific discovery. And they were open to everyone — regardless of country of origin. "That meant that the very best people in the world were going to be recognized," Lichtman says.

Today, choosing winners takes almost a year, from soliciting nominations to assessing to awarding the prizes.

"We are only allowed to award a discovery," not a person, says Juleen Zierath, a physiologist at the Karolinska Institutet in Stockholm, which hands out the physiology or medicine prize. "So we have to sort through who's been nominated. Are these people the right people? Did they really make a discovery?"

The organizations that award the prizes work hard to avoid bias, says Zierath, who was the first woman to chair a Nobel committee and remains in an assembly that chooses who wins the physiology or medicine prize. "We're 50 members ... to ensure it is not one person [making] a decision," she says. And "we're not restricting our nominations to only one region. We're reaching people throughout the world and requesting that they nominate."

Odds of winning

Most scientists, even very successful ones, will never win a Nobel.

Those who do tend to be white men. In 2023, Karikó became one of only 13 women to have received a Nobel Prize in physiology or medicine. Even fewer have won in chemistry or physics. Just one Black person has won any of the science prizes — W. Arthur Lewis in 1979 for economic science.

Winners are also usually from wealthy places like the United States and Western Europe. That's largely because these regions have long invested in funding science and contributed to strong research environments, Zierath says.

To be seen as prizeworthy, scientists have to make big discoveries. Often, this means working in big labs at important universities, places that can be hard for underrepresented groups to access. People of color and white women face a lot of barriers to succeeding in science, notes Harriet Zuckerman, a sociologist at Columbia University. There's an "array of obstacles that line the course of women's careers," she says, making it less likely for them to reach a place where they can do the type of work likely to win a prize.

"In order to get the Nobel Prize, normally, it takes — from the first nomination until you get the prize — 10, 20, 30 or even 40 years," says Nils Hansson, a science historian at Heinrich Heine University in Düsseldorf, Germany. This means that other scientists have to think a discovery is worthy of a prize — and keep nominating the scientist responsible.

Winning scientists most often are the heads of their labs. Victor Ambros, a developmental biologist at the University of Massachusetts Chan Medical School in Worcester, won a Nobel Prize in physiology or medicine in 2024 for discovering microRNAs, tiny bits of genetic material that help control how cells make proteins. He shared the prize with Gary Ruvkun, his former colleague at Harvard Medical School. Ambros' wife, Rosalind Lee, also a scientist, manages his lab and contributed just as much to the work, Ambros says. But she doesn't run her own lab and did not share the prize with him.

"Here's a life partner, [my] partner at home, [my] partner in the lab, [my] science partner," Ambros says. "It would have been terrific if we could have shared" the prize.

In 2023, biochemist Katalin Karikó became one of the few women to have won a Nobel Prize in physiology or medicine. ↓

© NOBEL PRIZE OUTREACH. PHOTO: NANAKA ADACHI

Finding meaning in the future

The Nobel Foundation likely won't change anything about the prizes. They are largely bound by limits Alfred Nobel wrote into his will.

That leaves out a lot of science. "Where does ecology fit in?" asks Robert Marc Friedman, a historian of science at the University of Oslo. Or the study of oceans? Weather and climate? Geology? Discoveries in these fields can be just as important as those in physics, chemistry or medicine. But most won't qualify for a Nobel Prize.

Still, Lichtman thinks the prize is important. It shows the world that science can change our lives.

Ambros agrees, and not just because he won one. "It's all about science and celebrating science," he notes. "I've talked more about my research publicly in the last couple of months than I did in my whole previous career." When people hear that he won a Nobel Prize, they don't only get curious about him and his work — they get curious about science. ✖

FUTURE MARTIANS WILL NEED TO BREATHE. IT WON'T BE EASY.

BY AARON TREMPER

A spacecraft slowly descends to the surface of Mars. Once arid and lifeless, the Red Planet is now lush and green. As a city comes into view, passengers see people strolling along busy streets, venturing into a park and breathing the Martian air. Many science fiction writers have envisioned futures like this for Mars. In these stories, humans use terraforming technology to make other planets more Earthlike. It's a huge challenge. To start, Mars would need an atmosphere with enough oxygen and that's thick enough to retain heat, allowing water to exist as a liquid.

In Earth's atmosphere, such greenhouse gases as carbon dioxide, methane and water vapor trap the sun's heat. Carbon dioxide makes up most of Mars' atmosphere, but there's not enough to trap heat. Less dense than Earth and half its size, Mars has weaker gravity, so it's "harder for it to hang on to an atmosphere," says Paul Byrne, a planetary scientist at Washington University in St. Louis.

So future Martians would first need a way to produce enough CO_2 to fill an entire atmosphere and jump-start the greenhouse effect, Byrne says. One idea is extracting CO_2 from Mars itself, creating the gas from carbon and oxygen in Martian minerals or releasing CO_2 trapped in Mars' polar ice caps or below the surface. But, he says, "there probably isn't enough to make an atmosphere even close to what we would need."

Using spacecraft observations, researchers have estimated that the entire planet would produce enough CO_2 to thicken the atmosphere to only about 7 percent of Earth's, not enough to create a significant greenhouse effect.

Other scientists suggest triggering volcanic eruptions to pump out CO_2. Future civilizations might try to redirect asteroids to create these eruptions. Humankind has already inched toward that feat, says MIT astrophysicist Sara Seager. In 2022, NASA's DART spacecraft bumped the asteroid Dimorphos closer to the larger rock it orbits.

But you'd probably need to whip a lot of space rocks at Mars to release enough CO_2 for an atmosphere, says Byrne. And the speed of incoming

OLLIE HIRST

asteroids would cause "catastrophically damaging impacts."

Let's say future engineers do figure out some way to warm and thicken up Mars' atmosphere. Then Mars colonists would want to start tweaking it to resemble Earth's. "We [would] need to have enough free oxygen that we can breathe," Byrne says. Free oxygen, a form not chemically bonded to other elements, makes up about 21 percent of the air we breathe. The rest is mostly nitrogen, with a smattering of other gases.

Oxygen-producing microbes could help replicate this blend. Research suggests cyanobacteria kicked off a rise in free oxygen on Earth a little over 2 billion years ago. Tweaking genes of these microbes could help them withstand Mars' extreme environment.

Through photosynthesis, these tiny workers can take in CO_2 and pump out breathable oxygen. That's probably safer than relying on machines to make oxygen. With machines, Seager says, "if one little thing goes wrong, we're all dead."

Engineers would also face other hurdles to terraforming Mars, from toxic salts called perchlorates on the dusty surface to deadly radiation from the sun and space, since Mars has no magnetic field to shield it.

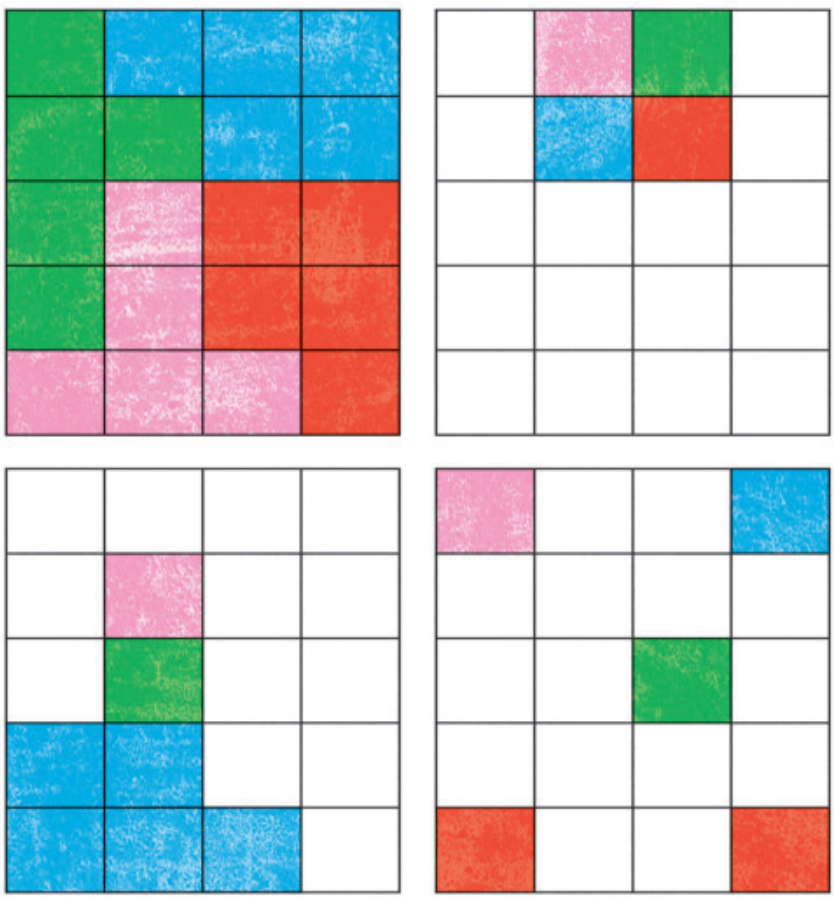
Space agencies are working to get the first astronauts to Mars, maybe within the next decade. But it could take anywhere from a few hundred to several thousands of years to perfect terraforming tech, Byrne says. "Certainly nothing remotely in our time."

The stakes are high. Small malfunctions to terraforming tech could be catastrophic. "We're just so fragile," Seager says. "That's why the whole terraforming question is so challenging." ✖

THE FOUR ISLANDS

BY BEN ORLIN

Once upon a time, four queens known as the queens of blue, red, green and pink were locked in a bitter feud. The monarchs lived on four islands, all the same size, yet each with its own distinctive wildlife and vegetation. Each queen plotted to conquer all four islands for herself, and war would certainly have begun, if not for the timely intervention of the four queens' wise and peacemaking daughters.



The clever princesses proposed a compromise:

1. So that everyone could enjoy the islands' full variety, each island would be broken into a grid of 20 equally sized plots, and each queen would rule over five plots on each island.
2. To avoid trespassing and border disputes, each queen's domain on each island would be a single well-connected region.
3. So that the queens could keep an eye on each other, the four domains on each island would meet somewhere at a single corner.
4. And lastly, to prevent outside influence and to maintain the peace, the maps would be kept a secret from outsiders.

Consumed with curiosity, I sent my assistant as a spy. He came back with one full map and three partial maps, which are shown on the left.

My assistant gathered one other scrap of intelligence: On the fourth and final island (bottom right), no two regions are the same shape nor the mirror images of each other.

From this information, can you complete the maps of all four islands? ✖

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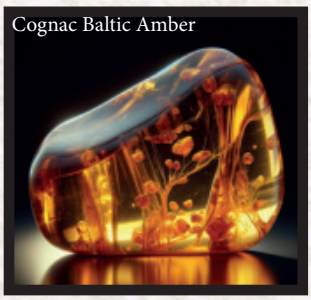
C. CHANG

Unlock Prehistoric Beauty and Flutter Your Way to Fabulous!

Over 44 million years ago in the Baltic region, a powerful force of nature was at work. Liquid Amber wept from the towering trees and slowly transformed over time, becoming what we know today as Baltic Amber. For centuries, this unique and beautiful gemstone has held a special place in the hearts and traditions of those who live in the region and is **often referred to as the "Gold of the North."**



With its rich history and natural beauty, it is no wonder that Baltic Amber has been used to create stunning jewelry pieces for centuries. And what better way to celebrate this natural wonder than by **pairing it with another symbol of divine beauty and grace: the butterfly.**

Our newest jewelry collection features exquisite Baltic Amber pendants and earrings - expertly shaped in the form of the butterfly to capture the intricate detail of these winged creatures. Each pendant and earrings set is crafted with the finest Baltic Amber, **designed by nature over 44 million years, creating a piece of jewelry that is not only stunning, but one which also holds the ancient energy of the earth within it.**

So whether you are looking for a special gift for a loved one or just want to treat yourself to something truly unique and meaningful, explore our Baltic Amber Butterfly collection today and let the beauty of nature inspire you. This stunning handcrafted set can be yours today for as little as **$79 (plus S&H) when using offer code: SN5NAB** at checkout.

DANIEL STEIGER

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A.

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- Luxurious Cognac Baltic Amber
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BALTIC AMBER

DESIGNED BY NATURE OVER

44 MILLION YEARS

THE GREATEST CHALLENGES OF OUR TIME

THROUGH THE EYES OF THE GLOBAL HERO WHO CHANGED THE COURSE OF HISTORY

HISTORIC EVENT

AN EVENING WITH PRESIDENT

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NOBEL PEACE PRIZE WINNER AND FORMER PRESIDENT OF POLAND

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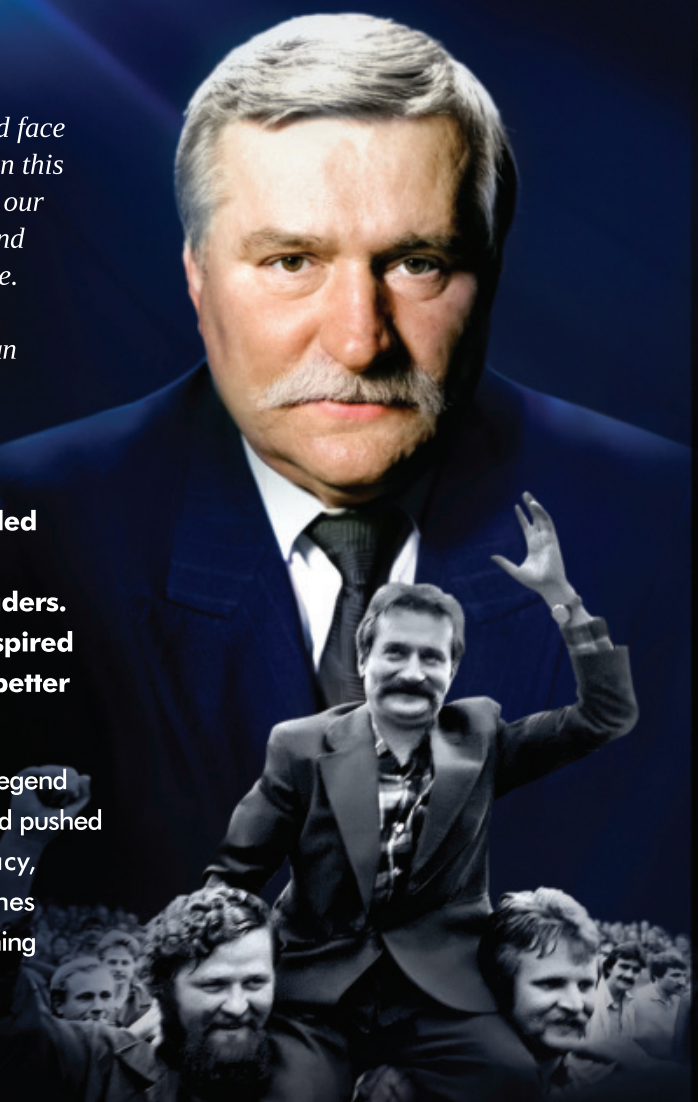
>
> **Lech Walesa**



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