

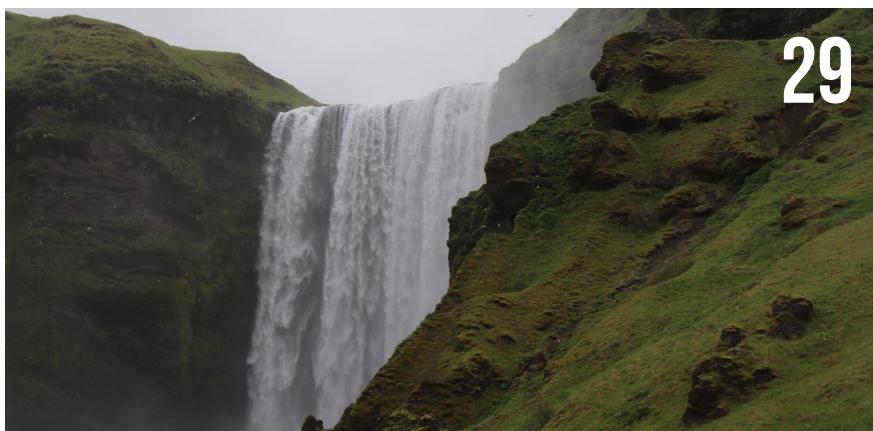
ISSUE 58 FALL 2023

NU SCI



VILLAGE

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LETTER FROM THE EDITOR

The desert sun is oppressive. It sears the desert floor, heat radiating off cracked earth like an invisible fire. The hot turbulent air flickers like flames — subjecting any light that dare traverse it. Distant images stretch, bow, snap, and bend. As light from near the horizon brushes down toward the ground, the hot low-lying blanket of air just off the surface warps it back up. On the horizon, a glimmer at first. The sky spills into the desert sand. Not a sea off in the distance, but a mirage.

Mirages appear over a wide range of ethereal conditions — not just in the desert heat. A cool ocean can conjure a replica of a ship, flipping it upside down and levitating it above the original. The arctic chill lifts an iceberg, suspending it midair. Even in a tame environment, the atmosphere is constantly distorting what we see — it's a consequence of light traveling through the air we breathe. For a mirage, however, the atmospheric distortion is so severe that it creates a new image entirely.

Sight isn't the only way we collect information about the world around us. We learn many of our truths through what others teach us, and just like the atmosphere distorting light, the cultural medium through which knowledge propagates distorts it. And sometimes, when our culture is particularly turbulent, it creates a mirage: the flat Earth, ghosts, Y2K.

In this issue of *NU Sci*, we look straight into the aberrations to see a twisted world. Enigmatic forms of lightning have puzzled weather scientists for decades. The imperfections and oddities of the human psyche make us susceptible to hallucinations, the placebo effect, and lucid dreaming. Election polls sometimes point to nothing more than an anomaly. Misconceptions and misogyny led to the demotion of a now Nobel prize winner. Pseudoscience and misinformation sneak through the murky undercurrents of our culture.

I thank our writers, designers, and photographers; the members of our software and web, outreach, and social media teams; our e-board; and our readers — all of whom have contributed to this issue of *NU Sci*.



A large, handwritten signature of Noah Haggerty, appearing to read "Noah Haggerty". The signature is fluid and expressive, written in black ink.

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Llamas: The unlikely hero of ecological restoration

BY CAROLINE GABLE, HEALTH SCIENCE & PSYCHOLOGY, 2026

DESIGN BY ANJANA BALAKRISHNAN, ART, 2026

Glacial retreat due to climate change is currently one of the most concerning environmental transformations. As temperatures rise, glaciers recede, unveiling vast, barren landscapes called glacial drifts. These areas, once buried beneath ice, pose unique ecological challenges for the establishment and sustainment of life. However, recent research has revealed a surprising ally in the race to restore these fragile environments: the llama.

Glacial drift is a geological term referring to the mix of unsorted material, such as sand, clay, gravel, and boulders, left behind by melting glaciers. These deposits vary widely in size and composition, forming soil that is challenging for plants and ecosystems to survive in. Normally, ecological development begins with the colonization of various plants and seeds to barren terrain, eventually allowing for more complex ecosystems to form. However, glacial drift presents several barriers to this process such as low soil fertility, plant species competition, and lack of biodiversity due to the inability of seeds to travel to glacial drift areas.

Recent studies have found that llamas, the domesticated camelid animals native to South America, could be the key to mitigating the challenges of establishing new ecosystems as glaciers melt due to climate change. A study published in September 2023 by researchers at the University of Texas at Austin, found that over three years, the rewilding of llamas to the glacial drift of the Uruashraju glacier in Cordillera Blanca, Peru had a significant impact on the landscape.

University of Texas at Austin researchers partnered with local Peruvian farmers to "rewild" or re-release domesticated llamas into the land left by the melting Uruashraju glacier. As a result, they found that llamas, which grazed and fertilized

the glacial drift, dramatically increased the nutrients in the otherwise arid soil. Llamas tend to concentrate their waste in specific areas, creating localized "hotspots" of nutrient-rich soil. This behavior enriches the glacial drift with organic matter including nitrogen and carbon, making drifts more conducive to plant growth. As a result, plant coverage in these areas increased by 57% within one year in comparison with control areas. Additionally, four additional plant species were discovered in the llamas-inhabited land due to llamas' function as "seed dispersers." Llamas can consume plant material from lower elevations or neighboring valleys and transport seeds through their digestive system. These seeds would otherwise be unable to travel to and take root in the glacial drift sites.

These findings show that llamas, and other Andean camelids such as vicuña, alpaca, and guanaco could strongly contribute to ecosystem establishment and conservation practices in glacial drift areas. Not only do these findings offer hope for the adaptation of glacial environments in the face of increasing global temperatures, but also point to a significant ecological benefit.

The primary reason Peruvian farmers partnered with researchers on this study was due to the phenomenon of acidic runoff which is caused by a lack of vegetation in glacial drift zones. Specifically, acidic runoff occurs when water from the melting glacier mixes with minerals and rocks in the drift site. This mixture can lead to the release of various chemical substances such as iron and sulfates, causing the running water to become more acidic. Eventually, this acidic water reaches farmlands in lower valleys, killing crops and rendering soil unusable. Therefore, an increase in plant coverage and biodiversity in glacial drift areas caused by llamas could also mitigate acidic runoff that would otherwise poison farmers' crops and jeopardize their livelihoods.

Given the findings of these studies, llamas have proven to be an unexpected ally and a testament to the power of human-animal partnership in mitigating the profound challenges posed by climate change.

Scientific Reports (2023). DOI: 10.1038/s41598-023-41458-x

PHOTO BY CLARA BARSOUM; POLITICAL SCIENCE, COMMUNICATION STUDIES & PHILOSOPHY, 2025



BIOLOGICAL DESERTS

The harms of monoculture tree plantations for carbon storage

BY MAGGIE EID, ENVIRONMENTAL & SUSTAINABILITY SCIENCES, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Plant a tree for every dollar donated, 10,000 steps walked, or 50 Google searches made. Across the globe, tree-planting initiatives such as these campaigns have skyrocketed in response to the rising threat of climate change. Numerous organizations, from nonprofits to governments to businesses, plant billions of trees each year in the hopes of offsetting greenhouse gas emissions through carbon sequestration – the process by which plants capture and store atmospheric carbon dioxide. Through photosynthesis, trees uptake carbon dioxide and incorporate it into their biomass, thus reducing atmospheric concentrations and providing long-term carbon storage. Yet, an increasing number of commercial tree plantations are joining this effort, financed by various public and private organizations, and causing greater ecological harm than good.

These plantations have targeted the tropics in parts of South America, Asia, and Africa, whose climate and topography favor rapid plant growth, thus maximizing carbon capture potential. Tropical regions consist primarily of forests and savannas, both of which provide vital ecosystem services beyond carbon sequestration, such as water and nutrient cycling, pollination, and forage for livestock. In their natural form, these regions are home to rich communities of species. Meanwhile, monoculture plantations consist of large stands of the same tree species, many of which are non-native to the tropics, such as eucalyptus, teak, and pine. When these plantations replace deforested areas and intact grasslands, people and ecosystems suffer.

Often referred to as “biological deserts,” monoculture tree plantations create a plethora of negative social and environmental impacts. These plantations frequently shift local community land ownership to private company holdings, thus displacing local communities and harming their livelihoods and access to resources. Ecological impacts include soil degradation, reductions in water availability, and greater susceptibility to fires and other disturbances. Additional consequences are increased invasion of nonnative plants into surrounding areas, increased risk of pest and disease prevalence, and loss of biodiversity. While developed nations are the primary carbon emitters, these detrimental effects greatly impact less developed countries where plantations are concentrated.

As plantations continue to encroach on tropical landscapes, these areas lose their diversity, both in the number of species present and the functional roles filled. These ecosystems are less resilient to future environmental

disruptions, such as fires, storms, insects, and diseases, which is particularly concerning in the face of a changing climate. Moreover, monoculture plantations can reduce carbon storage abilities, especially in grasslands. Grasses are a significant belowground carbon sink. Planting trees shades out these light-adapted ground-level plants and shifts the ratio of carbon in the ecosystem to be predominantly aboveground. Aboveground carbon stores have a greater vulnerability of being released into the atmosphere when disturbances such as drought and fire occur.

The rise in monoculture plantations for carbon storage is the result of valuing ecosystems solely for their carbon sequestration abilities. Neglecting the overall well-being of ecosystems in favor of one attribute has detrimental environmental impacts and is ultimately less effective. A more balanced and productive alternative is to focus on restoring global ecosystems and maintaining them in their optimal states. Protecting ecosystem diversity enhances their stability and overall function, including their carbon sequestration potential among other essential services. Moreover, including local communities in these initiatives is essential to enacting successful and equitable change for all of Earth’s people and ecosystems.

Carbon sequestration is only one piece of the puzzle in addressing the current climate crisis. The Earth does not have enough land to offset all carbon dioxide emissions solely by planting trees. However, when combined with significant reductions in fossil fuel use, trees provide a promising part of the solution, as long as planting efforts consider broader social and ecological contexts.

Trends in Ecology & Evolution (2023). DOI: 10.1016/j.tree.2023.08.012
BioScience (2020). DOI: 10.1093/biosci/biaa094
Frontiers in Forests and Global Change (2020). DOI: 10.3389/ffgc.2020.00058
Global Ecology and Conservation (2018). DOI: 10.1016/j.gecco.2018.e00419

PHOTO VIA SHUTTERSTOCK



NEW SNOWMAKING TECH IS HELPING NEW ENGLAND SKI RESORTS BEAT CLIMATE CHANGE

BY NOAH HAGGERTY, APPLIED PHYSICS, 2024

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Preparations for ski season start early in Vermont's Green Mountains. In early October, Greg Gleason, who runs snowmaking at Killington Ski Resort, gives his staff the all-clear. Over the next four hours the system of artificial snow production on which Vermont's tourism industry increasingly depends roars to life. Hundreds of thousands of gallons of water rush through miles of pipelines connecting the pump houses, 88 valve stations, and 5,000 hydrants. As more than 100 snow guns begin showering the mountain in snow, Killington quickly becomes the largest energy consumer in the area.

New England winters have warmed a blistering 4.5 degrees Fahrenheit in the past 50 years, faster than any other season, making the region the fastest-warming area in the United States. Warmer winters, obviously, produce less snow. In order to survive the uncertain climate, resorts have become increasingly reliant on fake snow. Now, over 90% of resorts have snowmaking systems, up from just over half in 1970, and many resorts, like Loon in New Hampshire, have more than doubled their snowmaking capabilities in the past two decades. To the great fortune of ski resorts from Stowe to St. Moritz, necessity is the mother of invention, and as global warming has accelerated, innovations in the snowmaking industry have kept pace.

"I've been doing this 18 years, and the technology has been changing at a rapid rate," Gleason said.

Most of those rapid advancements, it turns out, have been made right here in the Greater Boston area, by way of one Natick-based company, HKD Snowmakers. HKD's water hydrants can pump out three times more snow than traditional hydrants, and their guns' energy efficiency has improved 10-fold since the 1990s. After installing HKD snow guns, Loon Mountain was able to increase snowmaking by 60% while decreasing its energy bill.

HKD's snowmaking guns are used "all over the nation," said Chris Stimpson, the Public Relations Manager at Wachusett Mountain Ski Area in Massachusetts. "They're pretty much the leader in high-efficiency guns."

While snow can stick around even in above-freezing temperatures, making it requires temperatures of around 4 to 10 degrees below freezing. In a 2018 study, Ken Mack, the head of snowmaking at Loon, teamed up with Geoffrey Wilson, a scientist at a nearby ecologically studied forest. They found that Loon has experienced a 10% decrease in the number of hours with good snowmaking weather in the last 50 years due to climate changes. Yet, the resort was able to increase its snow production rate by almost 60% between 2002 and 2014 alone.

Wachusett Mountain has noticed the decrease in hours with good snowmaking conditions, said Stimpson. "That's why it's so important to take advantage of the hours we have."

December, the month of the year with the highest rates of visitation, has been warming even faster. In the 2016-2017 season, Loon sold over three times more tickets per day between Christmas and New Year's Day than during the rest of the season, yet the month has lost a fourth of its viable



The control panel of an HKD snow gun.

PHOTO BY NOAH HAGGERTY,
APPLIED PHYSICS, 2024

snowmaking time in the past half-century. And resorts' snowmaking operations have to rely on the warmer months of October and November to cover the grassy slopes with a thick, solid base of snow before they can add a softer layer that resort-goers actually ski on. Because of this, Killington brings an additional 28 portable air compressors to its early-season snowmaking, and keeps half of those operational through December.

The HKD technology

HKD guns provide resorts with extreme flexibility with the type of snow they can make. Shift the valve to one end, and snowmaker machines can produce thick, wet base snow in warmer temperatures. At the other end, the gun can produce light and fluffy snow to resurface slopes that are already open in colder weather. With warmer and more variable winters, this flexibility for snowmakers is key.

"From the manufacturing standpoint, how we try to balance it is to give the snowmaker flexibility," Mack said, who has since moved from Loon to working for HKD.

The HKD vision of snowmaking doesn't stop at efficient guns. They've expanded into software and hardware tools to analyze and improve the efficiency of a resort's entire snowmaking system, including water hydrants, fan snowmakers, and towers to elevate guns. This process is facilitated by iSNO, the computer software suite for automating and analyzing the whole process.

"The resort, engineering firm, or university can request that data, look through those reports, and find efficiencies or deficiencies in the operation," Mack said. "That's an incredible tool for resorts to really look at their operation and see, like, 'Oh wow, we could do better.'"

Controller rooms will use iSNO to monitor the entire system. These systems use industrial-scale pumps to draw water from a reservoir such as a lake or river. Human-made reservoirs add an extra layer of flexibility for snowmakers.

The system pumps water into the reservoir whenever natural water sources are plentiful, such as a high river because it rained upstream. Then, they can pump water out of the human reservoir when the weather is cold and conditions are right.

At the same, air compressors begin pressurizing air from the atmosphere. The pressurization process heats the gas to upward of 200 degrees, so the compressor house then needs to chill the air down to around 60 degrees with massive heat

exchangers and remove any moisture, which could damage the snow guns.

Finally, the air and water are pumped up the mountains to the snow guns. The guns blast the air and water together, creating an energetic mist. Snowmakers adjust the water-to-air mix based on the temperatures and the type of snow they plan to make. Once the mist hits the below-freezing outside air, it almost instantaneously freezes, falling down to the ground as snow.

Compressing air is an energy-expensive process and often a bottleneck in the process since local utilities limit the amount of energy resorts can consume. HKD's key innovation is specialized valves and nozzles that reduce the amount of compressed air needed. Old guns from the late '80s and early '90s would use somewhere between 300 and 400 cubic feet of air per minute. HKD has brought this down to between 30 and 120 cubic feet per minute — and down to 14 in certain applications.

"These days, 10 to 15 guns use about the same amount of compressed air as one old-school gun," Stimpson said.

However, even as the energy demand of snowmaking decreases, the amount of water needed to make a set amount of snow remains constant: the snow has to come from somewhere. This has led to strains on local water sources and has forced ski areas to get creative.

Loon created a massive water reservoir that allows them to pump in and store water from the local river whenever it's high. Wachusett draws water from a massive local natural reservoir to make snow, then at the end of the season, as the human-made snow melts, it runs down the slopes back into the same reservoir.

Killington, with a larger water supply than most resorts, hasn't had to worry about the warming climate yet. Simply, "If it's cold, we make snow," Gleason said.

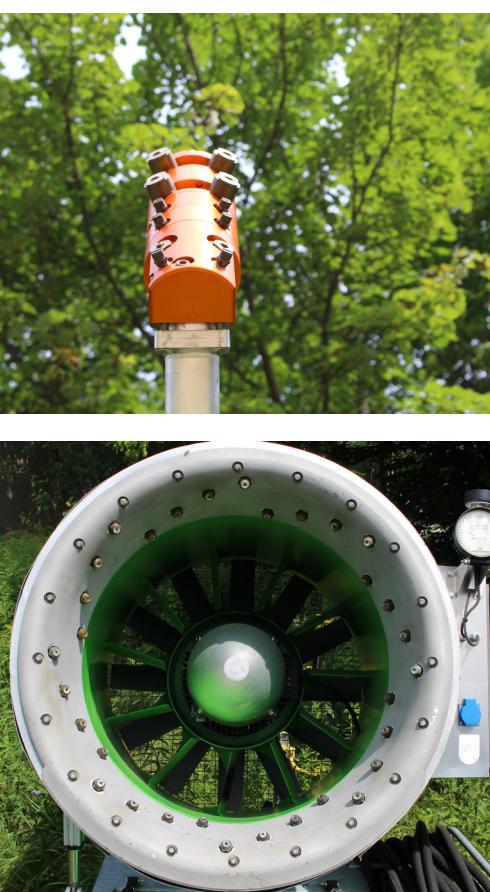
Action and advocacy

Yet some in the ski industry worry that a day may come when the warming is simply too great to put enough snow on the ground. It's a possibility that motivates resorts to advocate for environmentally friendly and carbon-neutral practices, partly through leading by example.

"It's definitely a concern. Resorts are making gains in efficiency to compensate for that, taking advantage of shorter windows," Mack said. "But they're also doing the right thing buying energy efficient equipment to lower their carbon footprint."

Over 200 resorts, including Killington, Wachusett, and Loon, have endorsed the Sustainable Slopes initiative by the National Ski Areas Association, hosting members of Congress — from both parties — and advocating for environmentally conscious practices, the reduction of carbon emissions, and increased climate action within the ski industry.

Ecological Economics (2014). DOI: 10.1016/j.ecolecon.2014.07.011
Mountain Research and Development (2018). DOI: 10.1659/MRD-JOURNAL-D-17-00117



NOT SO FOREVER CHEMICALS

A new treatment for PFAS removal in water resources

ARTICLE AND DESIGN BY SOPHIE DONNER, ENVIRONMENTAL & SUSTAINABILITY SCIENCES, 2025



Per- and poly-fluoroalkyl substances, known as PFAS, have persisted in the environment for decades, earning the name “forever chemicals.” These man-made chemicals, found in nonstick cookware, waterproof clothing, and grease-resistant packaging, have been manufactured since the 1940s, and have since impaired waters globally. PFAS contain carbon and fluorine bonds, one of the strongest bonds in organic chemistry, making them naturally indestructible. However, a newly developed PFAS treatment technology has questioned just how “forever” these chemicals may be.

A team of scientists and engineers at EPOC Environmental in Australia designed a method of PFAS removal, known as “Surface Active Foam Fractionation” (SAFF), which solely utilizes air bubbles. In the process, gas (typically air) bubbles through a contaminated aqueous solution. Since PFAS are water-repelling surfactants, they tend to accumulate on the air-surface interface of these rising bubbles, creating a concentrated foam at the surface that offers a more targeted and effective removal. With the main input being air, this method of remediation could be sustainable, cost-effective, and feasible on a large scale. Foam fractionation has been an established technique since 1961, but its application for PFAS remediation was only recently discovered.

The Army Aviation Centre in Queensland, Australia, within the Great Artesian Basin, was the site of the first field study of SAFF. As one of the largest deep groundwater bodies in the world, former fire training and hot refueling activities from the Australian Department of Defense vastly contaminated it with PFAS. Along the field trial site, the team installed an SAFF plant within a shipping container containing a chain of treatment stages. The first stage, or primary foam fractionator, produces a PFAS-free solution, which is pumped through a polishing stage and released as clean water. The contaminated foamate from this primary tank is separated from the solution, and a second fractionation vessel receives this surface foam, concentrating the substance further. Within a tertiary fractionation tank, the foamate left is enriched in PFAS, leaving only a small volume of highly concentrated substance for periodic disposal, potentially through incineration. The team sampled water upstream of these

In each of the 35 samples at all sites, SAFF removed around 99.5% of three primary types of PFAS.”

SAFF tanks and downstream of the SAFF plant to measure PFAS presence. In all 35 samples, SAFF removed around 99.5% of three primary PFAS types.

Unfortunately, the SAFF technique is not as effective on shorter-chain PFAS molecules with lower absorption coefficients, leaving behind some contaminants in treated waters. A follow-up treatment, known as anionic exchange (AIX) resin polishing, can remove 100% of all detectable PFAS chemicals from sampled water when used downstream of SAFF methods. AIX resin works to replace ions in the contaminated solution with ions of a similar electrical charge. When used in combination with secondary downstream treatment techniques, SAFF is extremely effective in reducing PFAS concentrations to drinking water quality standards. These additional treatment technologies, however, do not offer the sustainability of simply utilizing air bubbles; Resin must be replaced and disposed of, whereas SAFF alone generates zero waste.

Allonnia, a bio-ingenuity company based in Boston, Massachusetts, has begun to distribute this PFAS treatment across North America, offering SAFF units to provide a sustainable solution to PFAS contamination. PFAS are prevalent in nearly all major water supplies in the United States and are also present in the atmosphere and soils. In groundwater, PFAS spreads across long distances and can contaminate drinking wells. Manufacturers were not required by the EPA to report the use of PFAS in products until a final ruling in October 2023, making these chemicals inconspicuous for years. The 2014 National Health and Nutrition Examination Survey detected PFAS in the blood of 98% of Americans. Even at low exposure levels, PFAS can lead to cancer, liver or kidney disease, altered thyroid function, and a myriad of other health effects. While the use of PFAS has become restricted recently, these chemicals are still present and extremely persistent in contaminated water resources, making SAFF a crucial treatment in protecting humans and ecosystems from exposure.

Remediation (2021). DOI: <https://doi.org/10.1002/rem.21694>
Environmental International (2019). DOI: 10.1016/j.envint.2019.105048

PHOTO VIA SHUTTERSTOCK

Aerial electricity: Lightning and other poorly understood phenomena

BY PATRICK J. DONNELLY, ELECTRICAL & COMPUTER ENGINEERING, 2026

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING & DESIGN, 2024

Lightning is not uncommon, nor is it particularly subtle. In fact, with approximately 9 million strikes per day, it is one of the loudest, brightest, and most common natural phenomena known to the terrestrial sciences.

Most people know lightning as loud arcs of light that sometimes occur during severe storms. Indeed, this is the most common form. However, much stranger electrical phenomena, from floating balls of light to glowing pieces of plane fuselages have also been described.

That being said, with references dating back to antiquity and academic consideration beginning as far back as Benjamin Franklin's first foray into electrostatics in 1746, lightning should be understood quite well — if meteorology were ever that simple.

The classic arc-shaped lightning strike is the most thoroughly documented type of lightning. Nevertheless, its formation is still debated in academia, with its underlying mechanism being unknown and rather contested, though most every model begins with triboelectricity.

The triboelectric effect, better known as static electricity, is the observation that rubbing certain materials together produces an electrostatic charge like wool socks on carpet. Triboelectricity has been observed for millennia, with the Ancient Greeks writing of rubbing animal fur and amber together to produce sparks, from which we derive the term "electricity," from the Greek ἡλεκτρον (*élektron*), meaning "amber."

It is thought that strong updrafts in thunderclouds are able to lift small ice crystals high into the atmosphere, rubbing past falling masses of soft hail called graupel, producing triboelectricity. These ice crystals carry positive charge upward, concentrating at the top of the cloud, with the opposite occurring for negative charge at the bottom of the cloud.

While this explanation for the accumulation of charge is generally accepted (except for the number of regions of charge created, which is a much more complex problem), the problem of how and why these pockets spontaneously and violently discharge is heavily debated.

Whether the charges produced are strong enough to break through the air, or whether the lightning needs a catalyst to form is debated. What that catalyst may be, whether more ice crystals or cosmic rays, is also uncertain. What little is certain, is that lightning occurs and that it involves electrostatic discharge of some variety; all else is of continuing research and debate.

Two lesser-known and more elusive forms of lightning are Saint Elmo's fire and ball lightning. Both phenomena are extremely rare and very different from traditional arc lightning, sighted most often (but, strangely, not exclusively) during thunderstorms.

The former, named Saint Elmo's fire after the patron saint of sailors in Christianity, is a phenomenon by which high-altitude high-conductivity structures may begin to glow and emit sparks, similarly to a Tesla coil. The event was most commonly reported by sailors at sea during storms, who would report seeing the metal tip of their ship's masts glowing ethereally.

The leading theory for Saint Elmo's fire is quite similar to that for traditional lightning, with the same ice-graupel polarization process accounting for the required charge difference for ionization of the air surrounding the conductor. The main difference, aside from the incredible rarity of the event, is that the metal conductor much more easily handles the resulting discharge, leading not to a quick, severe clap of thunder, but a slow burning of fire abreast the conductor.

The last major lighting-adjacent phenomenon is ball lightning, perhaps the most mysterious event in all of meteorology. Very few have seen ball lightning, so few that its existence was questioned even up until the advent of photography.

In general, ball lightning is described as an ethereal ball of light suddenly appearing in the open, whether in a storm or in the clear evening air, usually disappearing within seconds. However, reports of shape, size, color, duration, altitude, and intensity all differ wildly.

Unlike classical lightning and Saint Elmo's fire, there is no clear explanation for the phenomenon, nor is there even a consensus. In a review of the current scientific literature, researchers Mikhail Shmatov and Karl Stephan describe there being "dozens" of competing ball lightning models, none of which account for even a majority of the eight criteria most often associated with the event.

This is all to say that lightning, while a quotidian phenomenon in many parts of the world, is anything but straightforward. From arcs, to balls, to glowing halos, it takes on many different forms and functions. With millennia of research yet to reach a consensus, it shows us that science has yet more to learn about even the most conspicuous of phenomena.

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DOI: 10.1007/978-3-030-70795-8_34

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Physics Reports (2014). DOI: 10.1016/j.physrep.2013.09.004

PHOTO VIA SHUTTERSTOCK

Deep brain stimulation

Study provides biomarker to track recovery from severe major depressive disorder

BY SOPHIA KOLODNEY, HEALTH SCIENCES & PSYCHOLOGY, 2026

DESIGN BY JOSEPHINE DERMOND, ECONOMICS, 2021

Like the bottom of the ocean, major depressive disorder (MDD) is widespread, often dangerous, and yet largely shrouded in mystery. MDD impacts about 5% of the population — 280 million people worldwide — and its symptoms include the lack of ability to feel pleasure, extreme fatigue, and sleep and appetite disturbances. These symptoms cannot be measured objectively with a stethoscope or a blood pressure cuff, meaning clinicians often must rely on subjective feedback from patients themselves. Thus, finding the right course of treatment can be a lengthy process of trial and error.

Common treatments for MDD include talk therapies such as cognitive behavioral therapy and interpersonal therapy, as well as pharmacological solutions such as selective serotonin reuptake inhibitors. Those who do not respond well to talk therapy or medication may try brain stimulation procedures like electroconvulsive therapy or transcranial magnetic stimulation. For some individuals with severe MDD, none of these treatments make any difference in their symptoms. Because of the lack of “vital signs” for MDD, doctors struggle to determine why these patients are treatment-resistant and how best to help them. However, the development of an objective biomarker provides a possible solution to this dilemma. This development was introduced in a study led by Ki Seung Choi and Stephen Heisig of the Icahn School of Medicine at Mount Sinai. The study investigated deep brain stimulation (DBS) as a treatment for severe MDD and used new developments in neurotechnology and AI to track changes in subjects’ brain activity as they responded to treatment.

DBS is a surgical procedure in which electrodes are implanted in specific areas of the brain, providing electrical stimulation to relieve symptoms of neurological and psychiatric disorders. Electrical impulses are generated by a pacemaker-like device implanted in the chest, which is connected to the electrodes by a wire running under the skin. The level of electrical stimulation generated by this device can be controlled by a neurologist using a computer. DBS has been approved by the Food and Drug Administration for the treatment of movement disorders such as Parkinson’s, essential tremor, and dystonia, as well as for treatment-resistant obsessive-compulsive

disorder. Although the exact mechanism for symptom relief from DBS is unclear, the prevailing theory is that it is due to increased neuron firing in the targeted areas. DBS has been studied as a treatment for severe MDD since 2005 and usually involves stimulation of the subcallosal cingulate (SCC), a component of the limbic system that is especially associated with feelings of sadness. Although the treatment’s effectiveness is well established, finding the right level of stimulation is often a process of trial and error due to the lack of objective markers of recovery.

In the DBS study, researchers recorded the brain activity of subjects throughout a 24-week course of DBS treatment and trained specialized AI to distinguish between patterns of brain activity associated with illness and those associated with recovery. Researchers controlled for depression severity using a rating scale, as well as levels of white matter damage in the SCC associated with specific rating scores. Each of the 10 subjects entered the study with a score of at least 20 and proportional white matter damage, meeting the clinical criteria for severe MDD. After 24 weeks of treatment, 9 out of 10 subjects were classified as responders (greater than 50% decrease in scores) and 7 out of 10 met the clinical criteria for remission (scores below 8). The AI trained in this study will be used in future studies to track depressed patients’ response to DBS and improve its effectiveness as a treatment.

The development of this objective way to track recovery has the potential to alleviate some of the uncertainty of treating MDD. Doctors will have an easier time distinguishing between natural shifts in mood and genuine regression that might warrant an adjustment in treatment. For patients, knowing for sure whether they are improving may be a crucial motivator for the long, grueling path ahead. Just as submarines and deep sea divers use light to navigate the ocean floor, doctors and patients will now be able to navigate the mysterious depths of MDD with a sense of direction and hope.

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PHOTO VIA MEDPAGETODAY

Yes, being 'delulu' is normal

Mechanisms of hallucinations

BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Everyone is capable of hallucinating. Some illnesses and the use of psychedelics may increase the frequency and likelihood of hallucinogenic episodes, but this does not mean hallucinations make one mentally ill or a drug addict. The human brain is faulty at best — it makes mistakes, and hallucinating is only one of many. There are many reasons this occurs and the neurological mechanisms behind it depend on what kind of hallucination is being experienced.

Most people interact with the world with their five senses, using their organs to take in sensory information. Neural networks connecting these organs to various regions of our brain bring information to get processed, allowing us to perceive our environment — the things we see, hear, touch, smell, and taste around us. Hallucinations occur when these sensory processing regions of our brain activate without receiving any signal from our sensory organs. This causes people to perceive things that are not there. Auditory and visual hallucinations appear most commonly, thus most scientific research on this phenomenon focuses on this particular subset of experiences.

While the use of drugs such as psilocybin and LSD can induce hallucinogenic effects, something as regular as distressed emotional states, including grief after loss of a loved one, can also induce hallucinations. These are thought to be normal and not a physiological concern. What is not normal is having these symptoms occur on a regular basis. Structural abnormalities in the brain leave some more susceptible to hallucinations, as found in patients with illnesses such as dementia, Alzheimer's, and schizophrenia. Lesions and reduced grey matter — the parts of the brain containing neurons — in certain brain regions have been found in patients suffering with hallucinations. While these abnormalities differ between different subgroups of psychological and neurological disorders, they both contribute to abnormal brain reactivity.

On the other hand, hallucinogens do not require a person to be distressed nor have brain abnormalities to induce its effects. These directly activate neural receptors in the brain, commonly the 5-HT2A (a type of serotonin) receptors, which can lead to altered levels of neurotransmitters and even change the shape of the brain regions it acts upon. The psychedelic effects induced by these synthetic shifts

in the brain's chemical balance may be different from the hallucinations induced by physiological illnesses, but they may be helpful for psychiatrists. For one, the alterations in brain structures could be helpful in treating psychological and neuronal disorders.

Another interesting case of hallucination comes from studies centering patients that have gone completely blind. Called the Charles Bonnet Syndrome, some patients report "seeing" things ranging from simple shapes to detailed movie-like scenes. These findings reveal a new side of how the brain operates. As mentioned before, the brain uses the information collected by sensory organs to create one's perception of reality. When deprived of this information when people lose their sight, the brain may continue to try staying faithful to its job. However, due to the lack of sensory information, the reality it conjures does not accurately recreate the world as before. While the sensory organ may cease to function, the brain remains active, desperate to recreate reality whether or not it receives information.

It seems obvious to say that hallucinations are the product of our brains, but in reality, the full mechanisms behind each unique case still remain a mystery to scientists. Hallucinations come in many colors, sounds, and flavors. For different subsets of patients and different studies, researchers have found many conflicting results, demonstrating how complex the phenomenon is. For some, hallucination is temporary. For others, it is a part of their regular lives. For some, hallucinations mean illness. For others, it is an escape. And for others still, it could mean recovery.

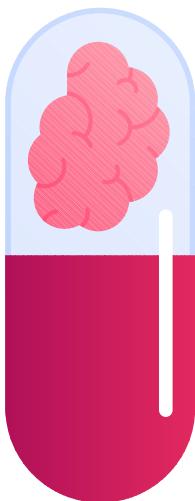
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MIND OVER MEDICINE

THE PLACEBO EFFECT

BY RESHIKA SAI DEVARAJAN, HEALTH SCIENCE, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

The placebo effect is a phenomenon observed in many experiments, most often medical. This peculiar occurrence is when patients are given a control treatment, such as a sugar pill rather than the true medication being tested, yet have considerable positive gains in their condition. In other words, patients' conditions are improving despite not receiving any real treatment. In this way, a psychological effect stemming from the patient's mind can have very significant and beneficial physical manifestations.

The placebo effect is a moderating factor in many experimental contexts. In fact, for a medication to get approval for widespread use, it needs to perform better than a placebo in clinical trials and show significant results that are unlikely to be due to chance. The use of a placebo in an experiment helps to reduce the influence of patient expectations on treatment results. Common placebos include sugar pills, saline injections, therapeutic rituals, and sham interventions.

In a single-blind procedure, patients are not told if they are in the experimental or control group, and therefore they are unaware of the nature of the treatment they are given. In double-blind procedures, neither the patient or administrator are aware of the treatment given to participants. However, what about when patients are aware they are taking a placebo? Research has found that even when patients are aware they are receiving a placebo treatment, called an "open-label placebo," they still experience improvements in their condition on average. Placebos are not capable of everything – they cannot cure cancer or reverse severe physiological conditions, but they can improve certain symptoms such as pain, nausea, fatigue, and mood. In this way, although they can be useful, they are not a replacement for real medication and are ineffective for serious illnesses.

Additionally, there are some ethical concerns with placebo use. Placebos are administered to patients with full informed consent. However, patients are being subjected to a lack of medical treatment – effectively delaying the use of any effective medications until after a study is done, which could potentially lead to a patient's condition worsening. Ultimately, in order to test the efficacy of new drugs on the market, placebo controls are an unavoidable process, but it is essential to strike a careful balance between conducting

ethical research and ensuring the well-being of patients. Placebos must be used when only justified, and studies with placebo control groups must take care to minimize any risks to patients. If halfway through a study, the experimental drug displays overwhelming evidence of its efficacy in comparison to a placebo, it is generally agreed upon that it is the ethical duty of researchers to stop the study and give the control group access to the experimental medication.

The placebo effect boils down to the impact that mindset can have on a treatment plan. By simply thinking that a medication or treatment will improve their condition, a patient can trigger the release of dopamine and endorphins in the brain, which can significantly affect pain systems in the body. Positivity and confidence in the treatment plan is a major psychotherapeutic factor in why the placebo is able to work. Additionally, patient-physician interactions can significantly shape patient attitudes and expectations, further enhancing the placebo effect.

In the case of open-label placebos, the simple act of taking a medication can help improve a patient's condition. This is because human minds have been hard-wired to associate medical measures as healing practices. This connection can cause one's brain to react in the same ways as it usually does in the case of medical treatment. For example, if a patient is used to taking a pain-relief medication, such as Tylenol, and experiences lower levels of pain, they might associate this decrease with the medication. If the patient is presented with a sugar pill, and even if they know it is a sham medication, their brain might still associate said pill, reminiscent of Tylenol, with pain relief.

Ultimately, the placebo effect underscores the power of an individual's mindset in influencing the effectiveness of a treatment plan. The power of our minds can have important effects on easing mood-related symptoms and pain intensity. When we genuinely believe in our potential for improvement, it becomes increasingly likely that we will experience positive changes.

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PHOTO VIA SHUTTERSTOCK



EPIGENETIC AGE ACCELERATION

How traumatic childhood events can lead to faster aging

BY CECELIA KINCAID, BEHAVIORAL NEUROSCIENCE, 2027

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

New research suggests that childhood home environments may have a say in the aging process. Adverse childhood experiences (ACEs) are potentially traumatic events. They include all forms of abuse and neglect, but there are other ACEs such as exposure to parental substance use and parental incarceration. ACEs can have physical, mental, and emotional effects that reach into adulthood.

One of these physical effects is aging, which can be classified into two types. Chronological age refers to the number of years an individual has been alive. Biological or epigenetic age expresses how able and functioning an individual is, and increases at different rates for everyone. The term “epigenetic” refers to an environmental or behavioral influence on DNA. Epigenetic factors aren’t necessarily DNA mutations, making them reversible. These factors affect how the body reads DNA, rather than the DNA itself. Essentially, epigenetic age acceleration is a measure of whether individuals are aging faster or slower than their chronological age due to epigenetic factors.

In June 2023, Kyeezu Kim and her lab measured epigenetic aging of a cohort study at 15 and 20 years of follow-up. The study consisted of more than 800 adult participants with ACEs, recruited from the Coronary Artery Risk Development in Young Adults (CARDIA) study. The CARDIA study explores the determinants and development of cardiovascular disease, as well as its risk factors. It has been suggested by previous research that ACEs can modulate epigenetic pathways, such as aging, leading to health issues later in life. Kim and her team wanted to bridge the knowledge gap and explore the associations between ACEs and epigenetic age acceleration.

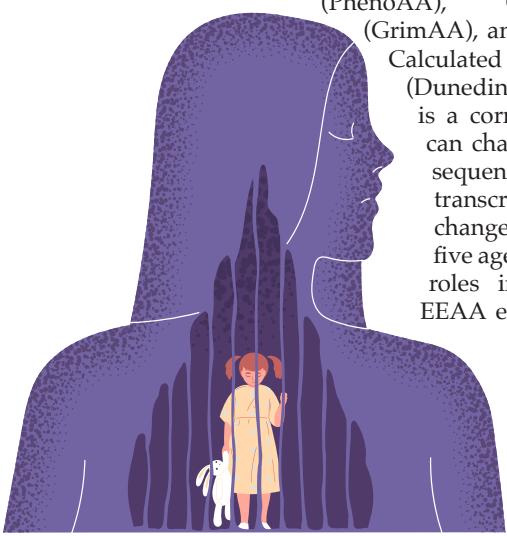
To measure epigenetic aging, the team used five different DNA methylation-based epigenetic age estimators: intrinsic epigenetic age acceleration (IEAA), extrinsic epigenetic age acceleration (EEAA), PhenoAge acceleration (PhenoAA), GrimAge acceleration (GrimAA), and Dunedin Pace of Aging Calculated from the Epigenome (DunedinPACE). DNA methylation is a cornerstone of epigenetics. It can change the activity of a DNA sequence, typically by repressing transcription, but does not change the sequence itself. These five age estimators served various roles in the study. IEAA and EEAA estimate age based on cell

intrinsic characteristics of the aging process as well as age-related changes in leukocyte (white blood cell) composition. PhenoAA and GrimAA estimate health and life span. DunedinPACE measures the pace of aging and can be used to represent physiological decline.

Kim’s team concluded that ACEs were associated with epigenetic age acceleration in middle aged adults. More specifically, individuals with four or more ACEs were likely to have older epigenetic ages compared with their chronological ages, due to lasting biological changes. These toxic stress-induced changes could include disrupted cellular properties, inflammation, impacted immunity, and an altered endocrine system. They also noted that results were typically consistent across subgroups including race and sex, indicating that ACEs are related to epigenetic age acceleration regardless of demographics.

Kim and her team reported several limitations to their study. First, participants were all middle-aged adults, but ACEs occur during childhood, so there is a possibility of a recall bias leading to misremembered events or details. Second, this study excluded certain ACEs: sexual abuse, parental separation/divorce, parental mental illness, and parental incarceration. While the reason for this exclusion is unknown, Kim’s lab emphasized the importance of further research that includes these unmeasured ACEs.

This research is critical to the current understanding of aging and the varying effects that environmental factors can have on an individual’s biology. It opens doors to future research in epigenetics, such as the role of behavior in DNA changes, or how ACEs relate to stress and resilience. The work done by Kim’s lab illustrates the need for expanding public health education to include childhood traumas and conditions. ACEs are important to include in medical histories and records to ensure the best care for patients. Many physical conditions have roots in mental or emotional traumas, which are crucial to consider in diagnosis, treatment prescription, and therapy. Future directions could also include research on early detection and intervention for health-related outcomes later in life. Furthermore, if scientists are able to discover the molecular mechanisms of epigenetic age acceleration, more medicinal and therapeutic research can be done to determine the best way to promote health for middle-aged adults with ACEs. Ultimately, the association between ACEs and epigenetic age acceleration highlights the need to prevent ACEs and to monitor individuals who have suffered them.





AWAKE OR ASLEEP? THE SCIENCE BEHIND LUCID DREAMING

BY ROHAN GUPTA, CELLULAR & MOLECULAR BIOLOGY, 2024

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Everybody dreams. Whether we remember their intricate plots or feel them slipping away the second we wake, sleep science has long known that all humans dream. Many have experienced the dread of sprinting at a snail's pace through hellishly personalized nightmares, others discovering fantasy worlds where human flight and super strength are made possible. However, regardless of how different our dreams may be, nearly all dreamers are an audience to their own illusions, grabbing first-person seats to a story they have no say in choosing. But what if dreamscapes weren't out of our control? What if we could snap ourselves awake without losing the ability to fly or even play god in our nighttime storylines? That's how lucid dreaming is defined by Dr. Ursula Voss and her team: "the experience of achieving conscious awareness of dreaming while still asleep."

Lucid dreaming, despite its early controversy and dispute of legitimacy, has been accepted as a known phenomenon for centuries, with its first mention by Aristotle in the fourth century BCE. The term "lucid dream" itself, however, was coined as recently as 1913 by Dutch psychiatrist Frederik Van Eeden, who himself experienced both lucidity and its initial skepticism. In his recollection included in the *Proceedings of the Society for Psychical Research*, Van Eeden wrote of how "many authors will not accept my definition [of lucid dreaming], because they deny the possibility of complete recollection and free volition in a dream." In a modern era more receptive to lucidity, sleep studies have revealed that lucid dreaming is linked with rapid eye movement (REM) sleep, the fourth and final stage of the human sleep cycle involving a "wakeful" body state critical to the development of concentration and memory. Dr. Benjamin Baird of the University of Wisconsin-Madison and his team found "higher-than-average levels of physiological activation during REM sleep" when reviewing electroencephalography (EEG) results from their study utilizing lucid dreamers. The association of lucid dreaming with a specific segment of sleep has provided a resolution to the skepticism that initially clouded the inclination to study the phenomenon.

Research has taken an obvious interest in lucidity in recent decades and findings have been increasingly progressive. But the question may arise, how is it possible to communicate with someone while they're asleep? How are scientists drawing conclusions about an individual's dream awareness while they're snoozing away on a "research" mattress? The current gold-standard method of lucid dream signaling in research settings is called left-right-left-right (LRLR) eye movement. Researchers are able to note

the precise moment when dreamers enter a lucid state by identifying the outlined action using electrooculograms (EOG). This method was discussed in a 2018 study headed by Stanford University's Stephen LaBerge and Baird. While awake, participants were instructed to repeat the ocular movements once they've achieved and recognized their awareness during a dream. Researchers can then accurately monitor when dreamers carry out pre-sleep tasks in their lucid state, which are confirmed by participants' dream recollections once they wake. The method was utilized by Karen Konkoly, a cognitive neuroscientist at Northwestern, in which "researchers spoke yes-or-no questions or math problems in the sleepers' ears" once they signaled lucidity. This 2021 study yielded unprecedented results in which "29 total correct responses came from six different people" over 158 attempts.

There are, however, continued limitations to studying lucid dreams, one of the most prominent being the lack of a sample population available for researchers to study. A 50-year analysis of sleep research showed that only about 55% of individuals have reported experiencing a lucid dream once in their entire lifetime, with 23% falling into lucidity once a month and less than 1% pioneering their dreams more than once a week. Even once researchers are able to produce a significant sample size of dreamers for their study, consistently inducing lucidity has proven to be an additional obstacle of uncertainty.

As the science continues to broaden and new observational techniques are being trialed for more considerable implementation, clinical applications have already entered the discussion for future directions. Lucid dreaming techniques are being considered for potential therapeutic effects that could benefit those struggling with chronic and recurring nightmares, especially those associated with PTSD, by exercising control over their dream actions. The research behind lucid dreams is constantly evolving, and with its recent boom in the world of sleep science, the advancements of today are sure to be only a gateway into a future of further understanding.

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PHOTO VIA SHUTTERSTOCK

SUBCONSCIOUS COMMUNICATION

WINDOWS OF AWARENESS

DISCOVERED DURING SLEEP

BY MAYA BRINSTER, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

It is widely believed that one is completely disconnected from the outside world during sleep, unreactive to anything happening around them. New research, however, reveals that this may be far from the truth; in a recent study, researchers led by Delphine Oudiette, Isabelle Arnulf, and Lionel Naccache at the Paris Brain Institute found that during certain periods of sleep, people are able to process and accurately respond to external information at a high level of cognition.

Prior research has shown that there is active unconscious sensory processing during sleep, such as the learning of new information or processing of external stimuli, at least occasionally. Most research studying consciousness during sleep, however, does not account for variation among populations, which makes it difficult to generalize and confidently draw conclusions about findings when studying such a complex topic. Because of this, Oudiette, Arnulf, and Naccache's team sought to obtain more subjective data by analyzing behavioral responses, which are often assumed to be impossible during sleep and therefore neglected in previous research.

In the past, the team showed that people could respond to questions sent while experiencing REM sleep, in which they are conscious of being asleep and dreaming. In this recent study, they wanted to study consciousness in almost all sleep stages and examine neural activity in addition to behavioral responses to stimuli during the trials. Researchers studied brain activity and eye and facial movements of 49 napping participants to determine whether communication is possible during REM sleep, in which sleepers are most responsive, and most other sleep stages. 27 of these participants had narcolepsy, a sleep disorder that causes excessive daytime sleepiness and uncontrollable sudden sleep attacks. Narcoleptic individuals tend to quickly and easily enter the lucid REM sleep stage, in which they are aware of being asleep. The higher likelihood of lucid dreaming made them the ideal candidate, as researchers predicted that participants would be most responsive during this stage due to their past work.

Participants performed a lexical decision task while napping – they either smiled or frowned depending on whether a verbal stimulus, presented in one-minute periods alternating between off and on, spoke real or fake words, respectively. Electromyogram (EMG) sensors, which detect muscles' electrical activity, recorded contractions associated with frowning and smiling to generate behavioral data. Researchers also analyzed electrophysiological markers,



such as specific brain signaling patterns, associated with higher and lower cognitive states, or states of increased and decreased brain activity, respectively, in order to determine whether a richer cognitive state during stimulation corresponded with higher response rates.

Participants in both categories displayed a response accuracy of at least 70% across all sleep stages, although accuracy and response rates decreased with the depth of the sleep stage. Interestingly, those who entered lucid REM sleep could explicitly recall performing tasks, whereas those who did not lucid dream were unable to. Responsiveness is also correlated with brain activity during sleep, a more complex brain state with faster brainwave oscillations prior to the verbal stimulation corresponded with higher response rates, which suggests that higher cognitive levels correspond with a greater ability to produce behavioral responses to external stimuli during sleep.

These results reveal that there exist transient windows during sleep in which humans can respond to external stimuli. Naccache explains "Our research has taught us that wakefulness and sleep are not stable states: on the contrary, we can describe them as a mosaic of conscious and seemingly unconscious moments." This discovery opens doors to a variety of clinical applications and further research investigations. According to Oudiette, this could lead to the development of new sleep communication protocols, advancing research investigating sleep disorders or how brain activity during sleep impacts consciousness. Communicative windows could potentially be used to better treat sleep disorders, facilitate learning during sleep, or, excitingly, communicate with sleeping individuals during various sleep stages. Maybe someday you will be able to learn the answers to questions you have been dying to ask your partner or friends without them even knowing! These cutting-edge findings serve as the foundation for an entirely new way of studying and defining sleep, and will lead to exciting possibilities in the future.

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PHOTO VIA SHUTTERSTOCK



Music Moves the Brain

BY ALYSSA LEE, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY KATHRYN FURMAN, COMPUTER SCIENCE AND MATH, 2025

If you want to improve your academic level, take a music class! Studies have shown that taking music lessons can improve your academic ability. There is only one catch: you need to start your lessons ... 18 years ago. Children who take music lessons have improved academic ability in the future at the college level. Fortunately, there is no need to fret — learning an instrument also has positive implications when it comes to aging. It improves cognition and memory and can protect against age-related diseases such as dementia and Alzheimer's. However, what exactly is this magical connection that can turn ordinary children into geniuses or reverse memory loss that happens with aging?

Music training has been shown to change the structure of the brain, known as brain plasticity. Brain plasticity is what allows us to learn new things, from skills like coding to the entire Krebs cycle from biology class. For every new thing learned, the brain's structure changes. It makes sense that learning a new instrument also causes a change in brain structure, so why are we focusing on music and not another arbitrary topic? The special result of learning music is that it changes structures in the brain other than the ones specifically used for making music. A group of researchers from Beth Israel Deaconess Medical Center found that white matter increased in the temporal lobe in adults who could identify the tone of a pitch compared to adults who could not. Auditory processing occurs in the temporal lobe, explaining why we see this change happening there related to exercises that musicians have experience in.

In contrast, circling back to the study mentioned earlier, engagement in musical training during childhood was actually able to predict academic performance at the college level. When the brain changes, it does not just change randomly. Different parts of the brain have specific functions that cause structures in the brain to grow or shrink depending on how often they are used. There are connections between neurons called synapses. As a person repeats an action, such as playing the piano, the brain prioritizes the connections responsible for playing the piano, such as areas related to memory, auditory, and motor function. As a person plays the piano more and more, these connections become even stronger. If this person starts to play the piano less, these connections will start to weaken, and eventually the connections will cease to exist altogether. We can understand the changing brain better by looking at studies that show how music changes the brains of music makers, from children to adults. Sima Anvari and his team of researchers from McMaster University in Canada found a positive correlation between pitch perception and reading abilities. Broca's area is an area of the brain that is activated when we

produce language. Elif Ozdemir and his lab have shown that as adult singers actively sing, Broca's area is activated. The same changes that occur when children play instruments also occur when children are learning vocabulary words, how to speak, and how to read, demonstrating how pitch perception and reading abilities have a positive correlation.

While learning how different structures can change by playing music during childhood development is interesting, it does not stop there. Learning music has been shown to require communication between different areas in the brain. The usage of all these different areas in the brain has been hypothesized to delay cognitive impairment with age. A twin study by Alison Balbag, Nancy Pedersen, and Margaret Gatz found that the twin who played an instrument had a lower chance of developing dementia compared to the twin who did not play an instrument. They controlled for sex, education, and physical activity as confounding factors.

There is a lot of data that suggests that music changes the structures of the brain, which, in turn, can lead to altered behavior, such as improvement in class or decline of aging. However, a lot more data needs to be produced on this idea in practice. The studies that exist about the effect of music on non-musical actions are highly correlational and many do not account for confounding variables. Additionally, a question has come up of whether the music making itself is responsible for some of the brain structure questions or if some people are born with some of the brain structures that then give them an affinity for and attraction towards music. Some studies, especially longitudinal studies, have sought to find that music is what causes these brain changes, not the other way around. More of these longitudinal studies should be done in order to establish this link.

Ultimately, music has benefits throughout our lifespans and it is never too late to learn an instrument and improve your brain health!

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PHOTOS VIA SHUTTERSTOCK

MINDFUL EATING

SAVOR EVERY BITE

BY HEIDI HO, PUBLIC HEALTH & JOURNALISM MAJOR, 2027

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

You enter the dining hall and see different cuisines such as Asian lo mein, Mexican carne asada, and Italian pasta; your mouth starts to salivate ... it all looks scrumptious and delicious! Food tastes amazing and sometimes you may eat more than you plan to or don't have any vegetables on your plate. Unfortunately, you are not alone. Obesity is one of the two leading causes of death, contributing to a 42% prevalence rate in 2017 and costing the U.S. 173 billion dollars. On the opposite end of the spectrum, incidences of eating disorders such as binge eating and anorexia nervosa have also skyrocketed. With the COVID-19 pandemic exacerbating the issue, the National Eating Disorders Association helpline has received an increase of 70–80% of calls as of 2021. Lifestyle modifications and mindset shifts are critical for recovery. Mindfulness eating is a great starting point for those willing to take back control of their lives and eating habits. Although everyone benefits from mindful eating, it is also a promising strategy to reduce the prevalence of obesity and eating disorders.

Mindfulness is a term that originates in Zen Buddhism — it is the practice of being present. Mindful eating focuses on the senses that eating evokes. It has nothing to do with calories, protein, and carbohydrates; instead when we eat mindfully, we appreciate our food. We chew thoroughly — feeling textures, temperatures, tasting flavors— and savor everything. We should eat when we are hungry and take note of how eating food makes our bodies feel. The farm-to-table process is lengthy and requires extensive collaboration between many individuals. Before we dig into a piece of buttered chicken and rice, we need to ask ourselves, "How did my chicken curry end up on my plate?"

When we eat mindfully, we eat without distractions. While socializing with friends and family can supplement mindful eating, eating a meal in front of a screen can actually encourage mindless eating. Other ways we unintentionally commit acts of mindless eating is when we eat while we are doing something else, such as driving or working. According to a literature review published in the Cambridge University Press, when we take our time to enjoy a meal, we are more likely to eat to our stomach's content.

Mindless eating is analogous to skimming a text while

mindful eating resembles a close read where we are able to digest every piece of thought critically. When we avoid a deprivation mindset and savor every grain of rice and fiber of chicken, we are empowered to give our bodies the proper amount of nutrients, therefore having a happier meal.

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PHOTO VIA SHUTTERSTOCK



BLUE ZONES

Lessons from the longest lived

BY ANANYA JAIN, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Living to 100 years old and beyond is no doubt one of the greatest privileges that life can offer. As of 2021, just over half a million people — less than 0.01% of the world's population — are centenarians, a remarkable figure nonetheless. However, to live to 100 years old and be riddled with the pains of chronic diseases, doctor's visits, and the wearying atmosphere of a nursing home would resemble more of a prison than a privilege — over half of adults would rather die than live in a long-term care facility. Longevity researchers are tasked with unraveling the mystique behind a long and happy life, whether it stems from genetics, diet, or environment, and simulating those secrets across the globe.

Author and researcher Dan Buettner has spent the last two and a half decades traveling the world to gauge the environments of the longest-lived. As a pioneer in his field, he coined the term "blue zones" in 2004 to describe regions in the world where inhabitants are statistically more likely to live to 100. With dozens of published books, speaker events, and even a Netflix docuseries, he has observed five blue zones whose communities nurture exceptional lifestyles: Sardinia, Italy; Ikaria, Greece; Nicoya Peninsula, Costa Rica; Okinawa, Japan; and the Seventh Day Adventists of Loma Linda, California. As a U.S. native and fitness enthusiast (a Guinness-world-record-holding kind of enthusiast) himself, Buettner and his team at *National Geographic* sought to identify and apply their findings to American cities.

The habits Buettner and his team observed can be summarized into nine major categories, which are believed to extend both life expectancy and quality. From the Okinawans, they learned the term "ikigai," which closely relates to the Nicoyans' "plan de vida." Both signify that one should have an internal purpose in life. Food was a major aspect of longevity as well; most communities have one to two alcoholic drinks daily, focus on eating locally grown vegetables and legumes over meats, and eat until only 80% full. Preventing overconsumption is a key element in Okinawan society verbalized by the Confucian mantra "hara hachi bu." Finally, three categories revolved around a sense of community achieved through faith-based groups, surrounding oneself with lifelong friends, and living in joint homes.

Interestingly, none of the towns Buettner traveled to had nursing home facilities, nor was it the social norm to avoid living with grandparents. On average, nursing homes reduce average life expectancy between three to four years,

but they are still widely used, especially in the United States. Effective stress management is a contributing factor to their esteemed health too, as the Ikarians tend to nap while the Adventists pray. In an effort to reduce the risks of chronic and inflammatory diseases, these centenarians live in areas that encourage natural movement such as walking or gardening.

While lifestyle is a significant factor in longevity, genetics also plays a substantial role. If lifestyle was the only variable responsible for longevity, the percentage of centenarians could be drastically larger. A 2022 study found that 40% of life expectancy is determined by one's genome. The remaining percentage is impacted by environmental and mental factors that can mark the difference between a prison and a privilege.

In 2008, Dan Buettner gathered a team to replicate the habits he observed within the 9,000 residents of Albert Lea, Minnesota. The town rallied behind the project and embraced the prospect of becoming a blue zone. They created plant-based options in local restaurants, removed candy from local schools, and built ample walking paths. Through questionnaires and comparative tests, resident life expectancies increased by 3.2 years, the town collectively lost 7,280 pounds, and average healthcare costs dropped by 40%. After the remarkable success achieved in only one and a half years, Buettner's team traveled to 27 other American cities to do the same.

Interviews with centenarians in the original Blue Zones docuseries reveal their admirable zest for life. Incorporating the nine habits observed by Buettner can empower us to embrace a similar vitality. Dr. Ellsworth Wareham in Loma Linda assisted with heart surgeries until his mid-90s. 101-year-old Umeto Yamashiro in Okinawa regularly dances and plays games with her great-grandchildren, living by the philosophy of never getting angry. To live as long as these people do and still be thriving physically, socially, and mentally is a testament to the environment they've created for themselves. With these success stories at hand, longevity researchers can hope to someday make every zone a blue zone.

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PHOTO VIA SHUTTERSTOCK

Unveiling Mayan mysteries

Modern physics revolutionizes archaeology research

BY AANCHALIKA CHAUHAN, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING & DESIGN, 2024

Buried within blooming jungles in northern Guatemala lie ancient Mayan settlements with detailed palaces, monumental pyramids, and even ball courts for competitive sports. Within the archeological community, it had been generally accepted that this area in Northern Guatemala, known as the Mayan lowlands, was sparsely populated throughout history. However, with the help of modern technology, archeologists have identified over 1,000 ancient Mayan settlements, dating back to 1000 B.C.E, exhibiting infrastructure significantly ahead of its time.

Richard Hansen, a researcher at Idaho State University, is the lead author of a study identifying Mayan settlements using new technology and the director of the Mirador Basin, a group based in Guatemala dedicated to studying and protecting the Mayan lowlands. In collaboration with researchers from the United States and Guatemala, Hansen utilizes planes with lidar equipment to analyze the Mirador-Calakmul Karst Basin in Guatemala, an area spanning 1.6 million acres of tropical rainforest.

Planes with lidar and light-detecting equipment provide a special advantage to studying these areas because rather than exploring these areas on foot, a difficult task when these settlements are covered in vegetation, researchers can quickly identify and discern ruins of interest. A lidar sensor emits lasers into the area below the plane which then bounce off objects and return to the lidar sensor. Given this information, the lidar sensor can calculate the time it took for the laser to return and determine the distance the pulse traveled. This information is then processed using specialized software programs to create three-dimensional models of the settlements. Using this technique, researchers can remove the vegetation and produce settlement models without

harming the existing wildlife. Carlos Morales-Aguilar, a co-author of this research and a researcher at the University of Texas at Austin, states, "You can map in minutes what we once mapped in years."

Importantly, Hansen's group made this landmark accomplishment without harming existing wildlife in Northern Guatemala. The United States Agency for International Development reports that wildlife in Guatemala is at significant threat due to the trafficking of flora and fauna, climate change, criminal activity, limited governance, and lack of funding for restorative projects. As scientific and historical advancements continue, it is important to consider ecological impacts and develop techniques that preserve wildlife and promote climate awareness, such as the lidar sensor.

Within the past few years, archeologists have discovered fascinating findings; for example, the city of El Mirador was uncovered, containing "La Danta," a pyramid towering at 230 feet, among the largest in the world. In addition, the lidar data revealed detailed canals, temples, dams, ceremonial complexes, and over 100 miles of raised roads that have been deemed as the "first freeway system in the world." Not only does this reveal the extensive architectural capabilities of the Mayans, but it also demonstrates their ability to organize workers, planners, and architects to develop an expansive empire. In essence, without lidar sensors and a partnership with modern physics, the remarkable advancements of the Mayans would remain unknown to the world.

Cambridge University Press (2022). DOI: 10.1017/S0956536122000244

PHOTO VIA SHUTTERSTOCK



THE MAGIC BEHIND MISINFORMATION

BY SAMADHI WIJETHUNGA, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Social media's individualized, instant, and streamlined communication provides users with up-to-date information on world events, community opinions, and trending memes. However, with the uptick in AI-generated content and extremist views, social media can be incredibly deceptive, with the gap between fact and fiction looming larger and larger. Most recently, the New York Times reported that misleading information regarding the Israel-Hamas war has impaired the authenticity of news outlets and social networks, such as X (formerly known as Twitter), Instagram, and more. Misinformation and social division influence one another, perpetuating a cycle of increasingly polarizing views. At its core, misinformation can be defined as a type of illusion, where perception and interpretation are at odds with reality. To understand the fundamental techniques of illusionary observation and thought, researchers at the State University of New York Downstate Health Sciences investigated how magicians deceive their audience. These findings are key to discovering how to best combat misinformation, either as an audience member at a thrilling magician showcase or as a consumer of global digitized news.

Due to the finite amount of information humans process at a given time, psychologists believe that "attention" is a method used to emphasize a particular part of sensory information. As our attention shifts toward the item of focus, the human attentional system clouds the importance of everything else in that setting. Magicians take advantage of our narrow attentional system by utilizing a number of techniques that overwhelm our processes. For example, a sleight-of-hand technique along with storytelling might emotionally and cognitively engage the audience; while the audience is distracted, a gesture is likely to go unnoticed. Similarly, social media users are inclined to miss slight disconnections or reframings of a story when they are overwhelmed with information. Research suggests that watching videos containing multiple moving parts can prevent people from noticing important shifts in data. When moving parts are presented in rapid succession, it is also likely that viewers are unable to verify the accuracy and fact-check the information presented. This is a dangerous phenomenon in media consumerism, especially when streamlined information is received on a small ever-changing screen. The themes within images, videos, and text are viewed amidst a busy workday, resulting in a lack of time and effort to verify facts and shifts in developing stories.

Our internal illusions — prior biases, expectations, and memories — heavily influence our concluding thoughts and values. Magicians use these illusions to predict the audience's understanding of a particular trick, concealing a palmed coin or making a coin reappear. In the same way, we tend to trust information that is consistent with our preexisting ideals and notions. Confirmation bias — a term used to describe people who search for, interpret, or recall data that supports their beliefs — can often push people to disengage from differing information and new perspectives. Ultimately, users may reach a state of "social media fatigue" as new contradicting, unfamiliar, and uncomfortable information surfaces. However, to manipulate our biases, magicians use the power of repetition to overshadow our memories, recasting our experiences and then repeating these false events. Researchers propose that the repetition of highly irrational and implausible facts strengthens its credibility. In parallel, the way in which we process and encode memories can permanently shape our perception of an experience. Thus, although users can follow organizations, influencers, and brands, or interact with content they enjoy, their algorithm is still regulated to regurgitate the same information.

To battle these forms of misinformation, experts encourage creating an identifier to mark potentially inaccurate information. While this strategy may minimize the spread of misinformation, it doesn't completely prevent the issue. Researchers also found that viewers of media will often ignore the warnings altogether. In contrast, when people come to view these warnings as indicators of inaccurate posts, they might mistakenly assume that any post lacking a warning is accurate, when, in reality, that is not the case.

Similar to the audiences at magician exhibits, it seems we are no better than unaware, mindless audience members, vulnerable to the exploitation of perceptive and cognitive illusions. The reduction and elimination of misinformation, though tricky, requires a multifaceted approach, researchers say — one that has the rigor to battle deceptive media monopolies.

Publications (2022). DOI: 10.3390/publications1004003

PHOTO VIA SHUTTERSTOCK



THE SCIENCE OF SUPERSTITION

BY DESSY DUSICHKA, COMPUTER SCIENCE & BIOLOGY, 2025
DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Former Red Sox player Wade Boggs, known as the “chicken man,” famously ate chicken before every one of his games as a good luck charm. Boggs told MLB.com, “In 1983, we ate chicken every day, and I wound up winning a batting title in ‘83. So, the chicken worked.” While this pre-game ritual may have supplied Boggs with protein and energy, it’s unlikely that chicken directly caused his baseball success. Regardless, this was still a habit he never broke.

Boggs is certainly not the only person to exhibit superstitious behavior. Many people practice rituals before big games, exams, or interviews while others believe in good luck charms like lucky socks or four-leaf clovers. Boggs’ thinking illustrates the illusion of causality, the belief that one event causes another when in fact, the two events do not have any causal relationship.

Superstition is prominent in many cultures; one commonality across superstitious beliefs is that they tend to assume implausible or illogical causal relationships, almost akin to magic. And yet, people who recognize the limited logic underlying these beliefs continue to follow them. In fact, according to a 2022 review, scientists have failed to definitively link paranormal and superstitious beliefs with lower academic achievement and intelligence. This signals that it is not a lack of intelligence that prompts causal superstitious thought. Rather, these illusions can influence anybody, since the human brain naturally tends to draw causation from coincidence, shedding light on the human nature of rationality.

Superstitions bring about feelings of safety and reward and often have very little cost associated with them. One paper also notes that they tend to be “prevalent in conditions of absence of confidence, insecurity, fear and threat, stress and anxiety.” Given the number of events out of one’s control, superstitious rituals allow people to have increased feelings of control over their lives — purposely avoiding the number 13 or shattered mirrors makes people feel like they can prevent negative fates. Furthermore, most of these actions have a very low cost associated with them and potentially great reward. It’s easy to carry a good luck charm or forward a chain email; it’s a lot harder to deal with a bad exam grade or have a “curse” follow you around.

The feeling of safety after a simple ritual is well worth it for many superstition believers. This illustrates the illusion of control, a psychological phenomenon that causes humans to believe that their own intervention directly produces a resulting event, even when it likely does not. One study found “a direct relationship between a person’s level of self-reported superstitious belief and both the likelihood of experiencing an illusion of control and its perceived magnitude.” This highlights the tendency of these individuals to conflate results with certain actions, even when there is limited rational evidence to support these connections.

Another study explained that “superstition has its roots in our species’ youth, when our ancestors could not understand the forces and whims of natural world. Survival of our ancestors was threatened by predation, or other natural forces.” Thus, many superstitions came about because they brought protection to previous generations. For our ancestors, causal illusions were sometimes the only way to make sense of the world, and the longevity of this phenomenon shows how it is a natural human reaction.

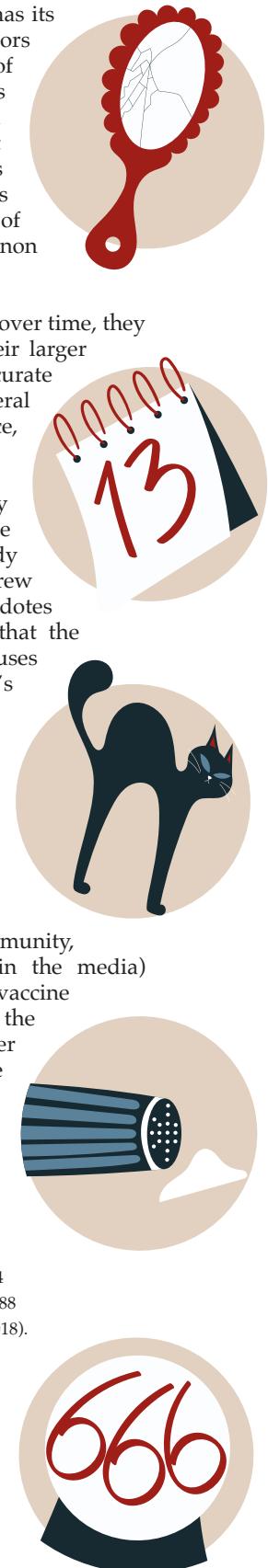
Although illusions of causality have evolved over time, they are crucial to consider today because of their larger societal ramifications. Amplification of inaccurate causal relationships can create harm in several areas including, but not limited to, science, medicine, and politics.

One notable example is the surge in popularity of the anti-vaccination movement in the late 1990s, triggered by a misleading study conducted by the now-discredited Andrew Wakefield. This study, a case report with anecdotes about 12 children, erroneously concluded that the measles-mumps-rubella (MMR) vaccine causes autism. An article summarizing Wakefield’s paper and its aftermath clearly explains the causal illusion, stating that “many children have autism and nearly all take the MMR vaccine. Finding in this case that among a group of a dozen children most of them happen to have both is not at all surprising. And it in no way proves the MMR vaccine causes autism.”

Despite being rejected in the scientific community, Wakefield’s paper (and its amplification in the media) reigned a dangerous global movement of vaccine skepticism. This flawed study highlights the danger of causal illusions, since a researcher mistakenly linked factors without true scientific correlation, sparking vaccine refusal that continues to threaten public health today. In an age where misinformation driven by superstitions is easily disseminated, it is crucial to be aware of cognitive biases like the illusion of causality.

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PHOTOS VIA SHUTTERSTOCK



Opinion: Deducing the truth behind the numbers of election season

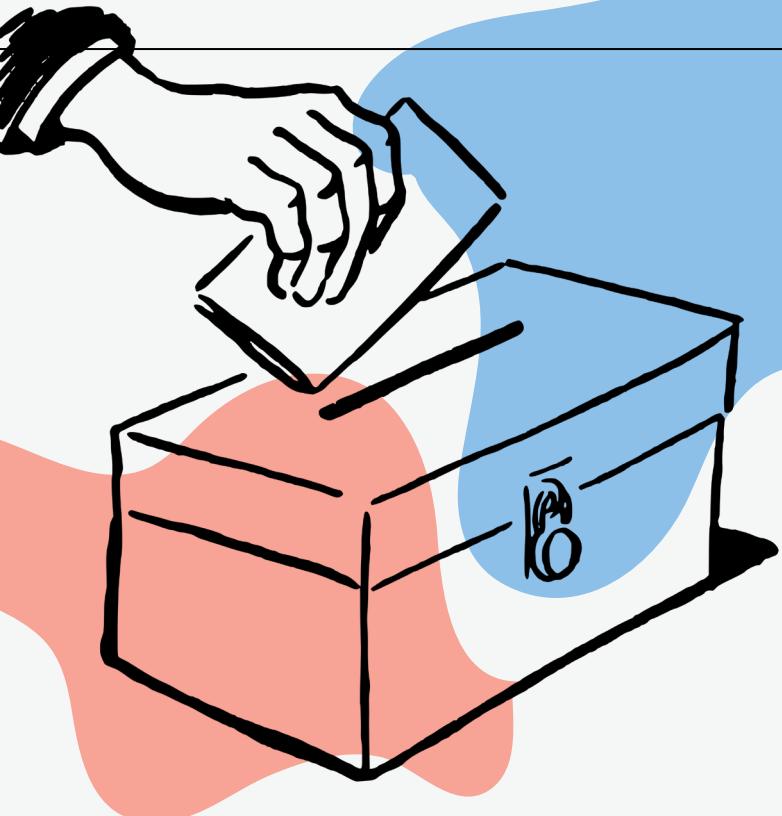
BY LILLY SCHAR; HISTORY, CULTURE & LAW; 2025

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

Those of us locked into the political world like to say there are “no days off” when it comes to working on and thinking about elections. But for those who are not at the mercy of the 24-hour news cycle, let me set the stage for you: We are mere months away from the start of the Republican presidential primaries where Donald Trump is almost certainly going to clinch the Republican nomination, after which he will face off with Joe Biden in November (possibly from federal prison) in an inevitably close election. Feeling any déjà vu?

I certainly am feeling a familiar sense of dread, which is why staying committed to being an informed voter is more important than ever. Voting and convincing others to vote is necessary for democracy. Voting is how we, the people, ensure our government reflects and protects our best interests. Staying informed, however, can be easier said than done. We are constantly being bombarded with information from all sides, and discerning the accuracy of facts and analysis of data to draw your own conclusions is increasingly difficult. Particularly when those facts have failed us before, it is our responsibility to account for the context in which those facts have appeared.

Voting is a hallmark of democracy, and to keep the government accountable, public polling can be used to gauge citizens’ thoughts on several issues to conclude how well the government is operating. Although many citizens rely on polls to gauge how their interests align with their parties and candidates, public polling is not a perfect science. The imperfection of public polls was prominent in the 2016 election when Trump’s win over Hillary Clinton shocked the left and contradicted numerous polls that put Clinton in the Oval Office. The disappointment and distrust that followed warrant a closer look at how polls are conducted and what conclusions can be drawn from them.



First, we need to understand the context of conducting polls. Numerous media outlets use differing techniques to conduct their own public polls. Pew Research compared six different sources and their own polling techniques. The study found that the use of opt-in survey samples yielded largely inaccurate results about public opinion. Although they are more cost-efficient and accessible to a broader population through the internet, opt-in surveys are more likely than probability surveys to yield inaccurate and unreliable results. Results from opt-in surveys draw from random samples of responses that do not account for the target demographic of a particular question. In the realm of U.S. politics, opt-in surveys are additionally susceptible to bogus responses from non-citizens who intentionally answer surveys multiple times in order to skew results. If pollsters insist on using opt-in polls for the mass convenience, it should also be their responsibility to scrutinize panel samples to ensure that the results accurately reflect the attitudes of respondents. Considering a news source and how that source conducts research ensures an accurate understanding of the information generated. Taking the time to go one step further by investigating the methods of a source is always worthwhile.

The samples from which survey conclusions are drawn are additionally important because targeting or accounting for specific demographics can distort results. In 2016, several polls showed Clinton with a healthy lead over Trump. The wide margin in polling between Clinton and Trump led to widespread belief that Clinton would easily secure the win on election day. Pew Research identified several possible explanations for the disparities in polling, estimating that likely culprits were nonresponse bias and errors in the methods pollsters used to identify whom to poll. Both of these factors led to polls that did not account for the people who would actually go on to vote in the 2016 election. I remember

when I woke up on Nov. 9 my heart dropped because I was so certain that Clinton would not just win, but win easily. Like the polls, I failed to account for those disillusioned from voting and responding truthfully to polls. I assumed certain demographics would vote for Clinton without doing the research to back that assumption up with evidence. Encased in a blue bubble, my false confidence led me to see Clinton's win as inevitable. Needless to say, I'm doing what I can to prevent my heart from dropping like that again — fool me once, fool me twice.

Besides the polls themselves, current events and the time between the poll date and the election date should influence how we interpret the results. Polls released a year out from an election date are extremely unlikely to predict the results of that election. Any such polls that claim with certainty how some race has already been decided without accounting for a year's worth of campaigning and global and national events are not to be taken seriously. Even polls released considerably closer to Election Day may not accurately predict that election. A Reuters poll released in August 2008, three months away from the November 2008 presidential election, showed John McCain had a five-point lead over Barack Obama. But, by mid-September of 2008, the worst financial crisis since the Great Depression dominated headlines and continued to do so through Election Day, leading to increasingly negative coverage of McCain. In 2013, Pew Research studied the effect of the crisis on the 2008 election. They found that in the critical five weeks leading up to the election, negative coverage of McCain largely outweighed the positive. By examining their own polls from those weeks, they found that McCain and Obama were polling evenly one week before the financial crisis, but every poll conducted after found McCain trailing Obama by at least six points. This example further illustrates how current events influence public opinion.

Bringing it back to the 2024 election, we should be using previous mistakes to revise our analysis of information generated today. We can comfortably predict the likelihood of Trump as the Republican nominee, and many polls have shown him neck and neck with Biden. The release of a poll

from ABC News and The Washington Post that gave Trump a 9-point lead in particular drew national attention. If one were to only read the headline of that poll without reading up on the methodology or accounting for the context of the poll, it might seem like that poll spells out the beginning of an end. But even as pollsters continue to investigate and treat the flaws in their methods, outlier polls are unavoidable. Identifying an outlier poll can be tricky, but one good tip is to compare that poll to others that ask the same question. ABC News and The Washington Post did the work to investigate why their poll differed so greatly from the average of national polls taken by higher-quality polling institutions. They identified the possible factors as partisan nonresponse bias and sample error. Interpreting outlier polls can be slightly more complicated. Although it is inadvisable to use one poll as the foundation for our political understanding, there is also a danger in cherry-picking polls with results we find favorable and discarding those we do not. Exploring the results of an outlier poll in the context of others — not just comparing results but actually comparing methodology and margins of error — can help situate the outlier poll either within the range of results or help us conclude that we can discard it completely.

Polling is not perfect. For every election, not just presidential elections, polls can only gauge the errors in their methodology and results after the election has accounted for all votes submitted. There will never be a poll that will account for the entirety of public opinion. If you want your voice heard, my advice is to vote. What polls cannot account for in public opinion we must make up through the ballot. Vote in local elections, vote in state elections, vote in national elections, just vote.

PHOTOS VIA RAWPIXEL & SHUTTERSTOCK

From nowhere to Nobel

BY DIVYA RAVIKUMAR, BIOENGINEERING & BIOCHEMISTRY, 2025

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

Katalin Karikó, the 13th woman to be awarded the Nobel Prize in Physiology or Medicine, was initially demoted from her position at the University of Pennsylvania for the same research on messenger RNA (mRNA) that won her the achievement in 2023.

Katalin Karikó and Drew Weissman jointly received the award in October for their chemical modifications to mRNA that prevent the immune system from sending an inflammatory response when it enters the body. Their research laid the foundation for the development of mRNA vaccines, which later became critical to fight the COVID-19 pandemic. However, until recently, their decades-long research was met with skepticism, and it was an arduous journey to receive support and funding for them to continue their work.

Before the pair began their research, mRNA was not believed to be a viable avenue for vaccines because it triggered a harmful immune response. When Karikó and Weissman started collaborating in the 1990s to address this issue, they discovered that natural mRNA formed within cells displayed additional chemical modifications that lab-manufactured mRNA lacked. They experimented with different modifications to lab-made mRNA and injected immune cells to observe their behavior, and they were successful in reducing the inflammatory response. However, their 2005 paper detailing their findings was dismissed by the majority of the scientific community, including *Nature* and *Science*. It was finally published in the small journal *Immunity* before being recognized by Moderna and BioNTech years later.

Karikó had been pursuing mRNA research long before meeting Weissman at UPenn, fully believing in its potential even though many around her did not share the same sentiment. Because she struggled to secure grants and resources, UPenn demoted her multiple times and cut her pay, regardless of any progress she showed. Undeterred, she hopped from lab to lab to continue her work until she landed in Weissman's lab, which initially wanted to develop a vaccine against HIV. Karikó's higher-ups at UPenn remained skeptical of her mRNA vaccine research throughout her entire employment and forced her to retire in 2013, citing that she was not "faculty quality." At the same time, Karikó and Weissman's work on mRNA modification was taken up by Moderna and BioNTech in the early 2010s to focus on

creating vaccines for MERS-CoV, the Zika virus, and others. Karikó left UPenn to become the vice president of BioNTech and later found herself at the forefront of the COVID-19 vaccine development.

When the need for a COVID vaccine became apparent, BioNTech, who partnered with Pfizer, and Moderna were able to hit the ground running thanks to the mRNA vaccine research they already had in progress. All strains of coronavirus are known for the spike protein on their surfaces, which helps the virus enter human cells. The mRNA vaccines from Moderna and BioNTech-Pfizer targeted that spike protein so that cells could build an immune response to prevent the virus from entering, and both vaccines contained the modification that Karikó and Weissman had discovered over a decade ago. Without their pivotal work and perseverance, the pandemic response could have taken an extremely different route.

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After the efficacy of mRNA vaccines was demonstrated with COVID, the concept has since gained popularity and transformed the biotech industry. Companies are currently trying to develop treatments with mRNA technology that target a variety of diseases, including cancer, and Karikó and Weissman's research lies at the core. Karikó's Nobel Prize is a symbol of recognition for decades of groundbreaking work that was constantly dismissed. However,

it has prompted the discussion that her struggle to be heard likely stemmed from being a woman and a foreigner in a male-dominated field. When people learned of Karikó's backstory after the Nobel Prize was announced, UPenn received backlash for its past treatment of her. Instead of responding to that criticism, the university released a statement of celebration, emphasizing its association with Karikó and Weissman while they worked on their research.

Being one of the handful of women awarded the Nobel Prize in Physiology or Medicine in its entire history after an uphill battle is an inspiring story. However, it also serves as a reminder that there are many scientists in similar situations working on important research that may get swept under the rug because people are unwilling to understand their visions. Their research may also, one day, prove to change the landscape of a field, just as Karikó shifted biotech with mRNA therapeutics.

Artificial intelligence in the world of modern science

BY DANIELLE BERDICEVSKY, BIOLOGY & MATHEMATICS, 2027

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

Previously unimaginable galaxies billions of miles away are now at our fingertips thanks to modeling powered by artificial intelligence. Artificial intelligence (AI) is the ability of a machine to learn from experience and carry out functions similar to the human mind. AI works by recognizing patterns from large data sets and making decisions similar to those of humans based on some sort of judgment encoded in an algorithm. If successfully implemented, the use of AI can transform the practice of science and alter the roles that humans play within the scientific community.

One of the many sciences that AI has greatly benefited is physics. A specific use of AI is called generative modeling, a strategy that produces a distribution of possibilities and their probabilities. In physics, it is currently being used to look at different galaxy shapes. Based on data that has already been collected, generative modeling collects information and spits out different possibilities for each galaxy. This allows researchers to quickly make hypotheses about what a galaxy will look like, making astrophysical research significantly more efficient.

AI is also proving useful in drug development since AI algorithms can analyze large datasets of chemical and biological information to identify potential drug candidates. This process makes the identification of compounds more efficient, reducing the time and cost in the initial stages of drug development. AI modeling and predictions can simulate the effects of potential drugs on the human body as shown in a recent study conducted by Rizwan Qureshi and their team. AI-driven robotics are also incredibly helpful when

performing research. Robotic systems can run experiments at all times of the day, making the drug development process even more efficient.

In the field of nursing, AI is transforming the way healthcare professionals deliver patient care. The Rothman Index, a machine learning algorithm used to quantify a patient's condition, acts as a "first set of eyes" because it is used before a nurse's opinion. The index continuously monitors patients' vital signs and alerts healthcare providers when any quantities are out of range. Nurses can monitor these metrics, increasing the efficiency of care and quickly identifying patients in need of attention. The Rothman Index can improve patient outcomes and reduce healthcare costs, highlighting the power of AI in clinical settings.

However, there are many controversies and challenges associated with the increasing role of AI. People often bring up concerns about data privacy, algorithm bias, and job displacement in many fields. Ethical questions surrounding the use of AI in decision-making, especially in healthcare, need to be addressed before making it becomes standard practice. Many people are struggling to understand and create a balance between AI capabilities and human decision-making. Despite the controversies and challenges, AI has made many scientific practices more efficient and, if used correctly, could continue making groundbreaking changes to the scientific world.

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PHOTO VIA RAWPIXEL



OPINION: IS SCIENCE UNIVERSAL? DISSECTING SCIENTIFIC BELIEF

BY CJ CROMBIE, CELL & MOLECULAR BIOLOGY, 2026

DESIGN BY CARINA HALCOMB, EXPERIENCE DESIGN, 2023

Science is indisputable, empirical, objective. Or at least, it's supposed to be.

The practice of science is methodical; designed to produce universally accurate knowledge. Ironically, there is a long and nuanced history of the cross-cultural approaches to science and knowledge. Science is, in other words, uniquely plagued in epistemology.

Science does not have to be so divisive, but the Western hemisphere — the United States in particular — doesn't seem to agree. In this part of the world, science is so often weaponized as a tool for political polarization, framed as an innate opposite of the word *belief*. Fueled by ethnocentrism, warped cultural definitions mark the difference between science and belief.

Perhaps the best example of this is medicine. The Western medical system is essentially founded upon modern science: Clinical practices are unquestioned and immensely authoritative. There is no treatment that is not backed by rigorous trial, and rarely is a diagnosis made that is not understood in the context of biological science. The dichotomy between science and culture is severe, leaving little room for interpretation.

As a progressive culture, we — the "West" — are aware of beliefs in other healing practices, but often dismiss them as primeval myths. These beliefs do not fit tidily into our universal science, and therefore they must be false. Rarely now does anyone devote thoughtful consideration to the significance of external practices, like traditional religious healing of South America or the East.

Anthropologist Byron J. Good offers some insight into the potential origin of this phenomenon. He's notable for his discussion on the nuanced interactions between rationality, knowledge, and medicine. Good places particular emphasis on the etymology of the word *belief*: In the Western lens, knowledge implies science and factuality. Conversely, belief implies a *choice* of faith in the unseen or unknown, something easily disregarded as fantastical or simply wrong. Good argues that our use of the word *belief* has destroyed our comprehension of and relationship with cultural knowledge: Information that might disagree with

"We — the 'West' — are aware of beliefs in other healing practices, but often dismiss them as primeval myths."

the scientific method, such as the combination of spirituality and medicine.

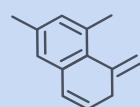
Belief used to signify a strong, entire devotion to something. Belief in science, then, could be described as a relentless pursuit of knowledge. To say that cultures believed in certain practices used to describe a commitment to their science. For example, Mayan Curanderos, traditional faith healers in South America, heal with prayer and the medicinal properties of plants as two equally important tools of medicine. While we might somewhat understand the use of plants for their physical properties, we still say they *believe* in plants and the power of their Spirits, and in doing so undermine the validity of the practice. The meaning of belief has gradually shifted towards a statement of truth and plausibility, one that leads us to disregard the very real and observable outcomes of such practices.

It implies that tradition takes precedence over logic: that the Mayans practice herbal medicine because they simply imagine that it is effective. We demean the approaches of outside cultures to science and medicine by referring to them as "belief systems" because we cannot see how they can be real and effective medical practices in the context of our science. How can Spirits — who simply do not exist to those outside the culture — have a tangible impact on an individual's health? And yet, they do: One South American woman, "possessed by an evil spirit," was healed with herbal tea and vigilant prayer, Rosita Arvigo describes in her book *Sastun*. After weeks of incurable illness, this was all it took for her to return to normal.

Ethnocentrism has subtly propelled us towards swiftly dismissing outside approaches that offend our "objective" science, indicating that it is perhaps not so universal at all. Whether intentional or not, the language used by the Western world makes clear an insularity against knowledge falling outside our beloved definition of science. The need for a more flexible integration of cross-cultural perspectives is increasingly clear in the context of modern science. However, there is no lab protocol for approaching knowledge that doesn't fit neatly within our predetermined schemas. If we wish to pursue *true* knowledge and expand our understanding of the natural world, we must mend the gap between our acceptance of knowledge that comes from science and evasion of knowledge resulting from belief.

Medicine, rationality, and experience (1993). DOI: 10.1017/CBO9780511811029.003
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PHOTO VIA SHUTTERSTOCK



Opinion: How fossil fuel corporations distorted the climate change conversation

BY SASHI NALLAPATI, CHEMISTRY, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

James E. Hansen's congressional testimony in 1988 officially introduced American policymakers to the need for a climate intervention. In the same year, George H.W. Bush declared greenhouse gasses as the enemy, in response to Hansen, when he promised to fight the greenhouse gas effect with "the White House effect" on the campaign trail.

However, a greater, more sly play was at hand. The Climate Change Countermovement (CCCM) initiative was launched into action a year later after his inauguration. This coalition sparked an ever-growing cascade of climate-denying misinformation, which we see the effects of today. They operated through the utilization of conservative think tanks funded by massive fossil fuel corporations and further expanded their reach to encompass a wide array of other misinformation tactics. These include recruiting contrarian scientists and providing more air time on television for these sentiments, along with other, similarly damaging methods. An appalling 90% of climate-denialist books published from 1972 to 2005 can be traced back to the conservative think tanks.

These sentiments were seemingly distributed with a disregard for the truth, as ExxonMobil's (one of the more prominent contributors to the CCCM) internal documents at this time revealed a clear acknowledgment of the validity of climate change. In 2015, investigative journalists uncovered concern for anthropogenic global warming by Exxon scientists starting as early as 1977. Other companies, including the American Petroleum Institute, TotalEnergies, and General Motors, have noted the potential for human-caused climate change since at least the 1970s, with the American Petroleum Institute aware of this idea since the 1950s.

The effects of this disinformation initiative are still felt today. In 2021, about 72% of Americans agreed that global warming was in effect. Paradoxically, this phenomenon is agreed upon by 90%-100% of publishing climate scientists. When compared to this consensus rate, it is evident that the percentage of Americans unbelieveing of this concept unnaturally diverges from an almost unanimous agreement from academics, whose opinions are usually highly regarded by the general public.



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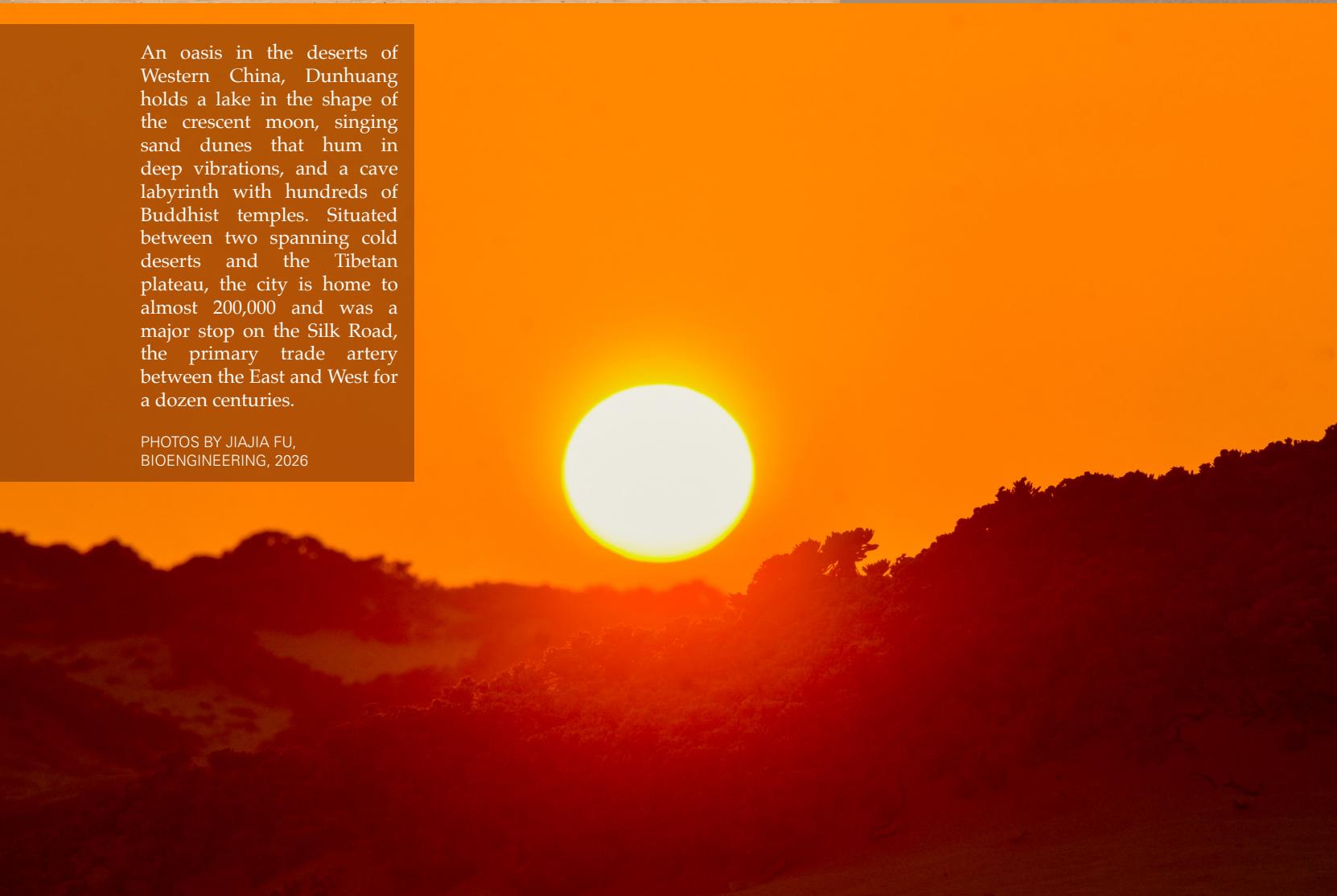
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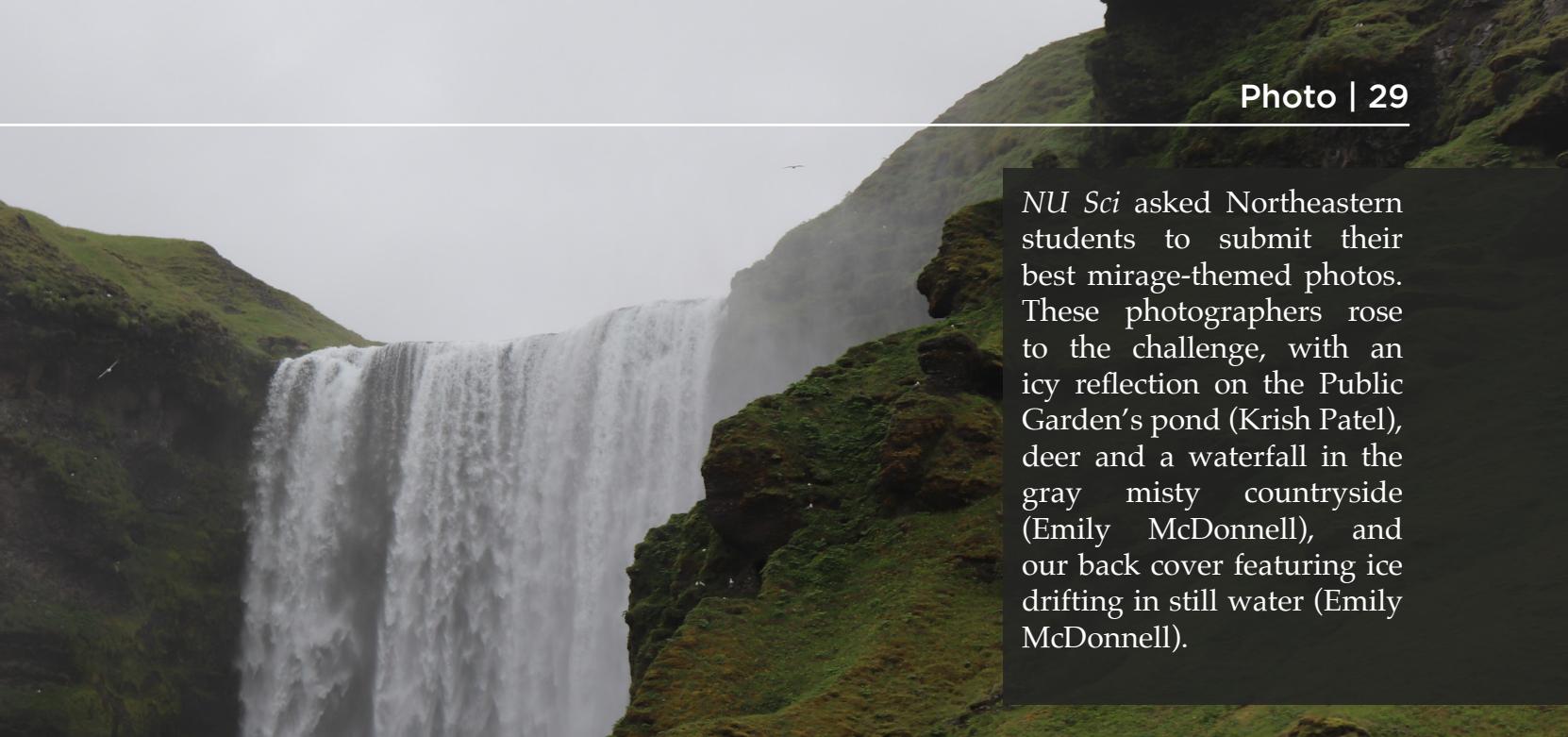
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An oasis in the deserts of Western China, Dunhuang holds a lake in the shape of the crescent moon, singing sand dunes that hum in deep vibrations, and a cave labyrinth with hundreds of Buddhist temples. Situated between two spanning cold deserts and the Tibetan plateau, the city is home to almost 200,000 and was a major stop on the Silk Road, the primary trade artery between the East and West for a dozen centuries.

PHOTOS BY JIAJIA FU,
BIOENGINEERING, 2026





NU Sci asked Northeastern students to submit their best mirage-themed photos. These photographers rose to the challenge, with an icy reflection on the Public Garden's pond (Krish Patel), deer and a waterfall in the gray misty countryside (Emily McDonnell), and our back cover featuring ice drifting in still water (Emily McDonnell).



Going 'green' for our health

BY ASHNA SHAH, BEHAVIORAL NEUROSCIENCE, 2025

THС, CBD, cannabis, weed, medical marijuana. The term "marijuana" is associated with a giant cloud of terms, but do we actually know the real definitions behind these buzzwords?

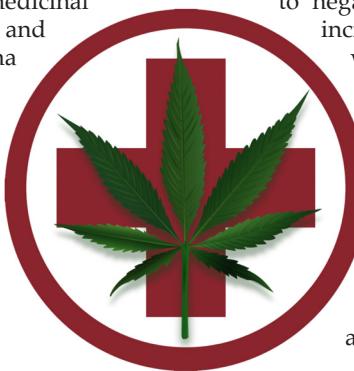
Marijuana and cannabis describe two different substances. Cannabis refers to a slew of chemical products originating from the *Cannabis sativa* plant. Marijuana, on the other hand, only refers to products of *Cannabis sativa* containing both cannabidiol (CBD) and high amounts of tetrahydrocannabinol (THC), which is what causes impaired function. CBD, commonly confused with THC, is a hemp-derived substance that does not cause any form of a "high." Hemp is another type of *Cannabis sativa*; it has significant levels of CBD but a THC concentration of less than 0.3%. CBD has the potential to reduce anxiety and insomnia, as well as chronic pain and epileptic syndromes.

Marijuana has both recreational and medicinal uses today. As of September 2023, 23 states and Washington, D.C. have legalized marijuana for recreational use, while 38 states allow marijuana for medical purposes. It is important to note that the U.S. Food and Drug Administration (FDA) has not approved *Cannabis sativa* for medicinal use and has only approved drugs containing select cannabinoids. Cannabinoid-containing drugs can be used for alleviating some symptoms of epilepsy, chronic pain, or multiple sclerosis.

According to the National Institute on Drug Abuse, dronabinol and nabilone are two FDA-approved drugs for treating nausea stemming from chemotherapy. These medications are synthetically-based, meaning the cannabinoids are formulated by chemists in laboratories but originate from a natural product. Epidiolex, a liquid medication containing CBD, was also approved for severe cases of childhood epilepsy. Both Canada and the United Kingdom, have developed a neuropathic pain management drug, combining both CBD and THC, called Sativex.

From a scientific perspective, *Cannabis sativa* falls into the botanical class, which produces drugs with large quantities of active chemicals we are unfamiliar with. This makes creating a uniform, reliable drug product difficult. This lack of consistency can cause doses of the same medication to have drastically different potencies.

Although potentially useful for certain medical conditions, the novelty of both CBD and THC as forms of medical treatment causes much apprehension. Generally, acute effects of THC include slower response to stimuli, impaired attentive abilities, dizziness, increased appetite, euphoria, and motor skills. The only widely accepted chronic



DESIGN BY KATHRYN FURMAN, COMPUTER SCIENCE & MATH, 2025

effect of cannabis is the potential for substance addiction, as about 30% of cannabis users develop a drug dependence. Since these medications are so new, researchers have not yet been able to complete longitudinal studies, which follow individuals over a long period of time, to observe those who incorporate THC or CBD-based medications into their lifestyles.

One comprehensive research study found that THC can alleviate the pain symptoms of amyotrophic lateral sclerosis (ALS), multiple sclerosis (MS), and Parkinson's disease. It can also reduce tremors in Parkinson's disease and alleviate muscle tension in both ALS and MS as well. Other applications of medical marijuana use include for anxiety and insomnia relief, according to research by Harvard Medical School.

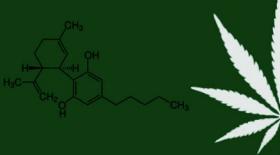
Contrary to these positive outcomes, cannabis use seems to negatively impact those with bipolar disorder, increasing mania and contributing to an overall worse general function in these patients. The Alcohol & Drug Abuse Institute blatantly stated that "Marijuana use and cannabis use disorders are markedly more prevalent among persons with bipolar spectrum disorders compared to the general population or persons with any mental illness." Habitual marijuana use amongst individuals with bipolar disorder is also correlated to earlier onset of symptoms and a higher chance of suicidal ideation.

Interestingly enough, though cannabis-based products are predominantly used by young adults, about 30% of users are above the age of 51. The impacts of cannabis use, whether medical or recreational, differ across developmental periods. Based on general findings in the field of neuropharmacology, cannabis is more impactful in adolescents because the brain is not fully developed. Based on this fact, medical marijuana may be better suited toward older adults who have fully-formed brains and can experience more of the benefits of marijuana compared to its brain-altering effects in younger people.

When these findings are all taken into account, it is clear that there is not enough compelling evidence to christen medical marijuana as a cure-all for pain and mental health disorders across all populations. For some groups, like older people experiencing chronic pain, medical marijuana can be especially helpful. However, based on the sensitivity of brain development to medical marijuana for adolescents, physicians and psychiatrists should take caution in prescribing THC to younger people. Research on the compounds of *Cannabis sativa* is still ongoing and important, and scientists are hopeful that THC can be implemented alongside other medications for pain relief.

Current Neuropharmacology (2017). DOI: 10.2174/1570159X14666161101095325
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CBD
Cannabidiol



THC
Tetrahydrocannabinol



PHOTOS VIA FLICKR & VECTORPORTAL

COVID has been found to induce POTS

BY MACKENZIE HEIDKAMP, BIOCHEMISTRY, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

With the release of the lockdown and the official announcement of the public health emergency's end, a good portion of the general public no longer sees COVID-19 as much more than a slight cold, and not many people associate COVID-19 with severe and non-respiratory effects.

With COVID having been around since 2019, hospitals and researchers are now starting to see some of the long-term effects associated with the disease. One of these effects is postural orthostatic tachycardia syndrome (POTS). According to the American Journal of Medicine, 79% of COVID patients who had consistent symptoms for weeks to months after diagnosis have met the criteria for POTS. To understand why this is occurring, it is important to understand what POTS is and how it could relate to COVID-19.

As we move further from the pandemic, more long-term effects may present themselves, proving that the disease is not synonymous with a cold."

Normally, a person's autonomic nervous system is responsible for pacing blood flow, and in turn, balancing heart rate and blood pressure. However, someone with POTS has a dysfunctional autonomic nervous system and, therefore, cannot keep their blood pressure stable. A common symptom of POTS is a very fast heart rate during the transition from sitting to standing. This explains the naming of the condition: postural (body position), orthostatic (standing upright), and tachycardia (a heart rate exceeding 100 bpm). People often develop POTS when they have an autoimmune disorder, experience head injuries and other trauma, or survive serious infections. The cause behind the connection between POTS and COVID is still unknown and debated by researchers. Three leading theories for the development of POTS in COVID patients that are discussed in a 2023 review paper are COVID's tendency toward hypovolemia, its neuroinvasive tendencies, and its autoimmunity.

Hypovolemia occurs when plasma levels, the fluid in blood, are too low. According to a case study done on a patient with COVID-19, the disease can cause hemorrhaging due to elevated c-reactive proteins in the body, which can ultimately result in hypovolemia. C-reactive proteins are produced

by the body when there is inflammation or some sort of pathogen. High amounts of these proteins, however, can cause tissue damage. This activation of the proteins seen in COVID patients could also potentially lead to stimulation of the nervous system and POTS symptoms.

The experts from the review paper believe that COVID's tendency to be neuroinvasive could also play a strong role in developing POTS. They pointed out that the virus can invade the central nervous system and the autonomic nervous system through multiple avenues including the GI tract, the ACE2 receptor of the brainstem, and the olfactory nerve. Knowing how essential the brain stem is in regulating the cardiovascular and autonomic nervous system, the neuroinvasive aspect may explain the prevalence of POTS in post-COVID patients. Focusing on the ACE2 receptor is also of interest to researchers. Once the virus enters through one of the receptors, it can replicate and attack any other organ expressing ACE2 which includes the heart and blood vessels (two organs involved in POTS).

While both ideas are potential explanations for the rise in cases, the writers of the paper believe that COVID's role in autoimmunity is the most likely culprit. Coronavirus is known to produce antibodies against autonomic nerve fibers. This alone could show a connection to POTS, but coronavirus's spike proteins are also an area of interest for researchers. The spike proteins can enter a cell and cause multi-system damage and dysregulation. Most importantly, the spike proteins have been found to be able to enter brain cells. According to a 2022 study by researchers at Tufts University, the spike proteins entering the brain could produce microglia and eventually cause inflammation, since protective molecules cannot cross the blood-brain barrier. Microglia are immune cells within the brain that are activated by certain stimuli. High amounts are associated with neuronal damage, and they could explain POTS and a dysfunctional autonomic system.

While the exact cause of POTS from COVID-19 is not definitively known, it has been established that this is a pressing concern with more research needed. As we move further from the pandemic, more long-term effects may present themselves, proving that the disease is not synonymous with a cold.

HIDDEN WITHIN US: THE DARK MATTER OF THE HUMAN GENOME

BY RYAN PIANKA, CELL & MOLECULAR BIOLOGY, 2025

DESIGN BY KATHRYN FURMAN, COMPUTER SCIENCE & MATH, 2025

The human genome is a vast library of over 3 billion base pairs, yet advancements in whole-genome sequencing reveal only 2% are protein-coding. This startling finding has prompted one of the most pressing missions of contemporary biology: to fully understand the role of the remaining 98% of the genome. Accomplishing this mission requires next-generation sequencing and transcription profiling to analyze historically overlooked non-coding stretches between genes, termed genomic “dark matter.”

Traditionally, molecular biologists theorized genomic regions not containing codons — the stepwise instructions for assembling proteins by their amino acid subunits — were functionless, evolutionary artifacts called “junk” DNA. However, late 20th-century advancements in molecular genomics challenged this viewpoint as researchers demonstrated that select “junk” sequences contained transcription sites for non-coding RNAs and abundant transposable elements. The traditional protein-centric view of the genome became less accurate, and an increasing number of researchers deemed it plausible that more non-coding sequences possessed functionality. Despite these advancements, the majority of non-coding regions remained poorly characterized due to unavailable whole-genome sequences and profiles of the human “transcriptome” — the complete set of RNA present in cells. However, the revolutionary launch of the Human Genome Project in 1990 and the subsequent Encyclopedia of DNA Elements (ENCODE) in 2003 provided biologists with the first high-definition genomic maps and catalogs of RNA transcripts. Combined with newly available assays for gene expression, these projects illuminated dark matter sequences and revealed new insights into genomic activity.

In the past decade, studies using data from the Human Genome Project and ENCODE have demonstrated non-coding regions to be more active than initially theorized. Specifically, 80% of non-coding DNA has displayed biological activity, with evidence for at least 75% of the entire genome being capable of transcription. Further transcriptome profiling has confirmed this, revealing that 98.8% of transcribed RNA is non-coding. From an evolutionary perspective, such high activity in non-coding regions equates to a tremendous loss of cellular resources if it does not confer a fitness advantage. Since a cell’s resources are finite, geneticists argue that such a large loss to functionless DNA is disadvantageous and likely to have been selected against by natural selection. This challenges traditional assumptions, suggesting many non-coding transcripts may have roles in maintaining cellular function.

Evidence supporting this claim has surfaced in recent association studies linking mutations of non-coding loci to many diseases, including cancer and muscular dystrophy. Further investigation into the mechanisms behind this phenomenon reveals RNA transcripts from these loci are

associated with regulating coding genes. These non-coding RNAs can assume multiple forms — microRNA (miRNA), piwi-interacting RNA (piRNA), small interfering RNA (siRNA), and long non-coding RNA (lncRNA) are among the most notable examples featured in recent studies. Interestingly, miRNA, piRNA, and siRNA possess remarkably similar three-dimensional structures and are all very small, generally averaging under 40 nucleotides long. Their relative simplicity allowed researchers to quickly determine they serve critical roles throughout the cell in supporting protein translation, regulating genes through protein interference, and other structural functions. Understanding the mechanisms behind these RNA molecules was a milestone in deciphering genomic dark matter, as it provided concrete examples of functional non-coding regions.

However, these small nucleic acid chains represent only a minority of the transcriptome. With lengths generally ranging between 200 and 10,000 nucleotides, lncRNA is the most variable and genetically prominent type of non-coding RNA. Due to the complexity of these molecules, research on lncRNA remains a frontier of modern genomics. So far, studies have suggested many lncRNAs are essential to targeted epigenetic modifications of genes by serving as flags for chromatin remodeling agents. For example, RNA sequencing demonstrates genes critical to development, such as Hox genes and Xist, utilize lncRNA while recruiting chromatin-modifying proteins. Yet, such studies have only begun to characterize the diverse lncRNAs in the human transcriptome — thousands more have yet to be studied. Furthermore, understanding how these molecules connect proteins to genes with high specificity remains a challenge. Next-generation epigenetic and transcription profiling technologies will hopefully aid in overcoming these obstacles, further demystifying the noncoding regions.

The investigation into genomic dark matter was pivotal to the advancement of modern genomics. Not only did it shift viewpoints from a simplified protein-centric model, but it also illuminated the complexities of the genome. While scientists are far from characterizing the entirety of non-coding sequences, many important discoveries have occurred. Among them is that RNA has critical regulatory behavior beyond synthesizing protein. Further studies into non-coding RNA may reveal new life-saving therapies, genetic engineering methods, and clarification on the least understood regions of the human genetic code.

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PHOTO VIA WIKIMEDIA COMMONS

The bumpy backroads: Metastasis of tumors in the spinal cord

BY NICOLE RODRIGUEZ, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

About one in every third person in the United States will be diagnosed with cancer at some point in their lives, an alarming statistic reported by the American Cancer Society. Although it is a largely researched topic, there are many gaps in the understanding of metastasis, or the spread of cancer to other parts of the body. Specifically, metastasis to the spinal cord can be debilitating and can occur in patients diagnosed with any form and stage of cancer, but the reason for the spread is unknown. Researchers are studying a line of stem cells to further understand why this spread occurs and why it localizes in the spinal cord to ultimately develop technology to pinpoint the types of tumors that grow in patients' spinal cords.

In September 2023, scientists from the Cornell School of Medicine showed that vertebral skeletal stem cells (vSSCs) largely contribute to the metastasis of tumors to the spinal cord from elsewhere. Stem cells are self-renewing, can multiply easily, and are usually undeveloped until a specific factor pushes them into a certain fate, or specific cell type. The *Zic1* line of vSSCs can secrete *MFGE8*, a metastatic trophic factor commonly expressed in tumor cells in patients with breast cancer. Metastatic trophic factors are proteins that activate the rapid multiplication of cells in tumors, causing cells that were not previously dangerous to be cancerous. These cells reside in long bones in the skeletal system with the spinal cord being the most prominent one. The scientists hypothesize that vSSCs ultimately contribute to metastasis in the spinal cord during late-stage cancers due to their uniqueness in the spinal cord and capabilities for multiplying.

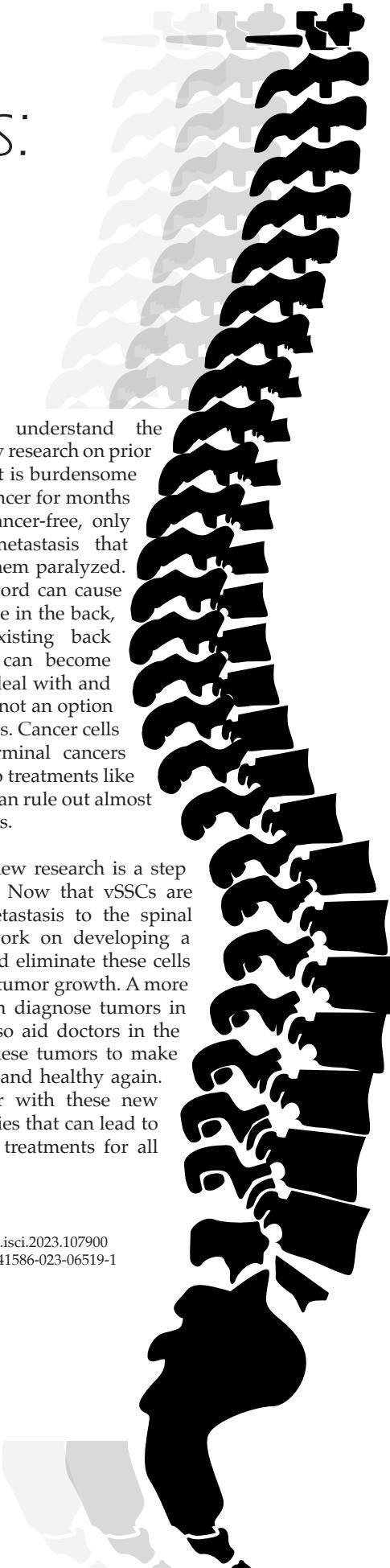
Engineers at the Osaka School of Medicine proposed a new program earlier in 2023 to aid doctors in the diagnosis of different types of spinal cord tumors. The program combines TabNet, a database used for storing patient information data, with a convolutional neural network of tumors to create a system that diagnoses certain tumor types. The convolutional neural network analyzes images of different tumors and, using TabNet, identifies tumors in the spinal cord and their characteristics. Lead scientist Kosuke Kita claims that the program can classify tumors better than physicians asked to identify them given the same conditions. AI strikes again!

It is important to understand the implications of this new research on prior knowledge of cancer. It is burdensome for patients battling cancer for months or years to become cancer-free, only to relapse with a metastasis that could possibly leave them paralyzed. Tumors in the spinal cord can cause shifting of the vertebrae in the back, further worsening existing back pain. Tumor growth can become incredibly difficult to deal with and chemotherapy is often not an option for some cancer patients. Cancer cells mutate rapidly in terminal cancers and become resistant to treatments like chemotherapy, which can rule out almost all remedies for patients.

That being said, this new research is a step in the right direction. Now that vSSCs are known to lead to metastasis to the spinal cord, scientists can work on developing a method to separate and eliminate these cells to prevent any further tumor growth. A more advanced tool that can diagnose tumors in the spinal cord can also aid doctors in the correct treatment of these tumors to make cancer patients happy and healthy again. The future is brighter with these new and exciting technologies that can lead to accurate and effective treatments for all types of cancer.

iScience (2023). DOI: 10.11016/j.isci.2023.107900
Nature (2023). DOI: 10.1038/s41586-023-06519-1

PHOTO VIA SHUTTERSTOCK



Sticky solutions: Octopus-inspired suction patches revolutionize drug delivery

BY TRICIA KRAKOFF, BEHAVIORAL NEUROSCIENCE, 2026

DESIGN BY JENNIFER MEDINA, BIOCHEMISTRY, 2025

The traditional approach of administering certain medications through direct injection can be particularly effective for drug delivery, but may be uncomfortable for children and those with needle phobias. While oral medications are available for some drugs, large-molecule drugs that treat chronic diseases such as diabetes, multiple sclerosis, or cancer can only be administered through an IV or an infusion. If these large-molecule drugs were to be administered orally they would metabolize much too late, rendering them almost useless.

A collaborative effort between researchers from China and Switzerland has led to an innovative and needle-free solution that draws inspiration from octopuses. The suction cups on the arms of an octopus have evolved for extremely strong suction as soon as they're applied to objects or prey in the water. Relative to humans, it is much too difficult to get any drug to stick to wet cheeks without damaging the mouth's tissue. Drugs typically dissolve before otherwise being diluted with saliva. Previously, it was much more difficult to get any apparatus to stick to wet cheeks without damaging the tissue of the mouth and to dissolve the drug into the cheek before it is diluted by saliva.

Usually, drug delivery through the dense cheek tissue is ineffective, but a new suction cup stretches the cheek and creates a larger surface area for the drug to pass through. These small rubber suction cups have a diameter of about 1.1 centimeters and are about 0.6 centimeters tall. The chamber holds more than 50 milligrams of a drug and can be passed through the cheek's lining efficiently. Its sealed suction to the cheek prevents saliva from interfering, keeping the drug in its most concentrated and effective form.

To understand more about the apparatus and its effectiveness, scientists conducted animal testing on beagles. The beagles were given Desmopressin, a drug that treats diabetes, in its various forms: injection, oral tablet, and drug-filled suction cups. Focusing on blood-plasma concentration, the researchers wanted to find out how much of the drug was actually being delivered into the bloodstream. The drug-filled suction cups outperformed traditional pills in their delivery to the bloodstream.

The blood-plasma concentrations

were 150 times higher in the dogs that used the suction cups as opposed to the dogs that took oral tablets. However, the suction cups seemed to be slightly less effective than the drugs delivered via injection.

The possibilities of this device were expanded in another beagle trial, working with a drug called Semaglutide, which has molecules that are four times larger than Desmopressin molecules. The results of this trial were still promising, and the beagles with the suction cup had a similar proportion of the drug in the blood to the beagles who took the tablet form.

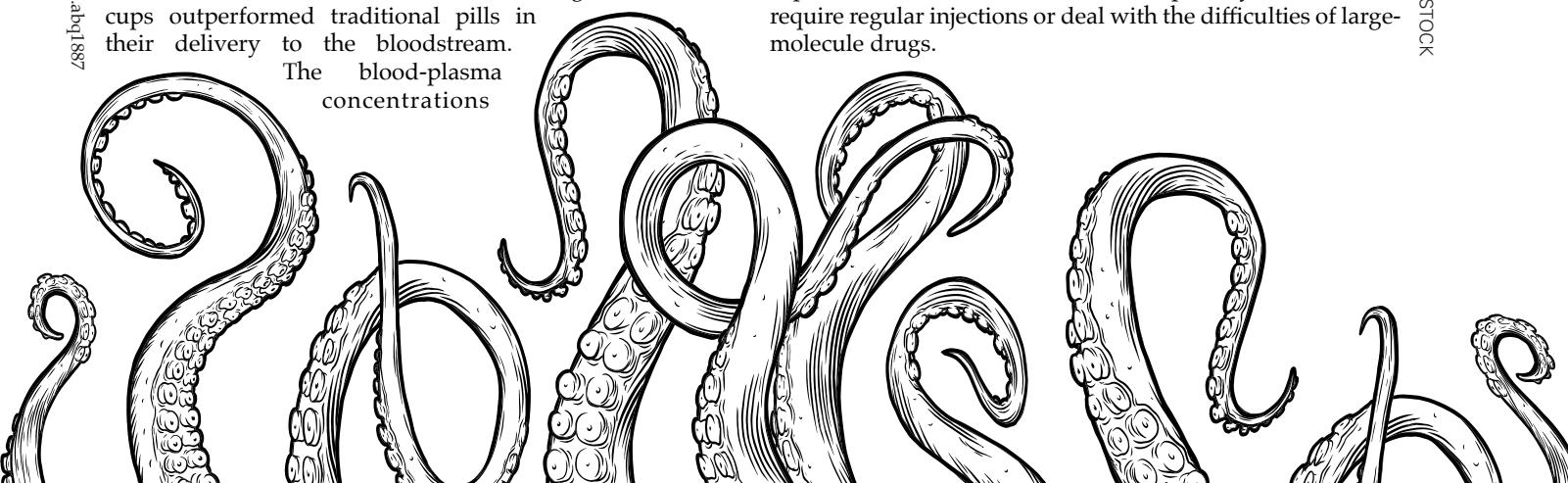
In a human trial, 40 individuals self-applied the suction cups that just contained water, as a way to determine how they feel and how well they stick onto the cheek. After the participants talked, moved, and rinsed their mouths, 35 of the 40 patches stayed on. The 5 of 40 patches that had fallen off were attributed to human error, by incorrect placement or excessive manipulation of the device by the study participants.

The suction will need further testing and human clinical trials to truly determine their effectiveness, but so far, they are considered a non-invasive and self-applicable medical device. The technology would be suitable for the administration of compounds that do not fare well in the gastrointestinal tract – creating an environment where they are fully absorbed and not degraded before they have a chance to function. For example, the biggest problem with insulin is that it degrades extremely quickly as it enters the gastrointestinal tract, losing its effectiveness.

The potential of this apparatus would also be seen in a specific group it targets: children. Children often struggle with vaccines and it may be an anxiety inducing experience for those who require regular injections. For everyone involved, suction cups could be a benefit and alleviate some of the stress that comes with injections.

This groundbreaking, octopus-inspired drug delivery method holds immense promise for improving patient experience and treatment outcomes, especially for those who require regular injections or deal with the difficulties of large-molecule drugs.

PHOTO VIA SHUTTERSTOCK



How lambs are saving future generations

BY KYLE KIRSHEN, BIOCHEMISTRY, 2025

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING & DESIGN, 2024



In 2020 alone, 13.4 million premature babies were born. In 2019, over 900,000 children died due to preterm-related conditions and complications. Premature is defined as being born earlier than 28 weeks of gestation, or 70% of the way through full-term. As it stands, premature birth is the leading cause of death in children under five years old, and even when a premature child makes it through development, it is rarely without problems. A report in the Journal of the American Medical Association estimated that from a sample of 5,931 children born premature, 78% had at least one chronic health condition compared to the 37% of full term babies. These health conditions include, but are not limited to, asthma, cerebral palsy, anxiety disorders, delays in mental development, hypertension, and epilepsy.

Knowing the severity and prevalence of premature births, the Children's Hospital of Philadelphia (CHOP) began research on the use of artificial wombs with baby lambs in 2017. Accomplished with the help of Vitara Biomedicals and \$100 million, the device known as the Extra-Uterine Environment for Uterine Development (EXTEND) was developed. CHOP's research started with eight lambs, all of which were born premature and were kept alive for four weeks with the help of EXTEND. These initial trials were deemed successful as the lambs were able to reach full brain maturity with minimally observed side-effects. Since 2017, CHOP has experimented with over 500 lambs and is currently seeking FDA approval to start clinical trials on humans.

EXTEND works by integrating the fetus into an artificial environment that mimics what it would experience in an actual womb. While the current machine ventilators provide oxygen and remove carbon dioxide, they lack an aspect of physical integration that a natural womb provides: amniotic fluid, which is necessary for proper lung development. EXTEND corrects this through the use of biobags which contain amniotic-like fluid and blood vessels that are surgically connected to the umbilical cord in a matter of minutes. This allows for the fetal heart to continuously pump blood and maintain proper circulation.

While CHOP's development of artificial wombs might seem like a uniquely futuristic approach, it is not alone. In fact, many companies across the globe are trying to accomplish the same thing. For example, researchers at the University of Michigan are currently developing a similar system, but it does not surround the fetus with fluid. Out of all of the approaches though, CHOP is believed to be the closest to human trials and is thus, most commonly brought into the public light.

On Sept. 19th, 2023, the FDA convened to discuss the ethical implications of this new technology and how human trials would work. While it met behind closed doors, there was a public opportunity to raise questions and concerns. Many of

these concerns stem from the lack of long-term data to justify the implementation of artificial womb technology.

To be approved, the FDA would need to be certain that human babies would benefit from the system with minimal risk. Even if the long-term data is adequately provided, there is still the problem that lambs are not humans and many wonder if that jump is too large to justify. In the context of EXTEND, lambs were chosen because of their manageable size when compared to a much smaller and more delicate human fetus. On the other hand, some experts in the field question whether or not artificial wombs are the correct way to spend research money. They believe that it would be more beneficial to focus on finding ways to lengthen the babies' gestation period, rather than focusing on their limited chance of survival after premature birth.

From an ethical standpoint, many questions also arise. The most prominent concern is how these artificial wombs define what birth, or even a fetus is, since it is no longer contained within a traditional womb. Abortion will likely become a larger point of contention as people debate what will happen if a woman chooses to abort a fetus when this technology is available. Similarly, the idea of consent and a physician's role in regards to the technology are both also under question and seemingly need to be mapped out before any human trials begin.

The FDA's current status is not known, but it has become obvious that the morality of science is more important than ever. As the world continues to advance, the two will become even more intertwined.



PHOTOS VIA SHUTTERSTOCK

Flesh-eating bacteria cases on the rise?

BY BRYANNA UPTON, CELLULAR & MOLECULAR BIOLOGY, 2027
DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

Flesh-eating bacteria sounds like an epidemic straight out of a horror movie: oblivious beachgoers infected by an aggressive germ with no hope for a cure! As far-fetched as it sounds, this prospective movie pitch is a growing reality for many residents of the East Coast of the United States. While usually confined to tropical waters in the Caribbean and Florida, warming oceans and recent intense storm surges have pushed these strains of dangerous bacteria as far north as Connecticut.

Flesh-eating strains are marine bacteria that have toxins, which can cause necrosis, or cell death, in soft tissue. Most people are infected when the bacteria, found in salt or brackish waters, encounters open wounds, cuts, or even bruises. The infection is extremely aggressive and can take anywhere from a few days to only a few hours to become fatal.

“

Climate change is making these more uncommon species of bacteria more and more relevant to our daily lives, yet our lack of knowledge mirages their dangerous potential.”

Interacting with this bacteria can cause a condition known as necrotizing fasciitis, an aggressive type of skin and soft tissue infection. While many strains of bacteria can be considered “flesh-eating,” it is *Vibrio vulnificus* that is alarming scientists. Once inside a wound, *V. vulnificus* produces a type of hemolysin called RTX. A hemolysin is a type of toxin that widens the pores in the membrane of a red blood cell, letting unwanted materials into the cell, and eventually leading to lysis, or the rupture of the cellular membrane. In short, RTX rips apart red blood cells. And if that wasn’t enough, an article from *The Journal of Infectious Diseases* suggests that RTX also aids *V. vulnificus* by protecting it from phagocytosis, a process in which immune cells attempt to ingest bacteria as a way of fighting infection.

But don’t get too nervous, luckily *V. vulnificus* infections are still very rare and are far less severe in healthy individuals. Most infections come from ingesting raw oysters infected with the bacterium, and typically do not fare well in the

low pH environment in our stomachs. However, *The National Library of Medicine* still raises red flags for anyone with diabetes, chronic liver disease, and especially those in immunocompromised states.

Although cases are rare, the spike in infections is still alarming. According to the CDC, *V. vulnificus* cases have increased 78% between 1996 and 2006. This trend holds strong ties to our changing oceans. In 1992, the northmost flesh-eating bacteria infections sat at the top of Florida. By 2018, cases were reported in New Jersey. Now, they have made appearances in Connecticut. The trend of strains moving further and further north is no coincidence! A *Scientific American* article reports that spikes in flesh-eating bacterial infections are tied to stronger hurricanes and more frequent storms, both of which are being fueled by climate change. This means that the warming climate is making unusual bacteria, such as *V. vulnificus*, more prevalent.

Northeastern biology professor Constantin Takacs is currently conducting research on another uncommon strain of bacteria being affected by climate change: the bacterium that causes Lyme disease, *Borrelia burgdorferi*. Rising temperatures have been pushing infected ticks, who thrive in temperate climates, farther and farther north.

“Functional principles [of any organism] will be generalizable,” said Takacs, “but then there are other processes that will happen differently in different settings ... that’s why we also have to study a diverse variety of organisms.”

Climate change is making these more uncommon species of bacteria more and more relevant to our daily lives, yet our lack of knowledge mirages their dangerous potential. This is why investigations into bacteria are so crucial. We simply don’t know how a species will react until we test it. “It’s hard to generalize,” Takacs continues, “it is going to depend on the type of behavior that that agent has inside you.”

In a warming world, we need to be ready for anything that may rear an unexpectedly ugly head.

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PHOTO VIA RAWPIXEL

To die or not to die

BY ELIZABETH LUO, CELL & MOLECULAR BIOLOGY, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

Death is often associated with negativity and darkness. However when it comes to the human body, death is a common, daily process. Our cells constantly die and duplicate, replenishing and maintaining the health of our body. Apoptosis, a form of programmed cell death, is a method for cells to replace old, faulty cells with younger, healthier ones.

Cell death is an essential part of life. From removing defective cells due to cell replication errors, to mechanistic problems that can alter cellular functioning, cell death provides the body with a way to protect itself against unwanted harms. There are many reasons why the body may need to get rid of a cell – reasons including external harm from sun exposure, stress, injury, or even uncontrollable reasons such as age – and the body is always monitoring the health of our cells to ensure the survival of the body through cycling of said cells. Additionally, cell death is not only for harmful ones; cell death forms us to appear as we are. There is cell death in the webbing of our hands to form the fingers and toes that we use for daily life. If there are any cells that the body may deem as problematic, the body will ensure death of such cells.

There are a few different types of cell death, ranging from silent to inflammatory. Silent cell death refers to the lack of an inflammatory reaction as a result of its death – apoptosis. There are many ways for silent cell death to occur, generally beginning in the internal pathways of the cell. Proteins within the cell trigger a cascade of reactions that can lead to apoptosis. There are two pathways to apoptosis, extrinsic and intrinsic, both ultimately leading to the activation of caspase-3 or caspase-7, protein enzymes that are responsible for the degradation of the cytoskeleton of the cell and other essential proteins for cell functioning.

Inflammatory cell death is when cells die by bursting or lysing, releasing messengers to local cells signaling inflammation. This can be referred to as necrosis, and it occurs due to the presence of noxious stimuli like tissue damage, where fluid fills the cell to the point of bursting. There are many reasons for this mechanism of cell death, ranging from physical

trauma to bacteria or viruses in the body. Dr. Nabeeha Khalid and Mahzad Azimpouran emphasize that figuring out the cause of necrosis can be a gateway into producing treatments for it is more essential than just removing these dead cells. Primarily, necrosis has been significant in the immune response against COVID-19. Necrosis prevents the spreading of a virus by killing cells and recruiting pro-inflammatory cells to help fight the virus.

Cell death is both important and essential to daily life functioning. Daily, we are fighting against bacteria and viruses, and cycling through damaged cells for healthier cells. Despite the importance of cell death, there is a Goldilocks principle that applies to cell death, where too little cell death would lead to the formation of tumors and cancer, but too much cell death can lead to potentially life-threatening tissue degeneration. Understanding the mechanisms behind these essential processes can be harnessed in the discovery and development of the effects diseases, viruses, and external harm have on the health of our bodies.

Underwater impostor

A MIMIC OCTOPUS'S GUIDE TO IDENTITY THEFT

ARTICLE AND DESIGN BY ANNIE CHRISTIE, ENVIRONMENTAL & SUSTAINABILITY SCIENCE, 2023

PHOTOS VIA SHUTTERSTOCK

In the depths of the ocean, one true master of disguise steals the spotlight. The mimic octopus, scientifically known as *Thaumoctopus mimicus*, is a species of octopus native to the Indo-Malayan Archipelago and Great Barrier Reef. A sand dwelling cephalopod, the mimic octopus is found at depths ranging from 2 to 12 meters near river mouths where the seabed is rich with crustaceans and worms on which to feed. Despite its alarming appearance, this soft-bodied and non-venomous creature is an enticing target for various predators. Consequently, the mimic octopus has developed an array of defensive adaptations. Among these, one astonishing talent has left scientists in awe of nature's genius: its extraordinary gift for mimicry.

Like many of its relatives, the mimic octopus expertly employs the art of camouflage to seamlessly blend into its surroundings, whether it be the sandy seafloor or rocky substrate. However, what truly sets the mimic octopus apart, as the name suggests, is its ability to mimic the appearance and behaviors of other organisms—a phenomenon known as mimicry.

Watch in amazement as the mimic octopus gracefully undulates across the ocean floor, extending all eight legs backward to take on the shape, motion, and speed of a fish. The octopus will even flatten its head and position its eyes prominently, just like the banded sole, a common flat-headed fish found in the same region. The mimic octopus has also been observed impersonating banded sea snakes and lionfish, depending on which predators are nearby. These three toxic animals all share the octopus's light and dark coloring and striped pattern, making it an effective mimic. Furthermore, scientists have observed behaviors suggesting that the mimic octopus might be capable of mimicking other marine organisms, such as giant crabs, seahorses, sand anemones, and jellyfish. The mimic octopus's preference for imitating predator species is better known by scientists as "Batesian mimicry," a phenomenon in which a harmless organism imitates dangerous ones to evade predation. Predation is the primary driving force influencing the development of such defensive mechanisms. The better the octopus blends into its environment or mimics more dangerous species, the lower the likelihood of it being detected by predators or potential prey. In the case of mimic octopus, mimicry may be linked to its

tendency to forage in broad daylight, where it is exposed and vulnerable to predation. At night, the octopus retreats to its burrow for safety. Ironically, the mimic octopus has its own copycat. The harlequin jawfish, a species of jawfish native to the same region, has been observed by researchers hiding in the shadows of the mimic octopus, blending in to avoid detection. While mimicry is a common strategy in nature, this octopus is the first known species capable of imitating multiple organisms.

Cephalopods, particularly octopuses, possess the fascinating ability to alter their body patterns to match changes in their visual background, a technique termed "crypsis" by scientists, or more commonly known as "camouflage." Octopuses have a unique skin anatomy composed of pigmented chromatophore organs, reflecting iridophores, and light scattering leucophores, enabling the octopus to instantaneously generate a wide range of patterns based on their environment. The octopus will change the spatial arrangement of chromatophores in their skin by contracting or relaxing these cells in response to visual cues. While scientists

have been studying this inherent adaptation for centuries, the mimic octopus's exceptional ability to morph into the appearance of other species remains a recent and evolving subject of study.

A fascinating illusion which repels predators with promises of death, the mimic octopus' appearance is not always as it seems. Challenging our understanding of the boundaries of mimicry and offering a glimpse into the intricacies of underwater life, the mimic octopus stands as a testament to the incredible diversity and adaptability of life below the waves.

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Only the shiniest survive

The science behind the astonishing iridescence of the *Morpho* genus

BY GABRIELLE WEINER, BIOLOGY, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

There's nothing quite like the brilliant shifting color of a butterfly's wings. Humans have long been fascinated by the dynamic properties of anything that sparkles – gemstones, the feathers of a hummingbird, the scales of a fish. What makes this elusive property of nature so unique is not only the colors that it exhibits but also the structural origin of such a phenomenon. Iridescence is the interactions between light waves, called interference, that are brought about by the structure and viewing angle of an object.

Perhaps one of the best examples of iridescence in nature is the butterfly genus *Morpho*. The wings of these butterflies display a range of brilliant blue shades, surrounded by striking black outlines and pale yellow streaks of color. This large genus of butterfly displays some of the most prominent iridescence found in nature through its vibrancy. However, blue pigment is not exactly what creates such an appearance.

The hue of all organisms can be accredited to either pigmentary or structural coloration. Pigmentary coloration, which exists most commonly in nature (think shiny beetles or the feathers of a peacock), is due to pigments synthesized by cells within the integumentary tissues. For example, the color of your skin is the result of the pigment melanin. In a group of species such as *Morpho*, however, individuals display structural coloration. Their color is continuously changing because of the structural composition of their wings. Depending on the angle at which a *Morpho* butterfly is viewed, its wings may appear a deep sapphire, a sky blue, or anywhere in between. This mesmerizing effect can be attributed to microstructures built into the composition of the butterfly's wings.

Iridescence serves purposes such as avoiding predation by maintaining an elusiveness that deceives predators through constantly shifting color. The functionality of iridescence also extends beyond predator-prey relationships among an ecosystem. The structural property functions as a method of communication *within* species, particularly in terms of mating selection; hence, the shiniest survive. The butterfly with the best display of iridescence appears as the most

desirable to a potential mate and thus is more successful in the continuation of the species.

In 2020, a group of scientists explored the effects of the structural coloration of two species of butterflies: *Morpho cypris* and *Greta oto*. *M. cypris* is a species of the *Morpho* genus that is native to Colombia and exhibits a brilliantly bright shade of cobalt when viewed from a particular angle. The scientists examined the behavior of light reflection from the butterflies' wings in its relationship to the viewing angle. In the experiment, optical and fluorescent measurements were taken as well as photographs and optical microscope photographs of the wings of the butterfly. Using these assays, they determined the relationship between viewing angle, reflected color, and angle of light. The findings, as expected, demonstrate that iridescent color greatly varies depending on lighting and viewing angle. As the wings didn't exhibit a fixed color, this is an example of structural coloration.

One of the experiments done by the scientists kept a fixed source of light and positioned the samples at various angles. Expectedly, the photographs recording this portion of the experiment depict a wide range of reflected color. The EDXS measurements mentioned in the report are an assay used by the team that record the chemical composition of the wings. Among the most abundant elements are sulfur, carbon, nitrogen, oxygen, and silicon – all key components of a substance called chitin. Chitin is what makes up the skeletons of arthropods, and this structural purpose is present in butterfly wings on a much smaller scale. Though a *Morpho* butterfly's chitin isn't a protection strategy like it is in an arthropod, it is comparable in terms of a primary method of structural composition. The microstructures that chitin forms directly correlate to the iridescent phenomenon that is characteristic of *Morpho*. The incredible display of color of the *Morpho* genus reflects nature's ability to balance form and function to craft a beautifully dynamic world.

Scientific Reports (2020). DOI: 10.1038/s41598-020-62770-w
Journal of Experimental Biology (2003). DOI: 10.1242/jeb.00709

Strength from unlikely places

How glass and DNA form a material stronger than steel

BY SERENA TRIPP, BIOCHEMISTRY, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

DNAs the fundamental building block of all life. Nearly every student learns about the master of genetic information as early as elementary school. DNA is the carrier of this important code within all living organisms. However, it isn't just what DNA encodes for that is important, but also its very design.

The structure of DNA is incredibly unique and useful in the realm of material science. Its molecular makeup aligns directly with the classification of polymers within this field. Polymers are a standard class of substances that are made of large organic molecules called macromolecules—for example, rubber. Polymers are often extremely tough and elastic—qualities that are very interesting to scientists when designing new materials. DNA, however, has specific properties of its design that are especially interesting to material scientists.

DNA is composed of deoxyribonucleotides, nucleotides for short, which direct the bonding sequence between the two strands. These nucleotides will bond in a specific manner, determining the shape of the DNA structure. For material scientists, this specialized bond sequence allows for the ability to 'program' how DNA folds into specific shapes of their choosing. These folded shapes are called "origami," which can self-assemble into a variety of structures based on the composition of nucleotides the researchers select.

Zooming out even further, these origami shapes can form a lattice—a repeating block-like structure that is extremely stable. The foundation of the lattice is these origami DNA shapes, but material scientists can add other inorganic or organic materials to alter the properties of the overall material. In fact, researchers from Columbia University, the University of Connecticut, and the U.S. Department of Energy's Brookhaven Laboratory decided to explore the properties of the structure by adding pure silica glass into the scaffolding of the DNA lattice.

The researchers wanted to enhance the properties of glass while minimizing its defects. They used microscopic layers of silica glass and coated the DNA frames. Typical pieces of glass are fragile, and easily develop flaws in their structure that cause them to shatter. The DNA-silica material, at first glance, seemed to be impervious to these flaws. In fact, the material seemed to be incredibly strong.

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Under the test of nanoindentation, this material showed to be over four times stronger than steel."

The team specifically used a technique called nanoindentation to test exactly how strong the material may be. Nanomaterials like the DNA-silica lattice are too small to see with the naked eye, so extremely specialized tests must be used to learn about their qualities. Nanoindentation applies pressure to the material on a small scale to compress it, and the compression behavior is monitored by highly specialized equipment. Using this technique, researchers can measure if any cracks form, or if the structure begins to fail during compression. Under the test of nanoindentation, this material showed to be over four times stronger than steel. Not only is it stronger than steel, but also its unique composition means that it is almost five times lighter than steel.

The success of such a material to this degree is currently unparalleled, and the applications of this nano DNA-silica lattice are incredibly promising. Additionally, the discovery of such a strong lightweight material may result in a myriad of fabrication of other incredible nanomaterials in the future.

The dog days of AI: Unraveling the secrets of canine scent

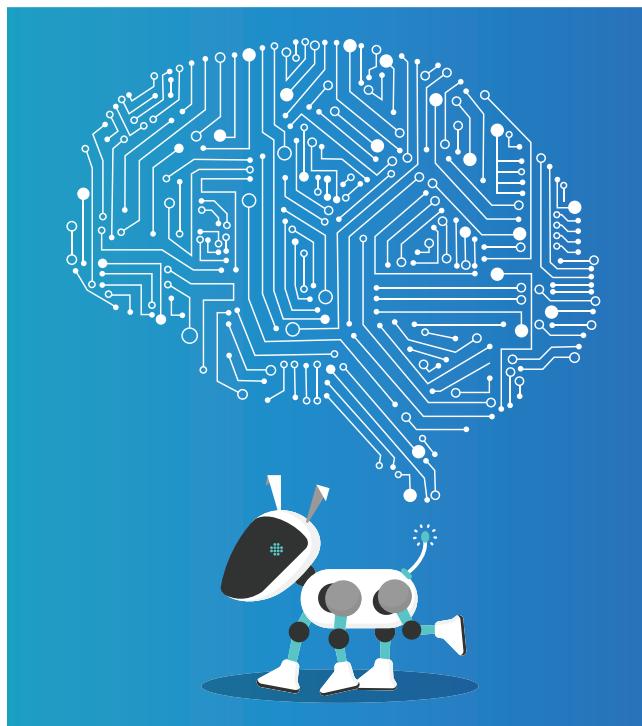
BY KEVIN LU, COMPUTER SCIENCE & MATHEMATICS, 2026
DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

A simple dog walk is an odyssey of olfactory exploration. As they venture outdoors, dogs eagerly dart around to investigate various scents — poop, carcasses, and fire hydrants are like neon beacons to them. While humans have a decent sense of smell, dogs reign supreme in the olfactory realm. This difference is rooted in biology. When a dog sniffs, some of the inhaled air enters a complex labyrinth lined with a sticky sheet called the olfactory epithelium, where smells are initially detected.

Humans share similar olfactory mechanisms, but dogs have more of everything: a larger olfactory epithelium, dozens of times more neurons in that epithelium, and nearly twice as many types of olfactory receptors. In the end, a dog's nose is 10,000 to 100,000 times more sensitive than ours. This heightened olfactory ability makes dogs invaluable for various scent-related tasks, including detecting bombs, drugs, and even diseases. Recent studies have shown that dogs can identify diseases like COVID-19 and prostate cancer with over 96% accuracy. However, the precise mechanism behind their olfactory prowess remains a mystery. What combination of compounds are they smelling that signals the presence of a disease? Can we replicate their sensitivity using chemical techniques? A recent multinational study conducted by researchers from Johns Hopkins University, MIT, and Medical Detection Dogs in the United Kingdom attempted to answer these questions using chemical analysis and artificial intelligence (AI).

Initially, the research team trained two dogs to detect the presence of prostate cancer in urine samples with an accuracy of 76%. The researchers then examined two components of the samples: the distribution of volatile organic compounds and the microbial profile. Manual analysis of these quantities failed to yield a definitive master biomarker template, a series of molecular concentrations in urine that would yield a positive cancer diagnosis. Consequently, the researchers turned to AI as a research tool to "sniff out" connections that eluded human observation.

Rather than attempting to predict whether an individual had prostate cancer, the researchers employed an artificial neural



network (ANN) to predict whether a dog would categorize that person as positive or negative. They trained the ANN using the chemical and biological samples that the dogs had diagnosed as cancerous, creating a model that represented the characteristics the dogs sought in the samples.

AI is often portrayed as a statistical "black box," where the inner workings are inscrutable and the method it uses to generate results remains unknown. However, imagine being able to visualize a model and navigate through it to identify the most crucial connections. Network skeletonization facilitates precisely that; unimportant nodes are pruned from the model, revealing the critical factors influencing the output. The researchers were then able to identify intervals and peaks in the volatile compound graphs that were essential for canine diagnosis.

This discovery was corroborated by auto-associative filtering, which functions as a generative AI network that produces canine-negative profiles. The network establishes a model of normalcy, which is compared with sample inputs to uncover anomalies. The AI can then pinpoint key data features and patterns associated with the dogs' diagnoses. In particular, a combination of unusually abundant bacteria, *alloscardovia omnicondens* and *dulosigranulum pigrum*, were closely linked to a positive canine diagnosis.

The natural world harbors a wealth of algorithms and sensors hidden right under our noses. Our four-legged companions are, in essence, scent-sensing supercomputers. Octopi exhibit remarkable biological prowess, and mantis shrimps are formidable undersea fighters. The emergence of AI research heralds a new era of understanding these creatures and their extraordinary abilities. So, the next time your dog dashes off to investigate another dog's behind, there may be more to this simple act than meets the eye.

PHOTO VIA SHUTTERSTOCK



Infinitely larger: How Edwin Hubble proved our galaxy is not alone

BY MICHAEL OZGAR, ENVIRONMENTAL & SUSTAINABILITY SCIENCES, 2027

DESIGN BY CARINA HALCOMB, EXPERIENCE DESIGN, 2023

When most people hear the name Hubble, they likely think of the groundbreaking telescope that captured unique planets, blazing stars, and clusters of light in its stunning photographs. It is less likely, however, that they think of the famous telescope's namesake — Edwin Hubble, the astronomer who discovered the expanding universe.

Until the 1920s, astronomers had no evidence that the universe went beyond the borders of our galaxy and had even less reason to believe it was expanding. In 1923, Hubble received access to the Mount Wilson Observatory in Los Angeles — the biggest telescope of its time. At this time, most scientists considered unknown patches of gas-like clouds to be far-off objects that existed within the Milky Way, but there was a small opposition that believed these objects were separate entities from it. Hubble pointed the Mount Wilson telescope at one of these objects — the then Andromeda Nebula — and discovered multiple stars within it that were uniquely farther than those usually observed in the Milky Way. This discovery led him to the conclusion that Andromeda was a galaxy itself, and repeated observations of other “nebulae” provided proof of the existence of millions of galaxies outside our own.

To measure the distance of objects from our galaxy, Hubble measured the brightness of Cepheid variable stars. A variable star varies in brightness over time, and a Cepheid variable star is a unique type that is both abnormally large and hot. Using an equation first derived by astronomer Henrietta Leavitt, Hubble predicted the brightness of a Cepheid variable star he observed through the Mount Wilson Observatory's telescope. Knowing the change in brightness over time of one of these stars allowed him to determine the

distance of that star from Earth, and therefore the distance of the realm it resided in. As he gathered more data on different Cepheid variable stars, he noticed that these distances were incredibly far beyond the bounds of the Milky Way and thus concluded that the universe extended beyond our galaxy. Through the continued study of other so-called nebulae and their Cepheid variable stars, he determined that there are at least millions of galaxies beyond our own — modern scientists estimate this number to be about two trillion.

In the same decade that he discovered a universe beyond the Milky Way, Hubble made another discovery: The universe was expanding. While measuring the light emitted from what he now understood to be other galaxies, Hubble noted that certain galaxies had more of a red color than others. He knew that when objects that emit light move away from an observer, the light seems to have longer wavelengths,

thus producing a red hue. This phenomenon is called “redshift,” and the observation that some galaxies were seemingly redder and smaller than others led Hubble to the conclusion that every galaxy was moving away from each other; the universe was therefore expanding. This discovery provided the foundation for the widely accepted Big Bang theory, as it suggested for the first time

that the universe was expanding from a single point.

The work of Hubble transformed people's understanding of the cosmos by revealing the reality of our universe's nature and laying the foundation for modern astronomy. It is no wonder that the Hubble telescope, capturing the breathtaking imagery of our cosmos, continued to further our knowledge of the universe long after Hubble's death.

PHOTO VIA SHUTTERSTOCK

“In the same decade he discovered a universe beyond the Milky Way, Edwin Hubble made another discovery: The universe was expanding.”

A search for the extraterrestrial: Artificial intelligence detects life

BY IBA BAIG, DATA SCIENCE & BEHAVIORAL NEUROSCIENCE, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

Recently, a group of scientists at the Carnegie Institution for Science created an AI model that can detect traces of extraterrestrial life. By analyzing the chemical composition and structure of past and present life preserved in sediments in different planetary samples — from Mars meteorites to the earliest specimens of life on Earth — the program correctly identified if life was present 90% of the time.

Many scientists believe that the fundamental biomolecules that might make up extraterrestrial life may completely differ from Earth's. That means alien life might not use DNA, amino acids, or other building blocks of life on Earth. The AI method instead searches for distributions of molecules that can arise only from the chemical processes needed to sustain life. All types of life generally produce greater quantities of a few functional compounds compared to systems without life, and understanding the demand for these compounds through AI is key to establishing life markers in samples.

In order to translate a sample into data the AI model could interpret, the scientists used measurements from pyrolysis — the process of heating organic samples — from a variety of terrestrial and extraterrestrial carbon-based materials, such as highly-degraded biological Earth samples. Next, the researchers arranged the samples with gas chromatography, which separates and quantifies individual molecular components in a mixture. The molecules were then transcribed into data using mass spectrometry — which helped detect the molecular composition. Finally, researchers passed this data to the AI model to conduct machine learning-based classification.

The team reached a 90% accuracy in differentiation between living and nonliving systems from training the machine learning algorithm with 134 samples, 59 biotic and 75

abiotic. Biotic, or living, samples were obtained from various organisms, like shells, teeth, bones, plants, and human hair, as well as ancient life preserved in fossilized fragments of coal and oil. Abiotic, or nonliving, samples included natural carbon-based meteorites or pure-synthetic chemicals, providing a baseline for molecular complexity. The AI could even distinguish abiotic samples of lab-created amino acids that are normally present in the biotic samples.

But how can scientists be sure a positive test is truly extraterrestrial life and not a random cosmological fluke? So-called “chemical rules of life” govern the creation of biomolecules and their prominence in biotic and abiotic systems. This novel usage of artificial intelligence in astrobiology research uses these universal rules.

The new technological integration can aid in finding fundamental differences in biochemistry between biotic and abiotic samples to determine signs of past life on Mars or ancient Earth. The methods can be used to study some of the oldest fossils on Earth, said to be in the Pilbara region of Australia, to resolve debate surrounding bacteria's early presence in Earth's history. Additionally, this revolutionary method could distinguish alternative biospheres from those of Earth, encouraging future astrobiology endeavors.

The future of AI systems in space exploration is expanding, with AI already embedded in smart sensors on spacecraft, landers, and rovers on the moon and Mars. By understanding the patterns of biochemical mechanisms of past and present life, AI can help detect potential biosignatures in extraterrestrial samples as scientists continue to extend their reach beyond the Earth.

PNAS (2023). DOI: 10.1073/pnas.2307149120

BY CLARA BARSOUM; POLITICAL SCIENCE, COMMUNICATION STUDIES & PHILOSOPHY, 2025



Northeastern University
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Supported by the
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