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LETTER FROM THE EDITOR

Almost nothing in life is as constant. It's a backdrop of life — hiding in every nook and cranny of every day.

The slanted floors and stained ceiling in a friend's Mission Hill apartment. The screech of train tracks, hastily introducing the Green Line's Boylston stop before the announcer. The friend group scattered across the country by new jobs. The crumpled corner of this magazine or scratch across its cover.

To live is to strive for safety, comfort, and insulation from the untamed universe around us. But against all our efforts, this sense of order always and inevitably collapses. It scatters. Sprawls. *Decays*.

It's a fundamental physical law of our universe. The second law of thermodynamics: Everything must decay. Unlike most quantities in physics, order is not conserved. It's lost. Unlike most actions in physics, decay cannot be reversed. It's final.

Life on Earth is an extraordinary, beautiful, and temporary island of order. The mechanical function of our bodies, our environment, our technologies, our society, are all highly ordered. But the reign of decay is tyrannical. Creating any amount of order requires creating a greater amount of chaos and disarray. Our relationship with decay is, thus, paradoxical. In order to protect ourselves from it, we must rely on it. Decay is both our death sentence and our source of life.

In this issue, we explore how scientists are studying and exploiting our relationship with decay. How the practice of medicine is constantly battling the deterioration of our bodies – from neurological decline to aging to cancer. How degrading our environment, in turn, degrades us. How a dead whale or downed tree nourishes its ecosystem. How – even in our insulated, built world – disorder and disarray still creep into our culture and politics.

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

Noah Haggerty
Editor-in-Chief

STAFF

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Cover Photos by Ian Hay and Gus Mueller

OUT WITH THE OLD

Geneticists reversed aging in mice

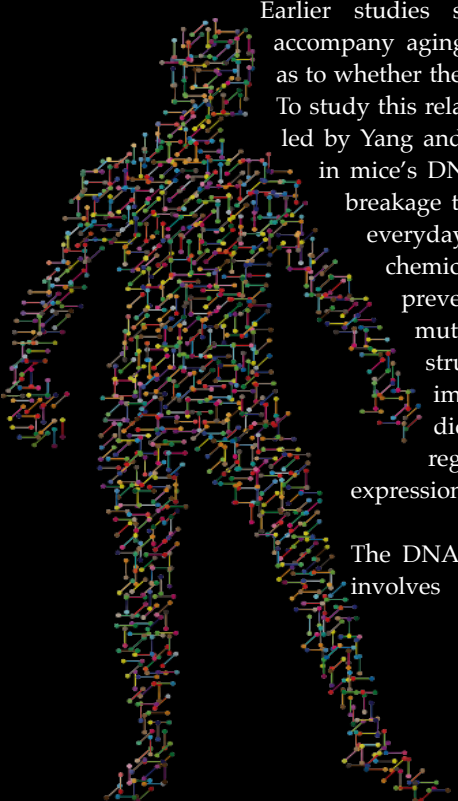
BY MAYA BRINSTER, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY ANANYA JAIN, BEHAVIORAL NEUROSCIENCE, 2025

Extending a human's lifetime sounds like something that would only exist in a fictional realm. A recently published study, though, shows that this ability may one day be achievable in our own world.

A common theory regarding the mechanism that drives aging is that the accumulation of genetic mutations eventually causes cells to lose their structure and identities. These changes in the DNA structure that prevent genes from functioning properly could lead to subsequent organ failure, disease, and death. But findings from 13 years of research conducted by a team led by Harvard Medical School geneticists Jae-Hyun Yang and David Sinclair reveal that the predominant forces behind aging are instead factors that impact the way DNA is folded and thus which genes are expressed at specific times during an organism's lifespan.

In the nucleus, DNA is coiled around proteins to form nucleosomes, which are further condensed to form chromatin fibers. These fibers can unwind to make certain portions of DNA accessible to molecules that help express genes coded by that specific sequence. Chromatin movement is controlled by chemical tags attached to the DNA, referred to as "epigenetic modifications," which are the reason why an organism's cells can have drastically different structures and functions despite all containing the same DNA sequence.



Earlier studies show that epigenetic changes accompany aging, but until now, it was unclear as to whether they were a result or the cause of it. To study this relationship, the team of researchers led by Yang and Sinclair created temporary cuts in mice's DNA to replicate the chromosomal breakage that occurs in cells as a result of everyday activities such as sunlight and chemical exposure or breathing. To prevent genes from developing mutations and ensure that only the structure and folding of DNA were impacted by the cuts, researchers did not make cuts within the active regions of DNA responsible for gene expression and protein formation.

The DNA damage response to these cuts involves the recruitment of epigenetic modifiers, diverting them from their normal regulatory function. At first, modifiers returned to these functions promptly after repair. As time passed, they eventually stopped returning, causing epigenetic disorganization. Mice experienced a rise in biomarkers indicative of aging and cellular deterioration, chromatin started to condense at the wrong places, and cells began to lose their identities. Researchers found that the epigenetic aging rate was about 50% faster in experimental mice, and accordingly, after ten months, signs of aging that normally manifest in mice near the end of their 2.5-year lifespan became clear; mice experienced long-term memory loss, a decline in spatial awareness, reduced endurance, increased brain inflammation, and other age-related defects. Based on the number of lost biomarkers attached to the genome, experimental mice were biologically much older than the control group despite being alive for the same amount of time.

After showing clear signs of aging, experimental mice were treated with three genes responsible for cellular reprogramming to attempt to return cells to a revived state. Shortly after, tissues and organs began to function better and cells experienced the permanent restoration of epigenetic factors they had when they were young. Although the mechanism as to how treatment with these genes restored function remains unclear, this experiment supports the hypothesis that mammalian cells' early epigenetic software remains unaffected by disruptive factors that cause epigenetic dysregulation and aging, and restoring them can revive cellular function.

Although much more information and future research are needed in order to make medical applications feasible, these findings can allow for more effective treatments of diseases associated with aging such as neurodegeneration, cardiovascular disease, and frailty. The team also plans on exploring other more effective factors than the three cellular reprogramming genes to control the epigenome and rejuvenate tissues, such as drugs or small molecule chemicals, and they are hopeful that eventually, the human health span will be able to be extended: "We have the technology today to be able to go into your hundreds without worrying about getting cancer in your 70s, heart disease in your 80s, and Alzheimer's in your 90s," Sinclair explained. This work opens doors for countless thrilling possibilities, and the rejuvenation of mice is only the beginning.

Cell (2023). DOI: 10.1016/j.cell.2022.12.027
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PHOTO BY PIXABAY

RUTHLESS ENVIRONMENTAL DANGERS DURING INFANCY

BY JULIE RATLIFF, BIOLOGY, 2023

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

An average of over 120,000 babies with congenital complications are born a year. Congenital complications are believed to result from genetics, maternal choices during pregnancy, environmental factors, and other influences. One environmental factor, air pollution, is associated with low birth weight (a birth weight under 5.5 pounds) and being preterm (born prior to 37 weeks of pregnancy).

Such birth complications are serious. As a result of being born prematurely or too small, babies are more susceptible to medical issues, including neurological injury, blood-related conditions, and pulmonary complications. Being born preterm or at a low birth weight are the most common causes of fatalities within a month of birth and amount to about 1.8 million deaths globally. The lower the weight at which the baby is born, the more severe birth defects can be. Additionally, it is not just during infancy that such babies are particularly susceptible to medical problems. If they live past the first few years of life, the babies are at an increased likelihood of developing both immune-related conditions as children and serious recurring illnesses as adults.

Certain chemical exposures during infancy can be highly detrimental to child development. For example, studies have shown that polycyclic aromatic hydrocarbons (PAHs), released from burning fossil fuels, at concentrations in the air in New York City, can negatively impact the IQ of youth, which suggests that they may struggle with school work over the long term. Growing amounts of data indicate that the negative impact of chlorpyrifos, a pesticide, is severe and chronic, triggering behavioral, locomotion, and intellectual difficulties in kids.

Air contaminants have been shown to have further negative impacts on children. Studies from the University of Colorado at Boulder have indicated that females who breathe in more air contaminants while pregnant have infants who become abnormally heavy in the first six months of life, which can lead to obesity and additional health problems during adulthood. One research investigation done about Hispanic moms and babies describes data indicating that air pollution might play a role in obesity in America. This is especially prominent for marginalized groups who often reside in areas with a greater amount of air contaminants. Past studies have indicated that females who smoke or breathe in lots of air contaminants during pregnancy are more likely to conceive low birth weight children. From birth to 12 months, such babies often put on weight abnormally quickly. Infants who experience such a rapid increase in weight are more likely to suffer from diabetes, heart conditions, and obesity as children or young adults. Black populations and economically disadvantaged people may breathe in 150% as many air contaminants as Caucasian people.

In addition, maternal behaviors like smoking can be quite harmful and even deadly for children. Tobacco smoke impacts brain maturation in infants. Nicotine from smoking goes across the placenta, leading to blood levels around the fetus that are possibly greater than in the mom. This can substantially impair the crucial components of central nervous system development that occur during this time. Further, tobacco smoke during fetal development can lead to poor academic performance for the child in elementary school. Despite the danger of smoking for fetal development, 10 million children five years of age or younger breathe in smoke in their residences. On top of this, babies from less fortunate or marginalized communities are more likely to have secondhand smoke exposure, as a greater proportion of adults smoke in these groups.

Pregnancy and infancy are essential periods in child development. However, the impact of the environment on young children can often be overlooked as they make up a minority of the population. Educating pregnant women and those who smoke about the potential environmental impacts of their actions is thus critical for addressing health concerns of babies and young children. In addition, society must look to sources of pollution, like corporations, farming industries, fossil fuels, and cars, which are equally at the heart of the issue. Change is possible, but it will take bringing about a collective and consistent effort.

NeoReviews (2011). DOI: 10.1542/neo.11-7-e363

Environmental Health (2021). DOI: 10.1186/s12940-021-00753-8

PHOTO BY PIXABAY

YOU WILL FORGET ABOUT THIS ARTICLE

BY CAROLINE GABLE, UNDECLARED, 2026

DESIGN BY VY PHAN, BIOENGINEERING & BIOCHEMISTRY, 2025

Forgetting is an inevitable part of the human experience. People forget names, dates, appointments, and even entire events. It is frustrating to have something on the tip of your tongue, only to forget it completely moments later. But why do humans forget things? There are various theories as to why forgetting occurs, including biological, environmental, and even psychological factors.

One of the most popular theories as to why people forget things is simply due to the passage of time through a process called memory decay. Memory decay refers to the gradual fading or weakening of memories over time. Memory decay was originally hypothesized by professor John Brown of the University of London in 1958, in a groundbreaking study done to quantify forgetfulness. The theory was that memory traces decay over a brief time period until a threshold is reached and the memory becomes unreachable.

According to Brown, forgetting is the direct result of decay. Essentially, memories are formed when neurons in the brain form new connections, known as synapses. These synapses create pathways for electrical impulses to travel through the brain. When the same path is traversed repeatedly, the connection becomes stronger, creating a stronger memory. However, if these pathways are not reinforced regularly, they can weaken over time, leading to memory decay. In a way, the brain's neural connections are akin to muscle tissue that needs to be exercised in order to stay strong. If a memory is not accessed or recalled for an extended period of time, the connections associated with that memory can decay, making it more difficult to recall the information or aspects of the memory later. While this theory does have numerous supportive studies, it is not the only theory proposed to explain forgetting.

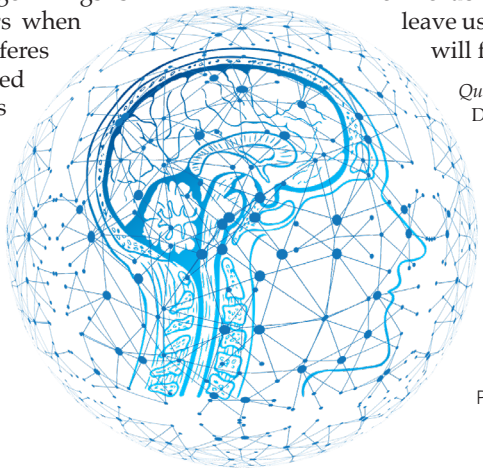
> "While we may never know exactly how and why memories tend to leave us over time, one thing is for certain: You will forget about this article in the future."

Another theory as to why humans forget things is due to interference. Interference occurs when new information is learned that interferes with the retrieval of previously learned information. For example, if one is trying to recall the name of a person they met last week, but then meets someone new with a similar name, it may become difficult to retrieve the correct name. This type of forgetting is known as retroactive interference. Proactive interference is the opposite of retroactive interference, where old memories interfere with the retrieval of new memories.

For instance, if someone has learned a certain skill, it can be challenging to learn a new one that contradicts the old one, even though it may be more efficient or effective. Due to the prominent correlation between interference and forgetting, a 2019 study from New York University used a variety of behavioral and neuroimaging studies and four separate experiments in order to find ways to reduce the effect of interference on memory. This study did ultimately identify ways to prevent interference from causing forgetting, such as limiting distractions in one's life and workspace. However, the study acknowledged that solely limiting interference does not account for other factors that can cause forgetting such as stress and age.

When people are under stress, their brain releases cortisol, a hormone that can interfere with memory consolidation, making it more difficult to form new memories. In fact, there is developing research that indicates high cortisol levels are associated with memory loss and cognitive dysfunction. This may even correlate to the development of Alzheimer's disease, a neurodegenerative disease impacting memory. Furthermore, aging is a factor that can contribute to forgetting. As people age, their brain undergoes changes that can make it harder to form and retrieve memories. For example, the hippocampus, a brain region critical for semantic memory, which stores statistical and objective information, can shrink with age, and the connections between neurons can weaken.

Overall, forgetting is a natural and inevitable part of the human experience. People forget things for various reasons, including the passage of time, interference, stress, and aging. While it can be frustrating to forget important information, it is important to remember that forgetting is a natural and normal part of the brain's functioning. While we may never know exactly how and why memories tend to leave us over time, one thing is for certain: You will forget about this article in the future.



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PHOTOS BY PIXABAY

A LOOK AT A NORTHEASTERN PROFESSOR'S CONTRIBUTION TO CANCER IMMUNOTHERAPY

BY CHRISTINA CURRAN, BIOCHEMISTRY, 2023

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

We are often reminded of basic health mantras to decrease your risk of getting cancer such as wearing sunscreen, avoiding smoking, and being wary of carcinogens. It might surprise you to hear that increasing your caffeine intake might be added to the list.

The concepts for this idea emerged in the early 2000s, when Michail Sitkovsky, director of Northeastern's New England Inflammation and Tissue Protection Institute, discovered that a specific receptor, the A2A adenosine receptor, inhibits immune cells from invading tumors. This enables the growth, proliferation, and spread of the tumor. It has long been known that tumor cells rapidly exhaust their blood supply, creating a low-oxygen environment. This oxygen shortage encourages the production of adenosine, which reacts with the A2A adenosine receptor to put local tumor-fighting immune cells to sleep. For years, researchers sought a drug that could combat this adenosine effect, but, Sitkovsky wondered, what if the solution was more simple than it seemed?

This question encouraged him to address the root of the issue: oxygen access. He and his colleagues found that access to supplemental oxygen — supplying the blood with two to three times more oxygen than typical — helps mitigate this A2A signaling and encourages immune cells to invade the tumor. These increased oxygen levels, known as "respiratory hyperoxia," were also found to stifle the spread of breast tumors. This mechanism serves as a potential avenue for enhancing the power of immunotherapies, a treatment method in which the body's own immune system is stimulated to specifically target cancer cells.

"Breathing supplemental oxygen opens up the gates of the tumor fortress and wakes up 'sleepy' antitumor cells, enabling these soldiers to enter the fortress and destroy it," Sitkovsky said. "However, if antitumor immune cells are not present, oxygen will have no impact."

Although respiratory hyperoxia is a powerful tool to equip the immune system, Sitkovsky hypothesized that more could be done to further inhibit the A2A receptor. For years, epidemiologists had found a link between coffee consumption and decreased cancer risk. Indeed, research from him and his colleagues in 2009 found that caffeine, a natural antagonist of the A2A adenosine receptor, further enhances the therapeutic impact of respiratory hyperoxia.

"Many of us consume coffee every day to keep ourselves awake and functional during the day. Our addiction might be helping us out in the long run!" Sitkovsky said.

Although some years have passed since this groundbreaking discovery, this mechanism has expanded beyond the original idea of cancer therapy. More recently, Sitkovsky points to the A2A receptor's role in treating patients with COVID-19-triggered pneumonia. Sitkovsky recalls how in the early months of 2020, COVID-19 was tearing through Italy's elderly population. This time, he worked with clinicians in Italy to explore the impact of administering adenosine to prevent inflammatory damage to the lungs. Although the study was small, it found that the presence of COVID-19 RNA rapidly decreased in 13 out of 14 cases within seven days, compared to no changes in the control group.

Sitkovsky stresses the versatility of this mechanism in immune-mediated therapies, citing several successful clinical trials and new drugs for numerous diseases. "This mechanism has the unique capability to not only be effective on its own, but boost the efficacy of other targeted therapies of cancer," he said.

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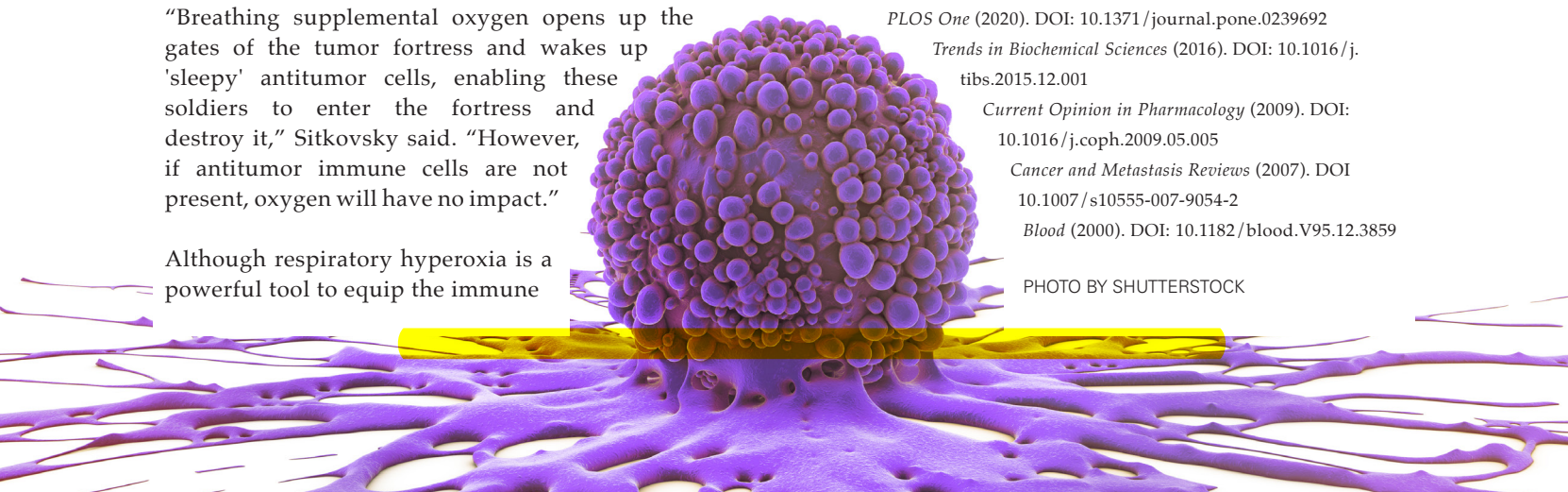
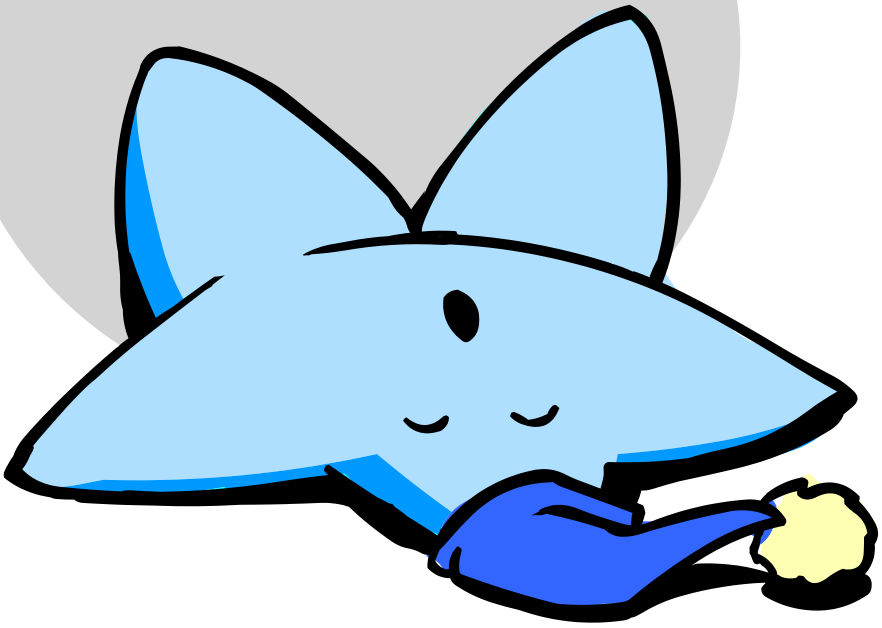


PHOTO BY SHUTTERSTOCK

NAPPING IT'S MORE IMPORTANT THAN YOU THINK!

BY ELIZABETH LUO, CELL & MOLECULAR BIOLOGY, 2026
DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025



Napping is a prominent part of today's culture; many partake in after-school naps, midday naps, and power naps before an exam, among other types. People often label those who nap as lazy, but studies show that napping provides both academic and physical benefits. Napping should therefore be regarded as productive, rather than the opposite.

Surrounding culture and society largely shaped the history of sleep. In preindustrial times, many embraced the biphasic sleeping pattern. They had their "first sleep" as the sun set and woke up during the night to socialize, read, or engage in other pastimes. They then fell back asleep for their "second sleep" and woke up just before dawn. In modern days, the nine-to-five work schedule forces everyone, including children, to follow an unnatural cycle of sleep to satisfy economic needs. This unnatural cycle makes it harder to get an adequate amount of sleep, which is more serious than one may think.

Reduced sleep muddles the interaction between circadian rhythms and homeostatic processes like appetite and blood pressure. Research shows that sleep-deprived children have reduced gray matter, which includes areas of the brain that are in charge of attention, memory, and inhibition control. A reduction was still evident two years after gray matter volume was first measured, which suggests that this effect is not quickly reversible. A lack of sleep can also be detrimental to the emotional regulation of children; if they do not get enough sleep, they can easily be overwhelmed, which causes grumpiness and emotional overreaction. In addition to impacting emotions, lack of sleep can cause attention issues, academic difficulties, mental health problems, and even changes in growth in children. Growth hormone is secreted during deep sleep, so reduced sleep deprives children of it, stunting not only their physical development but also their mental and emotional development.

So how can this be avoided? The answer is by napping. Naps are incredibly important, especially for children and growing teenagers. Research shows that napping is essential for academic advancement, memory consolidation, regulation of emotions and temperament, and physical development. According to the CDC, infants need around 12–16 hours of sleep, and teens need around 8–10 hours every day.

Napping helps clear the brain after encountering new information. It allows the brain to rest and sort through short-term memories from the day, allowing such memories to then get sorted into the cortex of the brain for long-term memory consolidation. Sorting is almost like a reshaping of the brain; during this process, new connections between neurons form, allowing signals to pass through and memories to form. This is especially important in children, as they are not only learning how to count numbers and read words, but they are also experiencing new feelings about the world around them. Noting that the sky is blue, that the sunlight feels warm on the skin, and that the grass feels prickly on their feet are all experiences that are brand new to them. Younger children, therefore, need more sleep to file away these new memories into long-term memory storage. Because naps allow children to sort through the day's events, they provide a clean slate for when children wake up to tackle new experiences.

Napping appears to be essential to the development of children. Changing the narrative from "laziness" to "normal" can help erase societal judgments on napping, allowing children to get the rest they need for optimum development.

PHOTO BY PIXABAY

WHEN DREAMS BECOME NIGHTMARES HOW ACTING OUT DREAMS CAN PREDICT BRAIN DISEASE

BY RESHIKA SAI DEVARAJAN, HEALTH SCIENCE 2025

DESIGN BY AMANDA BELL, DATA SCIENCE & BEHAVIORAL NEUROSCIENCE, 2023

Punching, kicking, throwing — not just daytime activities anymore. For some sleepers, these actions accompany their dream states. When a sleeper reflects what they are doing in their dream in real-time, despite being asleep, it's referred to as "acting out dreams" or REM sleep behavior disorder (RBD). So instead of punching an attacker, they might punch the pillow on their bed. Instead of throwing darts in their dream, they might catapult their stuffed animals across the room.

RBD occurs during the rapid eye movement (REM) stage of sleep, where sleepers often experience vivid and evocative dreams. During normal REM sleep, people tend to enter a type of sleep paralysis in which they cannot move their muscles. In contrast, those who experience RBD do not have such limitations and often move their limbs throughout their dreams. As sleepwalking and talking occur in different stages of sleep, they are not associated with RBD.

RBD is thought to result from damage to the brain stem that can occur due to various factors, including accidents and trauma. This damage reduces the body's ability to prevent actions during sleep, leading to the symptoms of RBD. Michel Jouvet, a groundbreaking researcher, conducted experiments with cats to study RBD. He observed and compared the sleeping patterns of cats with brainstem lesions to those without and found that the cats with damaged brainstems exhibited signs of RBD during their slumber.

Although RBD might seem harmless, it is actually a predictor of various degenerative brain diseases. It often manifests in older adults, particularly men, and is estimated to affect 1% of the population. Several studies have found that RBD is a clinical marker and is highly associated with the onset of a brain disease 10–15 years after the first RBD encounter. In fact, one study done at McGill University found that 73.5% of participants with RBD were diagnosed with a neurodegenerative brain disease 12 years after the start of the study.

RBD primarily predicts neurodegenerative synuclein aggregate disorders, such as Parkinson's, multiple system atrophy (MSA), and Lewy body dementia, which are characterized by the accumulation of abnormal protein clusters called synuclein aggregates in certain regions of the brain. These specific types of disorders have a large gap between when the disease's first symptoms begin to show and when the disease fully develops. This period is called the prodromal interval and can last over a decade for these specific types of neurodegenerative disorders.

For other subsets of brain diseases, prodromal periods are often identified through changes in parts of the brain in which the disease functions. In contrast, for neurodegenerative synuclein aggregate disorders, markers of the prodromal period are not limited to the area of the brain that is affected and in fact, are not limited by the brain at all. Motor changes, the onset of mental illness, changes in senses, and RBD are all various effects that mark the onset of these disorders.

The significance of RBD lies in its narrow scope and the specificity of the affected population. While other markers of the prodromal period can affect a large part of the population and happen for many reasons, RBD is a rare occurrence with a high correlation to the onset of certain brain diseases. RBD can help researchers and providers predict and treat brain diseases earlier, which is crucial due to the extensive length of the prodromal period. With RBD as a warning signal, physicians have the time to develop and implement well-thought-out, long-term treatment plans.

Although RBD may turn people's dreams into nightmares by creating anxiety about looming brain disease, its role in identifying potential health conditions is a blessing in disguise. RBD provides patients and providers with the necessary resources and time to plan for and manage future diseases.

Brain (2019). DOI: 10.1093/brain/awz030
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PHOTO BY PIXABAY

WORTH A (MICRONEEDLE) SHOT

Dissolvable microneedle vaccine patches are changing the future of healthcare

BY SITHARA SONNATHI, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY EVELYN MILAVSKY, CELL & MOLECULAR BIOLOGY, 2025

Shots are not fun. Many people experience anxiety right up until the needle pierces their skin. According to the Centers for Disease Control, the fear of needles prevents people from getting life-saving vaccinations each day. However, advancement in vaccine delivery technology is making it possible to receive these vaccinations without a needle. Transdermal drug delivery systems (TDDS) first surfaced in 1979 when scopolamine patches were approved for motion sickness. Not long after, nicotine patches for smoking cessation and pain relief patches for athletes were formulated. The implementation of these patches has paved the way for the development of dissolvable microneedle patches which are a more efficient, accessible, and painless method of delivering vaccines.

Microneedles are composed of about 100 microscopic cones, each of which is more than 50 times smaller than an inch. These microneedles penetrate the skin and target immune cells directly below the skin. The skin plays a substantial role in pathogenic invasion by governing what can enter and leave the body. By delivering the vaccine directly to the dermis, projections direct vaccine components to lymph nodes, evoking a robust immune response. Microneedle formations are composed of sugar and salt because the skin naturally allows these compounds to enter the body. Vaccine components can be integrated into a sugar and salt solution, dried, and applied to the skin. The moisture in the skin dissolves the microneedles, absorbing the vaccine components. Antigen-presenting cells in the skin recognize foreign particles and activate lymphocytes. These cells latch on and destroy invading pathogens.

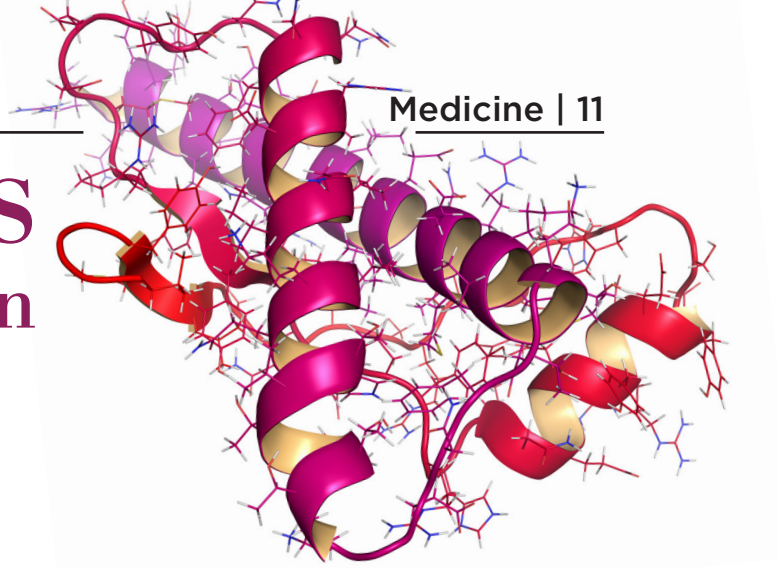
Why are dissolvable skin patches so effective when delivering vaccines? Intramuscular vaccination, the prevalent model of vaccination, uses a needle and prevents infections by identifying pathogens that are already inside the body. This is why individuals may get COVID-19 or the flu even after being vaccinated. Microneedle patches are more effective because they block viruses from entering the body by vaccinating through the dermis. Pathogens are neutralized before reaching other tracts in the body. However, if a pathogen gets past the dermal barrier, activated lymphocytes protect the host. In general, dissolvable microneedle patches provide both skin-level protection and whole-body protection. Marianne Chang, a biomedical correspondent for the Korea Biomedical Review, confirmed that, "Abion has been conducting joint research with Raphas, a company specializing in microneedle patches, to immunize its COVID-19 DNA vaccine through portable electroporation by mounting it on microneedle patches."

The vaccine is administered via electroporation, a technique where high-voltage shocks are applied to cells to allow for the entrance of antibodies, DNA, RNA, and other chemicals. This method is most efficient at 90 volts but causes more pain in patients. Global technology companies including Raphas have conducted tests to verify cell delivery through microneedle vaccine patches such as lower voltages like 25 and 50 volts. In a 2022 study, researchers at Abion and Raphas confirmed antibody production at similar levels to that of traditional needle injection methods in animals. The patches are designed to dissolve within just a few hours to enable a slow release of vaccine components. Intramuscular injections, however, attack the immune system with an entire dose of the vaccine which is why patients may feel swollen and sore. These localized immune responses are also the cause of post-vaccine headaches, runny noses, and sore throats. Through painless microneedle patches, the vaccine is delivered slowly without triggering a major inflammatory response.

Traditional mRNA vaccines are between minus 80 and minus 20 degrees Celsius and require cold chain shipping to ensure the thermostability of the vaccines. This disproportionately affects low-income countries that lack the resources to store the vaccines. Microneedle vaccines are delivered in a dried formulation and do not require special refrigerators, making them exceptionally convenient. These vaccines also use smaller doses and waste fewer supplies. Advancing technology has made it so that future models will not require a clinician to administer the vaccine and can be mailed to and used by patients directly, increasing accessibility to countries around the globe. Microbiologists at Boise State University stated that "dissolvable microneedle skin patches may face challenges to production, as does any new technology, but the benefits are pushing scientists to develop this new platform for vaccine delivery."

There is still so much left to explore in the field of vaccine delivery technology. Pharmaceutical companies are in the process of developing influenza multivalent vaccines and other chemical drugs. While scientists are making exceptional progress with dissolvable patches, further clinical testing will be key to getting this microneedle technology delivered to homes, schools, workplaces, and more importantly, into arms.

PHOTO BY SHUTTERSTOCK



PROTEIN PRIONS

The strangest pathogen of them all

BY DHRITI AIYLAM, BEHAVIORAL NEUROSCIENCE & ENGLISH, 2024

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

When we think of pathogens, our minds jump to evil little microorganisms — be it viruses, bacteria, or parasites — that infect and wreak havoc on us from the outside. But we hardly think that such pathogens can originate within our own bodies and that they do not even have to be alive. Deadly prion diseases, for example, are caused by proteins, the very building blocks that are essential to our survival.

Prion diseases, caused by abnormal prion proteins, are rare and fatal neurological diseases that can be genetically inherited, emerge sporadically, or spread via transmission methods like blood transfusion and ingestion. The best-known of these is bovine spongiform encephalopathy, also known as mad cow disease. Spongiform encephalopathies are another name for prion diseases due to one of their hallmark symptoms, vacuolation, in which the brain takes on a sponge-like appearance when vacuoles, or holes, start to form. But what really are protein prions, how can they cause such drastic damage, and how are these diseases treated?

To answer these questions, it is important to look at a protein called PrPC, expressed in the brain and lymphatic system. Protein folding is crucial to the functionality of our cells, and when PrPC is misfolded into the infectious PrPSc, also known as the "prion," it forms large clusters that build up in the brain and damage cells and tissues. However, it is neither the presence of PrPC nor PrPSc alone that is responsible for disease pathology. Rather, it is the conversion of PrPC to PrPSc that is so toxic.

The reason behind this still remains a mystery but looking into the progression of prion diseases could offer some insights. Prion diseases begin with synaptic damage. Synapses are the gaps between neurons that allow them to communicate, and PrPSc aggregates hijack this machinery by accumulating in these spaces and interacting with synaptic proteins, interrupting neurotransmission. Following synaptic damage is dendritic loss. Dendrites are structures on neurons that receive signals from other neurons and are responsible for determining whether a neuron fires a signal. However, the presence of prions crumbles the actin cytoskeleton supporting dendrites and causes their spines to swiftly retract. While this is happening, PrPSc buildup also puts remarkable stress on the endoplasmic reticulum (ER), the cellular structure responsible for modifying proteins and relaying them to different parts of the cell. Because of this, the ER eventually activates the unfolded protein response, a defense strategy against the buildup of misfolded proteins that includes moving them out to the cytosol for degradation, activating ER chaperones, and reducing the amount of translation that takes place during protein synthesis. The brain's immune response is also activated, leading to the next stage of the disease: brain inflammation.

The immune response of the brain is regulated by microglia, which are cells that digest pathogens. Microglia consume PrPSc deposits, which slows symptoms associated with their buildup. However, when the brain's tools are forced to go into overdrive, they can be weaponized against us, and the stress produced by hyperactive microglia exacerbates neurotoxicity and accelerates neurodegeneration. It is also theorized that the activation of microglia, along with another type of brain cell, astrocytes, could actually drive pathology, as inflammation-related genes are upregulated alongside the earliest changes in the brain.

The next stage of disease, large-scale neuronal loss, is what leads to rapid deterioration and the poor prognosis of prion diseases. One way in which this takes place is vacuolation; although the mechanisms behind it are unclear, it is speculated that it could be caused by increased membrane permeability and water content within neurons or by autophagy, a process that digests cell organelles and misfolded proteins. Another process involved in neuronal death is apoptosis, a self-destructive mechanism driven by ER stress. ER stress also causes calcium to be released from the ER into the cytoplasm. Maintaining calcium concentrations is crucial for neuronal signaling, and the imbalance caused by this aberrant flux induces neuronal death.

There is currently no cure for prion diseases, but there may be a way to prevent PrPC misfolding and prion replication. Researchers found that synthetic compounds called antisense nucleotides can stop the production of PrPC, the normal protein — the disappearance of which has actually reversed symptoms of prion disease in mice. Additionally, short synthetic fragments of prion protein can stop the conversion of PrPC to PrPSc, but this only works during early stages of the disease. Future therapeutic strategies could involve targeting antibodies toward the N-terminus of the prion protein. Upon the presence of PrPSc, the N-terminal domain of the protein disconnects from the C-terminal domain, binding to the cell surface and initiating toxic effects. There is still much to learn and many exciting discoveries on the horizon, but one thing remains clear: The world of microbiology truly is a complex and surprising one.

Cell and Tissue Research (2022). DOI: 10.1007/s00441-022-03683-0
Trends in Molecular Medicine (2011). DOI: 10.1016/j.molmed.2010.09.001

PHOTO BY SHUTTERSTOCK

YET ANOTHER REASON TO AVOID TRAFFIC

BY ASHNA SHAH, BEHAVIORAL NEUROSCIENCE, 2025
DESIGN BY AMANDA BELL, DATA SCIENCE & BEHAVIORAL NEUROSCIENCE, 2023

The Environmental Protection Agency estimates that the United States generated 67 million tons of air pollution in 2021. Ever since the Industrial Revolution in the 1800s, the amount of air pollutants (nitrogen oxides, carbon dioxide, methane, and sulfur dioxide, to name a few) in the Earth's atmosphere skyrocketed. With the increasing toxicity present in the air we breathe comes consequences for the way we think and behave. Past studies on the effects of air contaminants have studied respiratory impacts, cardiovascular risks, and developmental impacts. But, much is unknown about the cognitive effects of traffic-induced air pollution, as the neurological effects of air pollution are not as widely studied.

Earlier this year, researchers at the University of Victoria and the University of British Columbia released data from a study describing the negative impact of traffic pollution on the brain's default mode network (DMN). They describe the DMN as "a set of interconnected brain regions that play an important role in memory and internal thought." The DMN impacts our emotional perception of others and feelings of empathy, and it tends to activate in times when our attention is diverted from our surroundings and in instances of self-awareness (for example, daydreaming and self-analysis).

Through a brain scan analysis, the scientists concluded that exposure to 300 micrograms per cubic meter of diesel exhaust over a two-hour period causes a temporary reduction of DMN activity when compared to the effects of filtered air. They attributed this short-term effect to the fact that exposure only lasted for two hours, rather than the more continuous exposure that occurs in your typical everyday traffic. This decrease in DMN activity has complications. Since the DMN is linked to our sociocognitive abilities, scientists are aware of the potential for lower DMN activity caused by air pollution to result in sociocognitive deficiencies and symptoms of depression or other mental health conditions.

Unlike the majority of other research done by scientists on the impacts of air pollution, this study used 25 adult human subjects between the ages of 19 and 49. Each person was introduced to two environments — one with diesel exhaust and one with filtered air — with a two-week interval between each. The order of exposures was randomized. During the exposure periods, each individual was instructed to ride a stationary bike for 15 minutes in order to gain a base-level image of brain activity. Before and after the exposures, brain activity was measured using functional magnetic resonance imaging (fMRI), which records changes in blood flow and oxygen levels.

The general results from the fMRIs indicated that there was the greatest DMN activity post-exposure to the filtered air in regions of the brain controlling language processing and visual perception. The researchers ultimately concluded that brain activity in the DMN is diminished post-exposure to diesel exhaust. They also mention that, in the diesel exhaust environment, the individuals did not gain any of the cognitive boosts from light exercise on the stationary bike. This study is very important in the world of environmental science and neuroscience as it "provides the first evidence in humans, from a controlled experiment, of altered brain network connectivity acutely induced by air pollution," according to the authors of the recent paper.

This research echoes similar findings to a 2015 review by Nicholas Woodward and colleagues exploring the neurological effects of traffic-related air pollution on rodents, prenatal fetuses, and neonatal children. They explain how past research has found that exposure to traffic-caused air pollution can cause inflammation and cognitive changes, especially in male rodents. The authors also discuss how excessive air pollution exposure during the developmental stage of rodents can cause symptoms of depression, lower reaction times when introduced to stimuli, and attention deficits. Similar to the authors of the recent study, Woodward also acknowledges the gap in cognitive research in relation to pollution and advocates for future studies.

Since the University of Victoria and the University of British Columbia study only examined the effects after a two-hour period, Dr. Chris Carlsten, one of the authors of the paper, speculates that continuous exposure to air contaminants in traffic may lead to long-lasting impacts on the brain. Scientists as a whole admit that further study is needed on this topic to determine the actual neurological impacts for those who experience long stretches of traffic-induced air pollution on a regular basis.

Environmental Health (2023). DOI: 10.1186/s12940-023-00961-4
Philosophical Transactions of the Royal Society A (2020). DOI: 10.1098/rsta.2019.0314
AIMS Environmental Science (2015). DOI: 10.3934/environsci.2015.2.353
Frontiers in Human Neuroscience (2014). DOI: 10.3389/fnhum.2014.00074

PHOTO BY PIXABAY

EXPOSURE TO AIR POLLUTION, EVEN IN LOW LEVELS, INCREASES RISK FOR ALZHEIMER'S

BY MIKAYLA TSAI, BEHAVIORAL NEUROSCIENCE, 2026

DESIGN BY EVELYN MILAVSKY, CELL & MOLECULAR BIOLOGY, 2025

Inconspicuously, house keys and the location of home dissipates from memory. Progressing further along, even the familiar faces of loved ones fade out of recollection. The most common form of dementia, Alzheimer's disease, is the sixth leading cause of death in the U.S. This neurodegenerative disorder primarily affects the cognitive functioning responsible for retrieving, storing, and processing information. Common symptoms of Alzheimer's include the gradual inhibition of memory along with judgment-making capabilities of even the simplest of tasks. This disease primarily affects those over the age of 65. A reported one in three people of this age will pass away with Alzheimer's or other forms of dementia. Magnetic Resonance Imaging (MRI) scans reveal that Alzheimer's appears in the form of protein plaques and neurofibrillary tangles, which serve as the main physical features of Alzheimer's disease identification.

The initial stage of the disease is known as preclinical Alzheimer's disease, during which there are no noticeable changes in the individual's behavior observed by surrounding individuals. Clinical procedures including biomarkers and genetic tests are the only way to detect early symptoms of Alzheimer's, including protein accumulation. As the disease progresses, patients approach the stage of mild dementia, which is characterized by minuscule changes in personality including increased aggression and motivational decline. Furthermore, individuals may lose memory and forget personal details including their phone number or address. Severe dementia is seen as the final stage, in which "negative spillover-effects" are seen in other aspects of the body including the impairment of motor abilities and an inability to coherently converse, as well as significant memory loss and drastic altercations to personality. For years, scientists have sought to find a cause of this disease, but finding direct links to any known cause (aside from heritability) is difficult.

Some researchers have wondered whether environmental factors may contribute to the emergence of Alzheimer's. Studies in mice have shown that particulate matter from the atmosphere that enters the brain has caused biological changes that may serve as indicators of Alzheimer's. In 2016, a research team from Mexico City and Manchester, England, discovered that particulates could penetrate the brain by way of the bloodstream or through the nose lining. Positron Emission Tomography (PET) scans revealed that particulate matter accumulates inside protein deposits found within the brain. Protein deposits, known as amyloid plaques, are the primary indicator of Alzheimer's.

In response to this finding, researchers conducted experiments on transgenic mice to detect the effects of chronic low-level particulate matter exposure on the pathological accumulation of amyloid protein. Separated into two groups, the exposure group underwent five months of exposure, which led to fascinating results. Even at low concentrations, particulate matter exposure could still cause chronic conditions leading to morbidity. In addition, amyloid protein was found in several subcortical regions including the optic tract, which implied that particulates entered the body through multiple pathogenic pathways resulting in Alzheimer's.

Although there is no known cure for Alzheimer's disease, some drugs that have been approved by the FDA may help with symptom management and temporarily slow the spread of Alzheimer's. Galantamine and rivastigmine are examples of drugs that act as cholinesterase inhibitors, which prevent the breakdown of acetylcholine, a chemical essential for the functioning of cognitive processes. Furthermore, these drugs are only able to target the earlier stages of Alzheimer's and are useless in the stage of severe dementia.

Despite the fact that the underlying mechanisms of Alzheimer's remain shrouded in mystery, this neurodegenerative disorder has garnered increased attention within the scientific community in recent years. By taking action in our everyday lives to reduce particulate matter exposure, great gains can be made through consistent efforts, no matter how significant. Hopefully, in the future, more long-lasting solutions to remedy Alzheimer's disease will continually be discovered and become accessible to the vulnerable demographic in need of specialized care and assistance.

Particle and Fibre Toxicology (2022). DOI: 10.1186/s12989-022-00485-8

PHOTO BY SHUTTERSTOCK

HUMAN COMPOSTING
A NEW FUTURE FOR OUR DEAD?

ARTICLE & DESIGN BY JOSEPHINE DERMOND, ECONOMICS, 2025

The circle of life is an intrinsic part of existence. A flower buds from a seed, blossoms, loses its petals as it begins to frost, and slowly withers away, returning to the earth to be decomposed. From here, an orchestra of events occurs with microscopic creatures breaking down what once was alive and returning it to a new natural state on earth. This process is consistently ongoing in many forms, from plants to animals, to our food scraps. So why does this natural process sound so obscene and controversial when we apply it to ourselves and our loved ones? It seems there are complications when combining the complex sentiment around death and evidence-based science. Nevertheless, composting human bodies is not only possible, but slowly integrating itself as a method of after-life care.

Death does not prevent someone from having a positive or negative impact on the environment. There are many ecological and health implications to our current forms of afterlife care: burials and cremation. Cremation involves the incineration of a carcass in an industrial-like furnace at extremely high temperatures, leaving a heap of ashes. The rest of the corpse leaves the earth in a puff of dark black smoke. This 1 1/2 to 2 hour combustion process powered by fossil fuels emits toxic chemicals into the atmosphere such as carbon monoxide, sulfur dioxide, and nitrogen oxides, as well as an array of poisonous metals from dental fillings and implants.

Although formal cemetery burials may seem more environmentally friendly, preparing a corpse for burial requires formaldehyde: an embalming fluid and carcinogen used to prevent the body from decay. Morticians preparing the body for burial are at risk of frequent exposure. On the other hand, many cultures practice natural burials by disposing of bodies directly into the earth. This method is highly unsafe because as the body begins to decompose, fluid released from the body disperses into groundwater systems and carries pollutants and pathogens throughout the soil.

There is a stark difference between natural burials and human composting, more commonly referred to as terramation. Composting requires an environment suitable for microbes to thrive with a balanced mix of oxygen, carbon, and nitrogen. In terramation, a corpse is the nitrogenous element in place of food scraps, and the carbon elements are alfalfa, woodchips, and straw. These components, moisture levels, and temperature levels are closely monitored to create an environment suitable for the correct type of microbes, fungi, and bacteria to release from the corpse's skin. While the microbes are at work, energy in the form of heat is released from the body as its chemical bonds break down and transform into small pieces of dirt.

The human composting process was first tested in a 2018 study with six donors whose bodies were placed in a fridge-like insulated container in a Seattle warehouse. The process was inspired by the animal carcass composting used for the mass disposal of infected livestock. The illnesses present in these animals, such as salmonella and the avian flu, are not safety concerns when using the compost product because the heat emitted from the microbes is warm enough to kill these pathogens. Within the first few days, temperatures can reach up to 140 degrees Fahrenheit. Similarly, composting humans does not pose a health threat concerning pathogen transfer if high temperatures are sustained, except for extreme cases like ebola, tuberculosis, and prions.

Within one to two months, the bodies decay into nutrient-dense compost, ready to restore nutrients to the earth. However, legal restrictions on funerals, cremation, and burials limit wide scale terramation practice. Micha Truman, the founder of Return Home, one of the first and largest terramation companies, took his case to court in 2018 and fought to have the process legalized in Washington. Since then, the process has become legal in six states and is disrupting the funeral industry.

There is a notable rise in the "green death" movement, even though many can not bear the thought of receiving pounds of compost-filled bags instead of their loved one's ashes. The science is too new to determine with certainty that terramation is the most environmentally friendly method. For many, this process will remain creepy and inhumane, but for others, this may be the future of how we care for our dead. It seems as though the fate of terramation lies in the societal perception of death and loss, something so ingrained in our culture that the prevalence of this process remains unknown.

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PHOTOS BY PIXABAY AND FREEPIK

Biological antifreeze
Wood frogs and organ cryopreservation

BY ALEXANDRA MAROPAKIS, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY AMANDA BELL, DATA SCIENCE & BEHAVIORAL NEUROSCIENCE, 2023

On February 4, 2023, Boston hit the coldest temperature recorded since 1886 at minus 10 degrees Fahrenheit. While most of us were snug in our blankets with a warm mug of tea in hand, others were not as lucky. *Lithobates sylvaticus*, commonly known as the wood frog, is a fascinating vertebrate model of freeze tolerance whose study spells endless possibilities for regenerative medicine. When exposed to subzero temperatures in winter, the wood frog endures the freezing of 65% to 70% of its body and becomes metabolically inactive until spring, when it thaws as if merely waking up from a long sleep. Analyzing the biological mechanisms of this frog's pro-survival response has inspired the development of a new long-term storage technique to extend an organ's shelf-life pre-transplant. In their review, Rasha Al-attar and Kenneth B. Storey delve into how the *L. sylvaticus* survives its full-body freeze and cast a new light on cryopreservation in regenerative medicine.

The wood frog freezes from the outside in via ice nucleation, in which ice crystals on the frog's skin trigger a cascade of ice growth into extracellular spaces while intracellular spaces remain fluid. Freezing is usually lethal due to extensive architectural damage done to cell membranes, interruption of blood oxygen flow, muscular atrophy, and significant oxidative stress. Wood frogs survive this process by enhancing the anaerobic — non-oxygen-focused — metabolism, increasing antioxidant and antiapoptotic responses, and making cryoprotectant factors more available in the body. One of these major cryoprotectants is glucose, produced by metabolizing reserves of glycogen built up in the liver during the summer months. High blood sugar content stabilizes proteins during the stress of freezing without interfering with enzyme activity. One of these enzymes is Fr10, aptly called the "antifreeze" protein. Fr10 binds directly to ice crystals to prevent them from accumulating and growing in size, which lowers the risk of tissue and cell membrane damage as the frog continues to freeze. By the time the wood frog reaches its maximum ice content, its cells are thoroughly reinforced with proteins and sugars keeping its cells from rupturing, leaving it extensively prepared to lie dormant until temperatures rise.

When it comes to organ preservation, any tissue can be frozen at subzero temperatures. What truly makes *L. sylvaticus* a worthwhile medical pursuit is how it thaws. Defrosting rate is proportional to the glucose concentrations in the frog's tissues, as high sugar content lowers the melting point of intracellular fluids. Internal organs receive the most glucose, meaning that the frog thaws from the inside out. As cardiac activity is restored and blood is pumped throughout the body, organs warm up and tissues revert from anaerobic to aerobic respiration in the creation of energy for metabolic function. Over 12 hours, the wood frog resumes all normal limb reflexes, breathing, and nerve excitability, and eventually hops away to find its first meal of the spring.

Many of these changes essential to survival are regulated at the transcriptional level. Epigenetic modifications alter how accessible DNA is converted into mRNA and then protein. Similar modifications on proteins can change how enzymes interact with substrates; in the case of the wood frog, proteins such as Glycogen synthase kinase 3, which prevents glucose from being converted back into glycogen when it is needed for cryopreservation, are further stabilized to increase their activity and effectiveness. Other factors mediate the action of transcripts like those encoding components of the cell cycle. This action can suppress cell proliferation and apoptotic mechanisms to preserve the cellular structure. Metabolic rate depression needs not one, but all of these regulatory stages put in place, which is why it is increasingly complex to translate the frog's antifreeze strategies to humans.

Regardless, how could this little frog be the solution to a global issue? As of 2023, over 100,000 candidates are waiting for an organ transplant. In the final months of 2022, only 42,888 people received organ transplants. That is a projected less than 41% of patients receiving a life-saving medical intervention. Not only is there a shortage of transplantable organs, but those which are viable require an intensive supercooling, ice-free protocol to extend their shelf-life to merely four days. On the contrary, wood frogs freeze for months without injury. If the pro-survival mechanisms of *Rana sylvatica* are harvested, not only can organs be transported and analyzed for safety without fear of tissue breakdown, but long-term storage drastically increases the chance for candidates to receive a transplant and begin the next chapter of their lives leaping for joy.

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PHOTOS BY PIXABAY & HIPPOPX

BY NICOLE CERIANI, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

New York City Breaks Record for the Latest First Snowfall

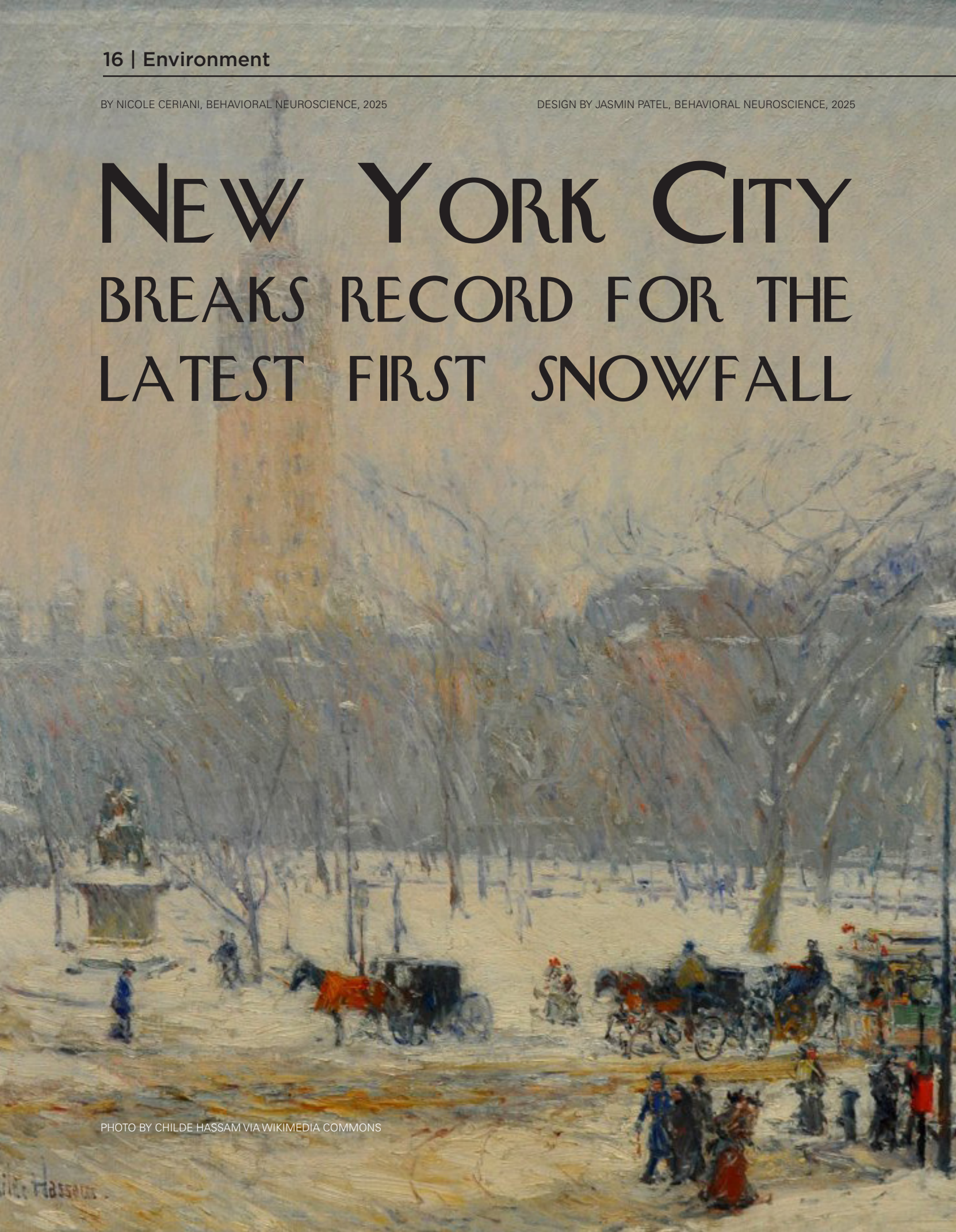


PHOTO BY CHILDE HASSAM VIA WIKIMEDIA COMMONS

New York City typically turns into a snow globe by mid-December, gracing its residents with a white Christmas, but not this season. Setting a record for the longest wait for snowfall since 1869, the first flurries came to the Big Apple on February 1, 2023. The overnight dusting covered the city with 0.4 inches of snow. The last winter with a snow drought this severe was half a century ago in 1973, when the city saw its first snowfall on January 29, 1973. It brought 2.8 inches in total, 14 inches less than the city's average. This year's 329-day stretch, from March 9 to February 1, beats 1973's record for the longest time without snowfall. Instead of snow, Central Park saw rain and flowers blooming through the month of January. New York wasn't alone. Much of New England has experienced a warmer, rainier winter this year. Why is this year such an anomaly? A combination of factors is responsible.

First, climate change is increasing average temperatures across the globe, though it does not impact each season equally. Over the past 30 years, the average winter temperature has increased by a full degree Fahrenheit, which is significantly more than any other season. In fact, winter is warming three times faster than summer. Higher winter temperatures, naturally, mean less snow.

Global warming causes not only droughts but extreme weather events like hurricanes and blizzards. The warmer atmosphere holds more water vapor and without colder air to condense the vapor, this moisture will remain in the sky and the land will stay dry. Sometimes this dryness lasts for extended periods of time as seen with California's drought

> "This year's specific La Niña conditions have brought the very real effects of global warming to light."

— for the past few years, California has battled its hottest and driest weather on record. On the other hand, when cooler air does arrive in the humid region, the vapor may condense and fall all at once as severe rain or snow.

October 2022 through January 2023 have been some of the warmest winter months to date, but there have been several days where temperatures plummeted 20 degrees

below average. Sporadic freezing temperatures, however, aren't sufficient to produce snowstorms. The development of snowstorms relies on cold and warm air colliding. The jet stream, a wind path that travels from the Pacific Ocean across the U.S. to the east coast, aids in bringing warm, moist air together with cold air to create storms. A disruption to this global wind pattern called "La Niña" is contributing to this year's lack of snow. The phenomenon occurs around every seven years, though there is no regular schedule. Due to the Earth's rotation, trade winds normally blow from east to west at the equator. During La Niña, these winds are stronger than usual, which causes a chain reaction that ultimately moves the jet stream further north. It is described as the "polar jet stream" when in this location.

The polar jet stream comes down from Alaska and turns east, passing through New York. It divides colder and wetter weather on its northern side from warmer and dryer weather on its southern side. It also acts as a route for storms to follow. New York City happens to fall south of this stream during this year's La Niña conditions. Thus, it has experienced dryer, warmer weather and has avoided winter storms that pass north of the city following the polar jet stream.

It seems as though this year's specific La Niña conditions have brought the very real effects of global warming to light — serving as yet another reminder of the climate crisis. Despite the uninspiring start to NYC's winter, the city typically receives half of its snowfall after February 1, so there is still hope for the snowman population to grow before spring.

Springer Link (2014). DOI: 10.1007/s10584-014-1257-2

THE MYCELIAL CYCLE
REPLENISHING THE WORLD WITH FUNGI

BY JIAJIA FU, BIOENGINEERING, 2026
DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Think mushrooms. Other than juicy, beefless patty substitutes sizzling on a grill, your first thoughts may have ventured to vivid, orange blooms sprouting out of rotting tree trunks. Fungi — even the term evokes vague revulsion or apprehension — are synonymous with rot and decay. They are harbingers of death, macabre forest floor scavengers who colonize corpses and thrive on their flesh.

Popular science fiction like "The Last of Us" and "Star Trek: Discovery" has introduced mycelium and fungi into the public lexicon; however, fungi already hold unfathomably far-reaching roles both ecologically and culturally around the world.

Mushrooms are only the fruiting bodies of fungi. Neither plant nor animal, fungi claim the third, massively complex branch of eukaryote. They were the first terrestrial colonizers, extracting mineral content from rocks to create soil. Fungi merged with liverworts, the most ancient land plant, into a singular symbiotic life form, laying the foundation for the first terrestrial plants to take root and birth complex ecosystems.

Mushrooms such as the pithy brown lingzhi are prized in East Asian traditional medicine for innumerable health benefits from lowering inflammation to slowing tumor development. Dedicated foragers in eastern Ukrainian forests are literally risking life and limb to continue the beloved Eastern European winter mushroom hunt.

Eons before humans existed, the first agricultural society farmed fungus. For 50 million years, leafcutter ants have marched through rainforests carrying serrated leaf slices. These leaves are not colony provisions, but Lepiotaceae feed. The fungus produces antibiotics that protect against common microbial infections in the Amazon basin, while the ants provide meticulously clean gardens free of pests and debris.

The largest organism on Earth is not the blue whale nor elephant, but a singular fungus encompassing 1,665 football fields in eastern Oregon. Via DNA fingerprinting and other gene identification techniques, Armillaria gallica, affectionately known as the "humongous fungus," has been identified as one individual ranging from 2,400 to 8,600 years old — also making it likely the oldest contiguous organism. The fungus differentiates along tree roots via hyphae, silvery filaments, which form mats that emit digestive enzymes for the fungus to feed and colonize simultaneously. This network is known as mycelium and allows entire ecosystems to exchange and reallocate resources and information.

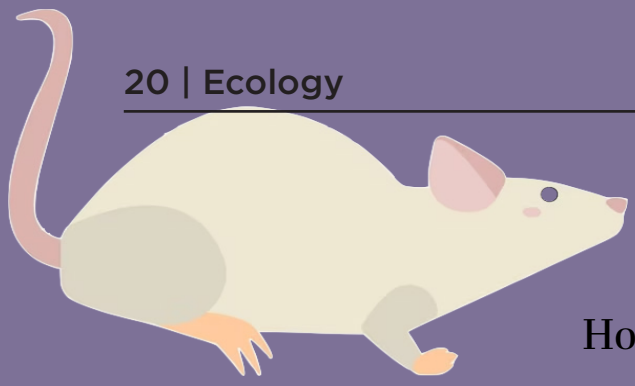
Forests are not just loose collections of plants and fungi. Mycorrhizal networks act as the "wood-wide web," connected by cables of mycelial threads stretching for kilometers beneath the forest floor. Since the '90s, researchers have identified mycorrhizal symbiosis within plant root cells — in exchange for revitalizing nutrient-poor soil with minerals and secreting antibiotics, the plants provide sugars and housing for the fungi. By tracking carbon isotopes moving throughout this system, we know this interaction extends beyond individuals and even neighboring plants. Bridged by mycelium, entire forest ecosystems are chemically linked in the exchange of resources into a sort of symbiotic super-organism. Not all is harmonious, however. Neighbors favor nearby relatives and wage war — rerouting nutrients or emitting toxins via mycelium to destroy parasites or rivals.

This diversity of fungal abilities has strong ramifications for science and society today. Mycelium's versatility makes it a sustainable biomaterial. Biodegradable, durable, and lightweight mycelium shoes, bricks, and houses are now on the market. Easily grown from food scraps with minimal facilities, mycelium is cheap and can be grown into most structures with molds. We can also harness fungi's most familiar ability — degradation. From polyurethane to oil spills to radioactive waste, there is likely a species (or bioengineered existing strain) that will eagerly consume our debris. With armories of digestive enzymes like catalases and lipases, fungi provide environmentally benign detoxification pathways to previously incalcitrant toxins like tanning byproducts or heavy metals. Despite expanding genomic analysis and protein engineering efforts, the endlessly diverse family of approximately 3.8 million fungi species remains widely undiscovered.

Unpopular opinion — fungi are beautiful. They thrive on death, and life is reborn. Embracing the circular lifestyle of the fungus may inspire us to clean up our messes and look toward a cleaner future. Opening our eyes to the diversity and immense range of fungal abilities may produce the solutions to our problems right below our feet.

Indian Journal of Microbiology (2016). DOI: 10.1007/s12088-016-0584-6

PHOTOS BY PRACHI THAKUR, BEHAVIORAL NEUROSCIENCE, 2025



OF MICE AND MENTAL HEALTH

How loss of social status leads to depression

ARTICLE BY DESSY DUSICHKA, COMPUTER SCIENCE & BIOLOGY, 2025

DESIGN BY ANANYA JAIN, BEHAVIORAL NEUROSCIENCE, 2025

Although mice don't have Instagram likes or followers to keep track of, social status is still a huge part of their societies. There is a clear hierarchy, with the top mice receiving first pick when it comes to food and mates and subordinate mice scrambling for whatever's left. As shown by a study at Zhejiang University School of Medicine in China, maintaining this alpha status is crucial, since losing it has been shown to cause depressive spirals in mice.

This phenomenon is not unique to mice and occurs in species ranging from monkeys to birds and fish. Scientists are particularly interested in the loss of social status as a trigger for depression since the same effect is not seen in mice with a consistently low social status. The ultimate goal is to find ways to alleviate this plunge in mood resulting from social pressures and apply this treatment to humans.

Researchers at Zhejiang University School of Medicine in China decided to create competition in existing mouse hierarchies by forcing alphas to lose their status to subordinates in a nonviolent manner. They did this using the dominance tube test, where pairs of dominant and subordinate mice are placed in the same narrow, clear tube. The exit was blocked for the lower-ranked mouse in each tube, giving it no choice but to push its alpha opponent. At first, the alphas resisted and stood up to their weaker opponents. After repeated trials, however, the alphas began to retreat, losing these individual battles and their status in society.

Almost instantly, the dethroned alphas found themselves without their privileged food and nest access. They started to show symptoms of depression and lost their appetite for sugar water. Researchers also used a metric known as the forced swimming test to measure mouse distress. This measures how long the mice stay afloat when dropped in a tank of water. The less happy they are, the more quickly they give up paddling. The researchers found that the dethroned mice spent significantly less time fighting after losing their social status.

The researchers also examined scenarios in which normally subordinate mice lost to already-superior mice whom they were expected to lose against. They found no change in their psychological states; lower-ranked mice seem to have more resilience and have adapted better to loss. Thus, it seems that loss itself is not the trigger of depression-like symptoms, but instead, unexpected losses are what cause this distress.

To see what was going on neurologically, the researchers used an imaging technique called fiber photometry. Of particular interest was the lateral habenula (LHb), an anti-reward region known as the "disappointment center" in humans. It blocks reward pathways and is typically activated when things go worse than expected and is often hyperactive in people with depression. When the alpha mice retreated in the experiment, their LHb regions lit up.

Having an active LHb is problematic because it blocks the neural pathways responsible for decision-making and managing emotions. This makes it much harder to have an optimistic and rational view of the world and makes an individual even less likely to meet expectations, creating a vicious spiral of frustration and reduced ability to cope. This cycle closely resembles depression and is very difficult to escape from without intervention or a rise in social status.

The researchers found that injecting the fast-acting antidepressant ketamine (which is currently also being used to treat depression in humans) into newly low-ranked mice helped to reverse their depressive spirals and make them more likely to win against their superiors. Regaining their social status reestablished a more optimistic outlook, showing the dynamic link between status and depression and offering hope for treatment options.

One limitation of the study is that only male mice were used as female mice have different social rules that don't align as closely with the competition set up in this study. Thus, the next step for scientists is to find a similar model of status-induced depression for women.

Overall, uncovering this neural mechanism should help us better understand the relationship between social mobility and one's psychological state, opening the door for intervention strategies. Since many cases of human depression are related to social factors and this neural mechanism appears highly conserved across species, it seems that mice are a promising model for depression in humans. The methods in this study appear useful for screening antidepressant drugs and while there's still more to uncover, this research provides an optimistic pathway for understanding depression and improving human mental health outcomes.

Cell (2023). DOI: 10.1016/j.cell.2022.12.033
Trends in Neurosciences (2014). DOI: 10.1016/j.tins.2014.07.005

PHOTOS BY FREEPIK AND WIKIMEDIA COMMONS

REINCARNATION

DODO OR DO-DON'T

BY JIAJIA FU, BIOENGINEERING, 2026

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

While the wooly mammoths, smilodons, and giant ground sloths starred in Disney's "Ice Age," do prehistoric creatures have a place on Earth today? When species go extinct, evolution fills the ecosystem gap with modern species, renewing balance and moving forward in evolutionary history. The hot-topic term "de-extinction" describes the process of using genetic engineering to synthesize and reintroduce an organism nearly identical to long-gone ones.

An argument for or against de-extinction must address the disastrous role of humans in this ecological "balance" of Earth. The rapid spread of humanity has caused a catastrophic decline of biodiversity, prompting University of Hawaii's researchers to call this era the sixth mass extinction, the first "to be caused entirely by humans." Ecological niche and resource abundance are constantly evolving factors of any species' success, and this normally allows natural selection to cultivate biodiversity. Since humanity has caused such an upset in these typical processes through habitat reduction, pollution, and introduction of invasive species, de-extinction could be a method of undoing some of our harm.

In a 2015 publication of the Washington University Law Review, UC Irvine professor Alejandro Camacho speaks to the subtle play between natural and human-driven changes, and how to tread carefully when looking to this gray area to enact de-extinction policy. His writing prompts questions like: what species should be brought back, what benefits would resurrection provide, and could resources be more effectively placed towards conservation efforts for extant species?

Some biologists, like Boris Worm from Dalhousie University, are firmly against de-extinction. Worm states, "Preventing species from going extinct in the first place should be our priority, and in most cases, it's a lot cheaper." This cost-benefit analysis is further explored by a philosophy professor from Northeastern University, Ronald Sandler, who agrees that funding for these projects could possibly detract from overall biodiversity efforts, but that this is not always the case. He cites an example of a bird from Martha's Vineyard, whose de-extinction efforts are privately funded and focused on restoring not only the bird but the whole ecosystem.

PHOTO BY JEBULON VIA WIKIMEDIA COMMONS

There could also be implications for de-extinction with relation to climate change and the future of bioengineering. Part of the effort to restore the Earth to a stable state is the attempt to slow the rising global temperatures, which de-extinction could help with. Shlomo Cohen, a philosopher from the Ben-Gurion University of the Negev in Israel, writes in Nanoethics about the potential benefits of reintroducing mammoths to tundra environments. This research has the potential to build up carbon-sinking grasslands as well as develop cutting-edge genomics research.

One excellent case study is the dodo. Colossal Biosciences, an established de-extinction company with offices in Texas and Boston, recently declared, "the dodo bird is a symbol of man-made extinction. A glaring example of the price of carelessness. It is our intention to partner with the government of Mauritius to establish a foundation for the de-extinction and rewilding of the beloved bird we all dearly miss." What makes the dodo such an interesting subject is its history and clear cause of extinction. Native only to the small island of Mauritius in the Indian Ocean, these flightless birds lived peacefully until humans arrived. We brought with us rats, cats, dogs, among other animals, which quickly developed a taste for the dodo's eggs. While many species of large birds only lay one egg at a time, the dodo's unique lack of caution, corresponding to a lack of natural predators, left them vulnerable and defenseless. Their sharp decline is directly attributed to hunting and this lack of prey instinct.

So, would bringing back the dodo and putting in place environmental protections for their population be worth it? It would forge a path to increasing biodiversity on the island, where not only the dodo but 23 other native species are also extinct, and nine endangered. It may also set a precedent that would allow humanity to hold the controls of biodiversity on the whole planet. With the tools to bring about destruction and resurrection at will, what would the world look like in 100 years? It is up to us to study the ethical questions and options to become better informed and ensure that the species we resurrect return a net positive to our world's ecosystem, and are not just alive to bolster our zoos.

Biological Reviews (2022). DOI: 10.1111/brv.12816

NanoEthics (2014). DOI: 10.1007/s11569-014-0201-2

Nature Ecology & Evolution (2017). DOI: 10.1038/s41559-017-0105

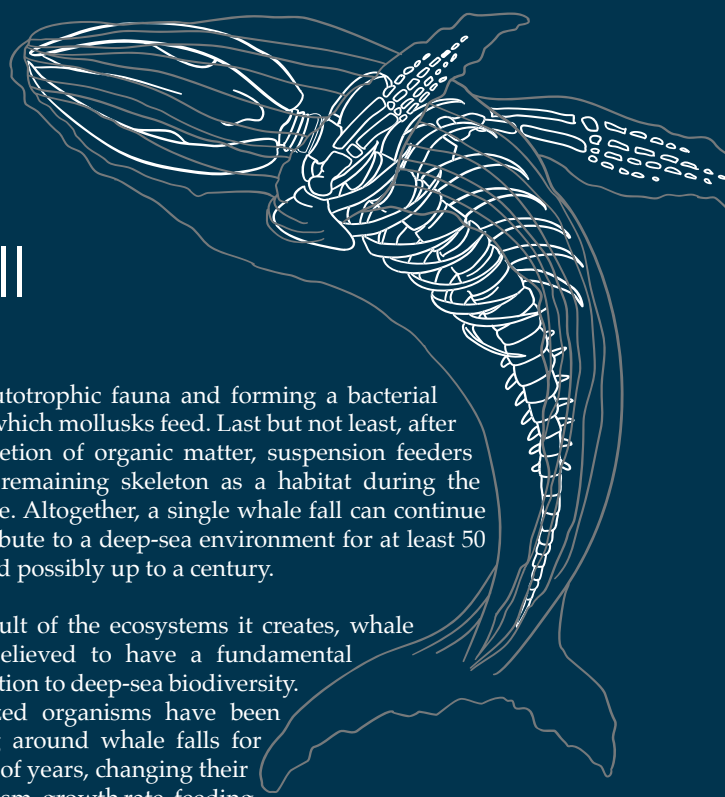
The hard, chiseled granite of Point Lobbs — just south of San Francisco — creates the stunning terrain of coves, cliffs, and caverns that frame the Point Lobbs Marine Conservation Area. Below the surface, the rock forms an underwater canyon that cycles nutrients to the coastline, nurturing life all the way up the food chain, from sardines and krill to humpback whales. California has over a hundred marine protected areas like this one that provide researchers with invaluable intimate access to thriving, undisturbed coastal ecosystems.

PHOTO BY IAN HAY, BIOENGINEERING & COMPUTER SCIENCE, 2023

Deep-sea banquets

The anatomy of a whale fall

BY FIN LI, MARINE BIOLOGY, 2026
DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCES, 2025



It's October 2019, and Exploration Vessel Nautilus is on its last expedition of the season, live-streaming footage from its submersible's cameras. At 3,240 meters deep, they're exploring the seafloor of Monterey Bay when a shape comes into view, and the team quickly erupts into enthused echoes of "ohhh, whale fall!" What lies in front of the submersible are the mostly skeletal remains of a baleen whale, morbid but a subject of delightful curiosity to these marine scientists. "Dinner is served," one of them comments, as the camera pans to scavengers feasting on the carcass like friends and family coming together to enjoy a Thanksgiving dinner.

Referring to the phenomenon in which whales die and sink to the seafloor, "whale fall" is a general term for a whale carcass, the process of its fall, and the formed deep-sea ecosystem. Since the first discovery of a whale fall by submersible *Alvin* in 1987, instances have been studied in the Pacific and Atlantic oceans — with some researchers even intentionally planting whale carcasses to further understand their effect.

What makes whale fall such a noteworthy phenomenon? For one, whales themselves are some of the largest living animals on Earth, able to have adult body masses ranging from 8 to 160 metric tons. Approximately 87% of that biomass is in lipid-rich soft tissues, making whale feasts of organic matter that are vital for low-energy and nutrient-poor deep-sea environments. In comparison to marine snow — organic matter debris from the upper ocean — whale fall transports organic matter to the deep sea 2,000 times faster and in much higher quantities.

> "Altogether, a single whale fall can continue to contribute to a deep-sea environment for at least 50 years and possibly up to a century."

Once a whale carcass reaches the seafloor, it attracts abundant organisms, essentially creating an ecosystem of its own whose ecological succession can be traced by four partially overlapping stages of decomposition. First, in the mobile-scavenger stage, scavengers such as hagfish and sleeper sharks eat from the intact carcass, removing soft tissues including blubber, muscle, and internal organs. In the enrichment-opportunist stage, animals like marine worms and crustaceans colonize the lipid-rich bones and organically enriched sediments in the area. In the sulfophilic "sulfur-loving" stage that can last decades, anaerobic bacterial decomposition of the lipids excretes sulfide, supporting chemoautotrophic fauna and forming a bacterial mat on which mollusks feed. Last but not least, after the depletion of organic matter, suspension feeders use the remaining skeleton as a habitat during the reef stage. Altogether, a single whale fall can continue to contribute to a deep-sea environment for at least 50 years and possibly up to a century.

As a result of the ecosystems it creates, whale fall is believed to have a fundamental contribution to deep-sea biodiversity. Specialized organisms have been evolving around whale falls for millions of years, changing their metabolism, growth rate, feeding behavior, and reproduction to better exploit whale carcasses. The species richness of whale fall ecosystems is estimated to be as high as 407 species, with scientists continuously recording new species. Additionally, one theory suggests that whale falls contribute to biodiversity by acting as stepping stones for faunal dispersal, allowing organisms that reside in hydrothermal vents and cold seeps to expand further by using whale falls as pit stops between distant habitats.

Whale fall doesn't only benefit the deep sea but can help another species that resides far off the seafloor: humans in our fight against climate change. Turns out, whales are an efficient means of carbon sequestration; they accumulate carbon (an average of 33 tons of CO_2 each!) in their bodies throughout their lives, and when they sink to the ocean's bottom, that carbon is taken out of the atmosphere for centuries. With enough whales, this natural solution has comparable potential to our technology-driven climate engineering projects.

Unfortunately, whale populations are not quite thriving, having been reduced to less than one-fourth of what they once were by commercial whaling and other hazards. In order to protect them, more value needs to be placed on whales, not only for their role as carbon sinks but for all they contribute to the ocean. We need to let the whales live, and let them fall.

Frontiers in Ecology and Evolution (2022). DOI: 10.3389/fevo.2022.885572
Annual Review of Marine Science (2015). DOI: 10.1146/annurev-marine-010213-135144

PHOTO BY SHUTTERSTOCK

Fungi's role in fighting the climate crisis

BY JULIA LAQUERRE; JOURNALISM, ECOLOGY & EVOLUTIONARY BIOLOGY; 2026
DESIGN BY PARKER HITT, BIOLOGY, 2023

As climate change escalates, preventative measures to reduce global warming are almost futile without a uniform attempt by civilization. Damage control is likely the future of sustainability and fungi may be an effective way to help in the restoration of forests after a wildfire.

Below the typical fruiting body or mushroom we see on the surface, the body of a mycorrhizal fungus is made up of a long and dense network of silk-like threads called hyphae. Under the soil, this extraordinary root system stretches for miles obtaining water and nutrients not readily available to the fungus' main body. Not only can the fungus gather nutrients from miles away, but it can also store them for later use. The hyphae threads also intertwine with plant roots, allowing for the exchange of phosphorus, nitrogen, and water in exchange for sugars and carbon.

> "Fungi have unique trait combinations and are more likely to survive off the unique nutrients resulting from a forest fire than plants."

Both plants and fungi benefit from this bidirectional nutrient transfer. This mutualistic symbiosis between mycorrhizal fungi and a plant's root system is called mycorrhiza and is incredibly valuable to both groups, specifically to the health of the plants. "Understanding and promoting the growth of mycorrhizal fungi is essential to the health of redwood forests and is especially critical for regeneration of damaged habitat," said Patricia Kaishian, a well-known mycologist.

Forests scorched by fire become severely damaged habitats and are frequent in California. According to the Center for Disaster Philanthropy's recent report, there have been 7,095 fires and 362,232 acres burned in 2022. Most high-intensity wildfires in coastal California occur during the summer months of June, July, and August. Zach Pipkin, a data analyst at Tableau Software Development, defines fire as high-intensity if it damages more than "75% of vegetation, extending into the canopy level." The high heat leaves the soil nitrogen-deficient and no longer able to hold moisture. Soil after a high-intensity forest fire has essentially no nutrients, but this is where mycorrhizal fungi come in.

Fungi store hoards of spores deep under the soil where they are safe from forest fires. A single spore can develop thousands of hyphae threads and bring needed nutrients to new and existing plants from afar. Fungi have unique trait combinations and are more likely to survive off the unique nutrients resulting from a forest fire than plants due to their "vast hyphal network, … high surface area to volume ratio, resistance to heavy metals, adaptability to fluctuating pH and temperature and presence of metal-binding proteins," according to molecular biology researchers Nahid Akhtar and Mohammad Amin-ul Mannan.

Some specific species, like the Clitocybe Nuda fungi, have distinctive capabilities of adapting to many environments and ecosystems. This soil-dwelling fungus is frequently found in or around redwood forests and is compatible with coastal redwoods. Its unique adaptability allows the fungus to quickly acclimate and utilize the meager nutrients remaining after the fire, thus helping the plants it is in symbiosis with. There is even a whole genus of fungi that have evolved to thrive off of fires: the Pyronema fungi. Ultimately, this mutualistic relationship between fungi and redwood trees is only one example of how powerful nature can be in healing itself. Global warming will continue to be a threat to our ecosystems, but with research into different symbiotic relationships like this one, we can work with our environment to better protect it.

PHOTO BY SHUTTERSTOCK

Mycologia (2022). DOI: 10.1080/00275514.2021.2024422
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THE TREES OF LIFE

BY LILY GARRETT, BIOCHEMISTRY 2025
DESIGN BY PARKER HITT, BIOLOGY, 2023

Trees are the underrated superheroes of planet Earth. They sustain human life by mediating droughts, capturing rainwater, increasing healthy soil, conserving energy, providing food, preventing water pollution, and creating and cleaning the air we breathe. Trees serve as essential caretakers for humans and the environments we inhabit. Moreover, trees *heal*. They have been shown to improve physical and mental health, spark community involvement and togetherness in green spaces, inspire exploration of the outdoors, and even reduce violence. Neighborhoods protected by lush trees and landscaping tend to reduce fear levels and retain lowered incidences of violence in comparison to more barren areas and communities. Mental illnesses affect people of all ages and walks of life, and access to trees has proven to facilitate the healing processes for diverse types of patients and reduce symptoms. In response to trees' relevance in human life and the environment, it is vital to study and comprehend their conditions to better maintain and protect the forests that sustain our Earth.

> "While their accomplishments prove them as unquestionable superheroes, they are not indestructible; natural ecosystems that house trees remain in endemic insecurity."

In 2016, a study led by Greg Gilbert at the Gilbert Lab at the University of California, Santa Cruz, analyzed the amount of internal decay and estimated damage present in living trees using the invisible yet powerful tool of sound. Sonic or acoustic tomography is a type of specialized equipment that scientists use to send sound waves through trees and measure the amount of time it takes sound to pass through each tree. By utilizing imaging techniques, the research team was able to convert the recorded sound waves into visual density color maps that illustrated the internal tissue makeup of trees. This form of high-powered tree technology translates tree health into a vibrant display of rainbow hues that represent the varying levels of decay or damage in the tree's vital tissue.

For instance, in the tropical rainforests of the Republic of Panama, live tree trunks ranging from a plethora of tree species were scanned with an Argus Electronic PiCUS 3 Sonic Tomograph by Gilbert's research team. Visual patterns and colors were developed with the sonic data acquired by the tomograph to demonstrate internal patterns of decay within the rainforest trees. Often, internal decay, also known as heart rot, is forensically determined by chopping down trees and analyzing wood decay. On the contrary, this innovative and non-invasive sonic technology of tomography was utilized in the study to complete highly visualizable results without the act of cutting down or harming trees.

Other non-invasive techniques including ultrasound, stress waves, and nuclear magnetic resonance have been used previously in wood decay studies but have never created fully reliable statistical representations. The PiCUS 3 Sonic Tomograph used by the Gilbert lab was proven to effectively and reliably detect decay and tree damage. According to the results of the study, sonic tomography and image analysis were proven to create a comprehensive approach to analyzing decay patterns and damage in tree tissue with a non-invasive approach. The knowledge accumulated by this study along with several other somatic applications to trees has allowed for a better understanding of tropical tree systems. Urban forestry has been found to benefit from sonic tomography technology, as the Gilbert lab's data is being applied to assess the health risks of urban trees in the Republic of Panama that have decayed or are vulnerable to destruction from environmental causes or harsh weather events.

Trees foster a healthy life in both the biological and social spheres of Earth. While their accomplishments prove them as unquestionable superheroes, they are not indestructible; natural ecosystems that house trees remain in endemic insecurity. Deforestation due to industrial agriculture, illegal logging, infrastructure expansion, and wildfires caused by climate change are growing obstacles that leave trees in continuous peril. To better understand trees' state in our environment, it is crucial to investigate trees, conduct research about their conditions, and analyze their decay and internal damage. Trees must be protected if they are to continue to stand tall as our heroes, protectors, and friends on Earth.

Applications in Plant Sciences (2016). DOI: 10.3732/apps.1600060

PHOTOS BY SHUTTERSTOCK

A couple walking down the center aisle of Grundtvigs Kirke — a monument in Copenhagen, Denmark, dedicated to the philosopher and theologist N.F.S. Grundtvigs. The church's six million bricks, crafted locally out of Danish clay, create the space's hallmark soft yellow glow in the sunlight. The still, peaceful atmosphere; sceneries of the 20th-century expressionist architecture; and weekly services are all open to the public.

PHOTO BY GUS MUELLER, MECHANICAL ENGINEERING, 2023

The town of Castelrotto, in northern Italy, rests atop the lofty, mile-high grassy meadows of the Seiser Alm plateau and under the iconic silhouette of the Schlern mountain. The town's intimate connection to the nature around it attracts skiers, hikers, and outdoor enthusiasts from around the world.

PHOTO BY IAN HAY, BIOENGINEERING & COMPUTER SCIENCE, 2023

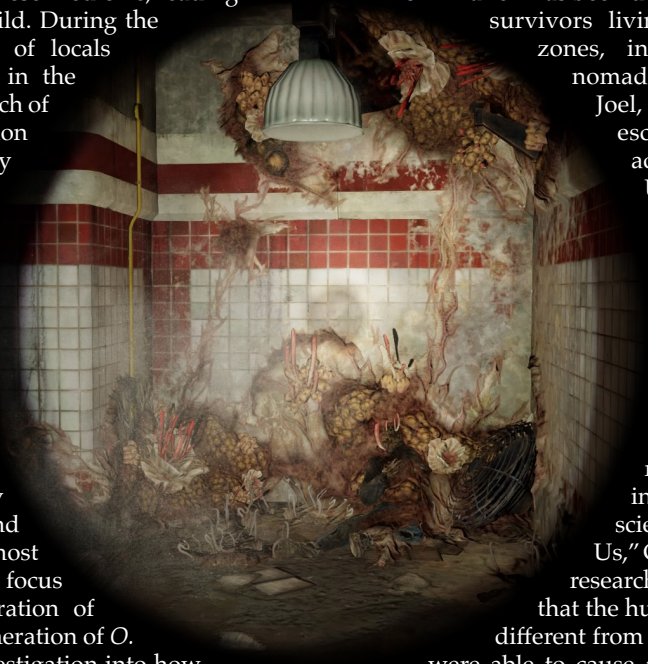
'The Last of Us' and the fungal apocalypse

The role of medical fungal science in post-apocalyptic fiction

ARTICLE & DESIGN BY ANNIE CHRISTIE, ENVIRONMENTAL & SUSTAINABILITY SCIENCES, 2023

In the video game and HBO hit series "The Last of Us," an outbreak of mutated parasitic fungi devastates humanity and the modern world — a threat based on a very real organism. *Ophiocordyceps*, also known as "Cordyceps," is a genus of fungi that grows on the larvae of insects, infecting the host and controlling its brain activity. The widespread genus, first scientifically described by British mycologist Tom Petch in 1931, contains about 140 species. The two most well-known species of Cordyceps, *Ophiocordyceps sinensis* and *Ophiocordyceps unilateralis*, have evoked discussion among medical mycologists for strikingly different reasons.

O. sinensis is an entomopathogenic fungus that parasitizes ghost moth larvae. Widely known in traditional Chinese medicine, *O. sinensis* has been shown to have effective anti-inflammatory and antioxidant properties according to research by Jin Xu, Ying Huang, and their colleagues. Furthermore, extracts and isolated compounds have demonstrated antitumor activities, inhibiting the proliferation of tumor cells and preventing the invasion of cancer cells. *O. sinensis's* rarity and popularity have made it well-known among practitioners of traditional Chinese medicine, leading to its over-harvesting in the wild. During the harvesting season, thousands of locals travel to its endemic habitat in the Qinghai-Tibetan Plateau in search of wild Cordyceps. The cultivation of artificial Cordyceps by Chinese doctors and scientists significantly increased due to its high demand and over-exploitation. With its introduction into the global trade markets, medical Cordyceps has become a popular health supplement.



PHOTOS BY FLICKR

Large-scale cultivation of *O. sinensis* has only been accomplished relatively recently, after decades of trial and error. Studies indicated that most successful cultivation methods focus largely on the artificial generation of ghost moth larvae, artificial generation of *O. sinensis* fungal strains, and investigation into how fungal spores attack moth larvae. Efforts to raise the host moth larvae have made cultivation of *O. sinensis* difficult, largely due to lengthy breeding processes and the low survivability of ghost moths under artificial conditions. The successful large-scale cultivation of *O. sinensis* may not only alleviate the pressures of human demand but also protect the sustainable utilization of limited natural resources.

O. unilateralis is an entomopathogenic fungus commonly known as the "zombie-ant" fungus. *O. unilateralis* is unique in its ability to infect and kill ants through cuticle penetration. However, it is much more unnerving because while the manipulated host may appear ordinary, it has become a puppet, coerced into exhibiting fungal behavior. A foraging carpenter ant walking on the rainforest floor may become infected with microscopic spores dropped by mature Cordyceps. Upon penetrating the cuticle, the infection progresses rapidly inside the host's body, manipulating its behavior. Two days post-infection, the ant leaves the colony and finds a leaf where humidity and temperature are optimal for fungal growth. The ant bites onto the leaf to prevent it from falling and then dies. Upon death, a large stalk begins to grow from the back of the ant's head, followed by a release of spores from its stroma. As far as we know, Cordyceps spores do not have the ability to infect humans.

This is the main concept behind "The Last of Us." The story begins when an outbreak of mutated Cordyceps spreads throughout the United States, transforming human hosts into aggressive creatures known as "the infected." "The Last of Us" takes place 20 years after the initial outbreak, when civilization has been decimated by the infection, with survivors living in totalitarian quarantine zones, independent settlements, and nomadic groups. The player follows Joel, a smuggler tasked with escorting a teenage girl, Ellie, across a post-apocalyptic United States.

Many credit "The Last of Us" as one of the most scientifically accurate works of post-apocalyptic fiction. While Cordyceps is a very real fungus, the threat of Cordyceps mutating with the ability to infect humans remains uncertain. In an interview questioning the scientific accuracy of "The Last of Us," Charissa de Bekker, a mycologist researching Ophiocordyceps, defends that the human body is so fundamentally different from an insect, that even if the fungi were able to cause a small infection it would not be sustainable. However, some medical mycologists have expressed concern about the impact that warming global temperatures may have on harmful fungi. Mycologists Norman van Rhijn and Michael Bromley suggested in a recent study that the geographic footprint of endemic fungi could expand as they adapt to higher global temperatures. If their optimal temperature approaches our regular body temperature, fungal infections may pose a problem for global human health.

Phytotherapy Research (2016). DOI: 10.1002/ptr.5673
Critical Reviews in Biotechnology (2014). DOI: 10.3109/07388551.2013.791245
Journal of Fungi (2021). DOI: 10.3390/jof7050367

The moral quandary of 'The Last of Us'

BY LILY WEBER, BIOLOGY & ENGLISH 2023
DESIGN BY PARKER HITT, BIOLOGY, 2023

This article contains spoilers for Naughty Dog and HBO's "The Last of Us."

The recent television adaptation of Naughty Dog's critically acclaimed video game "The Last of Us" has sparked renewed attention to its source material. The game paints a dismal picture: Humanity has fallen to the cordyceps fungus, which infects humans and takes complete control of their minds to violent ends. Society and civilization have crumbled, giving rise to a constant power struggle between military rule and factions of rebels fighting for freedom and the elusive "cure."

The main protagonist, Joel, is tasked with the transport of Ellie, a young girl who is immune to the fungus. She is purportedly the key to unlocking the cure the world desperately needs. Throughout the game, Joel's relationship with Ellie strengthens as they fight their way across the ravaged landscape of the United States. Where first he merely views her as goods to be transported, by the end of the game she is much more. It is clear the need for a cure is dire. Simultaneously, both the player and Joel grow attached to Ellie throughout their quest. This places the player in an interesting ethical situation in the final scenes of the game. The surgery required to biopsy Ellie's brain will be fatal. Is the potential for a cure worth the sacrifice of the child the player has bonded with? Joel faces a similar dilemma, ultimately choosing to save Ellie and escape.

The player has no agency in how the events unfold in the game. However, Joel's choice has provoked much discourse in the fan base. Some view his decision as moral, others as selfish and to the detriment of humanity. To explore such questions, one might consider aspects of the decision that Joel likely did not. Would Ellie's death have been to any scientific benefit at all? Is a vaccine for a fungus actually possible, is this surgical biopsy a wise approach, and is informed consent given?

As mentioned in a 2021 review by Lorena Oliveira and colleagues, there are currently no approved vaccines against fungal infections. This is due to issues ranging from the accessibility of animal models to challenges caused by the fungal cell structure. All vaccine development studies need animal models to determine safety and efficacy before human trials. The context of the game is relevant here. It is exceedingly unlikely they have access to sufficient animal models to test any vaccine that would result from Ellie's sacrifice. Moreover, even if the scientists had access to animal models, there are inherent barriers to developing vaccines that target fungal cell walls. Some fungal cells have the ability to alter the components of their cell wall throughout the course of infection. This means the fungal cell can decrease host recognition, impair the body's inflammatory responses, and increase the fungi's virulence. If today's society, with its boundless resources, cannot develop a fungal vaccine, what are the chances for the deteriorating world depicted in "The Last of Us"?

Secondly, scientists in the game plan to harvest Ellie's brain to develop a cure. As mentioned in a review led by the International Vaccine Institute, vaccine development typically takes between 5 and 10 years. Suppose the surgeons were successful in biopsying Ellie's brain; what then? Infrastructure has crumbled in the in-game world. How can they ensure adequate refrigeration to protect the samples? It is highly risky to immediately carry out the surgery without this assurance. Furthermore, once Ellie has died, there are no second chances. If something happens to the samples, they may not get another chance. The rash decision to perform the surgery could have resulted in the loss of life for nothing.

Lastly, the game raises the important subject of informed consent for medical procedures. As outlined in guidelines by Timothy Paterick and colleagues, informed consent is essential for the patient's right to accept or deny treatment. In a physician-patient relationship, it is the responsibility of the physician to identify the best treatment for the patient and discuss the *possible* benefits and risks. In "The Last of Us," informed consent is not obtained. Ellie is merely anesthetized without the explicit knowledge that she will die. This goes beyond failing to inform her of possible risks, as her death is framed as certain. The physicians in this scenario completely disregard any semblance of patient autonomy and informed consent. Thus, ethically, Ellie's death for the sake of a vaccine is dubious.

All in all, not only is the science behind the cure in "The Last of Us" shaky, but the ethics are as well. Many regard Joel's decision as impulsive and ill-advised, but the doctors involved in the quest for a cure are guilty of the same infractions. While it is unlikely that Joel took these technical notions into consideration, they nonetheless remain true, perhaps making his decision more palatable on both a scientific and ethical level.

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PHOTO BY SHUTTERSTOCK

BENEATH THE BANDAGES

A fresh look into mummification

BY KEVIN LU, COMPUTER SCIENCE & MATHEMATICS, 2026

DESIGN BY PARKER HITT, BIOLOGY, 2023

The word "mummy" often conjures images of King Tut, the Pyramids, and Indiana Jones's excursions into royal tombs. Lying within the polished stone sarcophagus, the mummy's body is perfectly preserved, as if frozen in time. The skin, now leathery and dry beneath the bandages, stretches over bones that hint at a once-regal face. While mummification is not exclusive to the ancient Egyptians, they certainly pushed the practice to its limits. Deeply entwined with their religious beliefs, Egyptian mummification sought more than just preserving a body after death: The elaborate burial technique was believed to help guide the deceased toward divinity.

The 70-day mummification process typically began with removing all organs except the heart — believed to contain a person's intellect — and soft tissue from the body. The Egyptians removed the brain using a special hook through the nostrils, while the other organs were removed by hand through an incision in the abdomen. The organs were then placed in canopic jars, which were buried with the mummy.

> "Beneath these bandages also lies a story of interconnected civilizations and specialized knowledge."

With the organs removed, the body was then packed with natron, a type of salt, and left to dry for several weeks. The now-dried body was then wrapped in layers of linen bandage, which were often decorated with amulets and other symbols designed to protect the deceased in the afterlife. A sticky resin was applied beneath these bandages to desiccate the flesh further and increase adherence to the body.

Finally, a special headdress and mask were placed over the face of the mummy, mirroring the deceased's appearance. The mummy was then placed in a wooden or stone sarcophagus, which was decorated with the carvings and opulence often exaggerated in movies.

Yet, beneath these bandages also lies a story of interconnected civilizations and specialized knowledge. A recent excavation of a 2,500-year-old embalming workshop in the Saqqara necropolis revealed the complex trade networks behind the ingredients used in mummification. Chemical analysis of labeled pots identified mixtures of botanical resins and other substances, some of which came from plants that grow as far away as southeast Asia.

The study also revealed the ancient Egyptians' exceptional understanding of material properties. Embalmers took advantage of specific biochemical properties, carefully heating or distilling mixtures of ingredients to enhance their antibacterial, antifungal, or odoriferous effects. Pots were labeled with instructions from "making beautiful the skin" to "make his odor pleasant," creating an intentional methodology for using substances in embalming. The substances identified also point to the existence of complex systems for the harvesting and transformation of products. For example, the production of wood tar through pyrolysis involves control over thermal processing and specialized knowledge, hinting at a far more developed science than previously understood.

As we look into the past, beneath the bandages we have placed over our broken history as a race, a beautifully collaborative and intelligent story emerges. Egyptian mummification was built upon and fostered long-distance exchanges, developed through scientific processes into an art form, and laid the foundation of an entire civilization's culture. Although mummification is no longer commonly practiced today, the marks *we* leave on history will stand the test of time, much like these bodies. As Indiana Jones once said, "Who knows? In a thousand years, even you might be worth something."

PHOTOS BY SHUTTERSTOCK

Nature (2023). DOI: 10.1038/s41586-022-05663-4

LANGUAGE ATTRITION

HOW LEARNING NEW LANGUAGES DISPLACES THOSE KNOWN

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

DESIGN BY PARKER HITT, BIOLOGY, 2023

Most people, at one point in their life or another, attempt to learn a second language. Whether they do so in high school or college to fulfill a foreign language requirement or well into adulthood as a fun challenge, it would be fair to say that a healthy portion of the population has forayed into bilingualism.

Yet, in the anglosphere, it is often conceded — if not as the butt of a joke and a somber reminder of what may have been — that those who have attempted to learn a second language rarely continue their studies. The language they had chosen fades into but a sentence or two of broken syllables.

Conversely, those who successfully learn a second language might find themselves forgetting their native tongue, especially if they live in a country whose primary language differs from theirs. Many immigrants find themselves, without constant support and practice, forgetful of even the simplest vocabulary of their native country's language.

In linguistics, this phenomenon is called *language attrition*. The first scenario, where the speaker forgets all or part of a non-native language, is called second-language attrition, or L2 attrition, where "L2" means one's "second language" or, more broadly, any non-native language. The latter scenario, similarly, is referred to as first-language attrition, or L1 attrition, where one forgets all or part of their first language or native tongue.

> "Those who learn a foreign language by rote, as the vast majority of Americans do, can expect to lose a significant portion of their L2 vocabulary in as little as two weeks of disuse."

Most people in English-speaking countries are required to study a foreign language in secondary school. In the United States, the principal language of choice for obligatory education is usually Spanish. This choice is pragmatic; being a European language of Latin orthography, as well as being the second most spoken language in the U.S., Spanish is reasonably easy to learn, neither requiring one to learn another writing system nor an unfamiliar phonetic system. It is also the language most likely, in the U.S., to be directly utilized by one who learns it.

However, second languages tend to be fleeting without constant practice, which the vast majority of American students fail to do once they graduate. As studies show, who learn a foreign language by rote, as the vast majority of Americans do, can expect to lose a significant portion of their L2 vocabulary in as little as two weeks of disuse. The sole exception to this rule appears to be concrete cognates, or, in other words, words that refer to physical objects and whose spelling or pronunciation are similar to one's first language.

While unfortunate, L2 attrition is common, if not expected. L1 attrition is understudied and often leads to crises of identity in those who forget their native tongue. Nevertheless, the root cause is the same: a lack of practice. Moreover, L1 attrition is also complicated by the process of learning the second language.

There are several working theories for the process behind L1 attrition. Most boil down to a combination of vocabulary decay and the mental rewiring required of L2 acquisition overwriting the existing mental lexemes of the L1 language, lexemes being the fundamental units of information in languages, generally forming simple words.

Thus, when one immerses themselves in a non-native language environment (e.g. immigrating to a new country), they are likely cut off from any speakers of their first language, causing the aforementioned decay of their vocabulary. A single year of first-language disuse can see a 20% or greater decrease in one's working vocabulary. The process of learning the second language additionally complicates matters and possibly accelerates this decay.

This loss of proficiency in one's first language can cause further feelings of isolation, as if separated from their background and culture. Failure to fully adopt a second language before experiencing L1 attrition may also leave one linguistically stunted. That is to say, it is important to maintain the practice of one's first language while learning a non-native language.

It is remarkable how something so instrumental to one's identity as one's native tongue can be so fragile, so transient as to simply fade from existence once displaced by another language, assuming one adopts another at all. Alas, *c'est la vie.*

PHOTOS BY SHUTTERSTOCK

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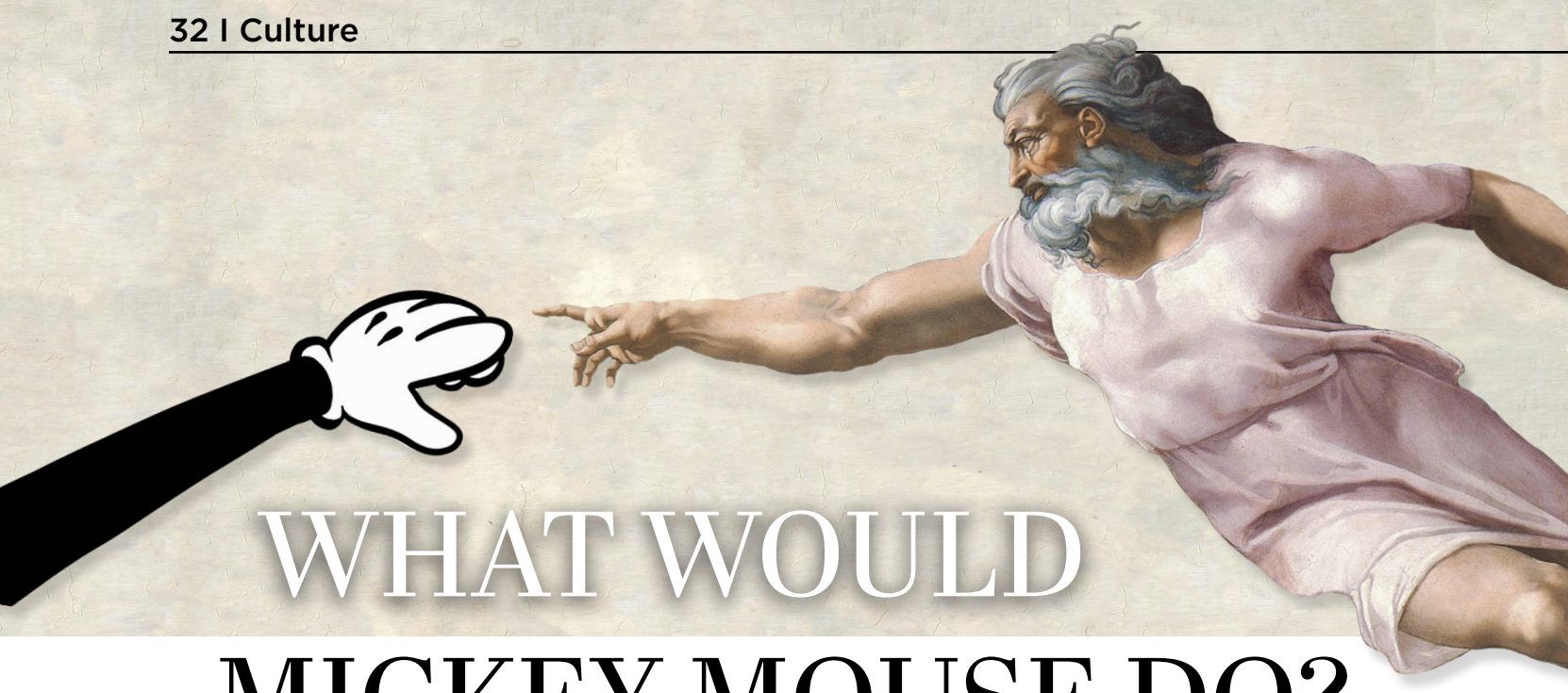

WHAT WOULD MICKEY MOUSE DO?

MICKEY MOUSE AND THE ORIGINS OF DEVOTION

BY ABIGAIL POTTER, PHYSICS & PHILOSOPHY, 2023

DESIGN BY PARKER HITT, BIOLOGY, 2023

Nobody lies awake at night contemplating the existence of Mickey Mouse.

Mickey Mouse is the world's most famous rodent. His conceptual existence is unquestionably true, and his physical existence is unquestionably false. He is, after all, fictional. Despite his widespread reach, it is generally assumed that no one lets the existence (or inexistence) of Mickey Mouse trouble them and no adult turns to a lone star and prays for Mickey Mouse to deliver them a miracle. Why is this an assumption? What makes questioning the existence of Mickey Mouse more bizarre than questioning the existence of a god?

The Mickey Mouse problem sprouted from these questions. It attempts to distinguish people's beliefs in fictional supernatural beings from gods. It raises two important theological questions: Why do we fail to believe in some entities, and why do we fail to become committed to some entities? The problem itself refers to the difficulty in predicting which counterintuitive agents are capable of inspiring religious belief and devotion. Counterintuitive agents are beings or entities that defy intuitive — or "folk" — expectations of how the world is. For example, a ghost is a person who follows all expectations we have about people (i.e. adhering to folk psychology) and who can walk through walls, defying our intuitions about physics (i.e. violating folk physics).

Mickey Mouse was likely chosen as the token character as he seems to claim a sort of fanaticism that is often comparable to religious zeal. In 2022, a Reddit post went viral on Twitter when a Disney adult claimed to have traded catering at her wedding for a Mickey and Minnie Mouse appearance. The post sparked a professor of religious studies at Lehigh University, Jodi Eicherler-Levine, to respond in defense of Disney adults. She claimed, "By its power in people's lives, then Disney is as much a religion as anything."

> "From this, they concluded that Mickey Mouse lacks the necessary ambiguity, beneficence, and ambivalence to inspire motivation that he is a god."

Her claim is one rooted in practices and rituals as opposed to a theological claim. And she is not the first to have made the claim, academics have discussed Disney parks as ritual spaces and pilgrimage centers since the '80s. Yet, even with these claims, Mickey Mouse has still failed to reach the type of devotion that deities hold.

A study conducted by Professors Thomas Swan and Jamin Halberstadt of the University of Otago sought to define this divide. The researchers asked participants on an

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online crowdsourcing marketplace to complete one of two surveys. The surveys consisted of three tasks, always in the same order, and differed in whether the word "fictional," defined as an entity "that people generally do not believe exists," or "religious," defined as an entity "that many people believe exists, and that is part of a religion," was used in the instructions.

The first task asked participants to "invent a new religious [fictional] being or entity with supernatural abilities," list five supernatural abilities it would possess, and rate the potential threat and benefit it posed. Next, participants were presented with a "list of supernatural abilities that might apply to religious [fictional] beings and entities" and asked to rate how likely the ability was "to be attributed to a religious [fictional] being or entity." The final task then requested participants to "name 5 well-known religious [fictional] beings or entities with supernatural abilities, from the past or present" and rate each entity they chose in terms of its potential harm and benefit.

The abilities chosen by the participants, as well as the abilities they were presented with, were coded by what folk domain they violated. The categories were psychology, biology, physics, none, and nonspecific or multiple domain violations. Entities prescribed as religious were more associated with folk psychology–violating abilities. Additionally, abilities that violated nonspecific or multiple folk domains were more important for religious entities to possess than for fictional agents.

Participants rated both their invented and well-known religious entities on average as more potentially beneficial than the fictional entities. Individual religious entities also had smaller differences between their potential harm and benefit ratings, whereas fictional entities were typically rated as either almost entirely beneficial or harmful. This led researchers to conclude that these religious beings were seen as more ambivalent than the extreme heroism or villainy ratings the fictional entities were prescribed.

The researchers suggested a religious agent template, where an agent capable of becoming a god must have abilities that are ambiguous or violate folk psychology and are beneficial yet ambivalent. From this, they concluded that Mickey Mouse lacks the necessary ambiguity, beneficence, and ambivalence to inspire motivation that he is a god.

Another researcher at Oxford University, Nathan Cofnas, sought to answer the question of commitment. He looked at Santa Claus as an example. Santa has a list of counterintuitive, folk-violating abilities including flight, immortality, and moral knowledge. He also possesses credibility-enhancing displays — at least to some young children. Presents are left under trees and cookies and milk are consumed in the middle of the night on Christmas. As children age, they realize, at some point, Santa's abilities are "impossible" for a human, and a layer of the magic is lost as they see Santa as *too* counterintuitive.

Mickey Mouse lacks credibility-enhancing displays. He lacks the evidence necessary to support our belief in his physical existence. In fact, the explicit message declaring his fictional-character origins as a work imagined by Walt Disney causes our common sense to deny any other possibility. Cofnas declares that even should "compelling evidence" to believe in Mickey Mouse's physical existence exist, it is unlikely that his believers would sacrifice their lives for this belief.

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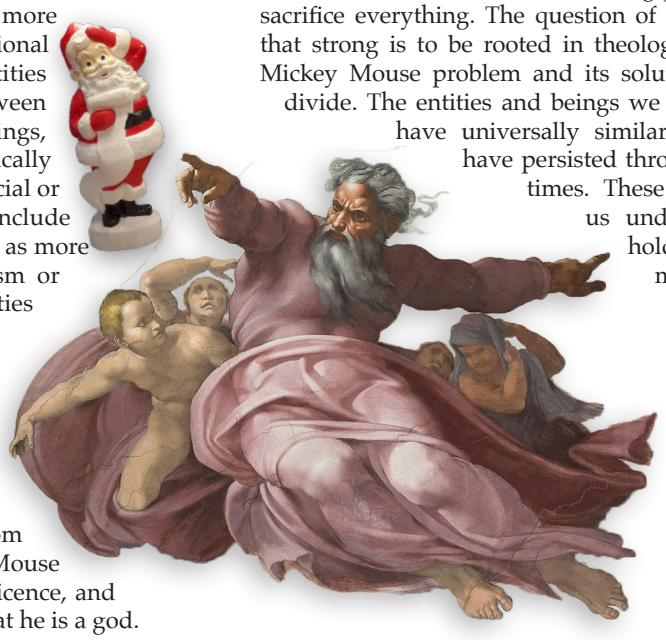
Religion exists in two parts: practice and belief. With the internet and the rapid spread of pop culture, the line between what constitutes religious practice and casual enjoyment is blurring. Fandoms' impact on people's lives and habits is widely documented. However, impact alone does not constitute a belief so strong people are willing to sacrifice everything. The question of what makes a belief that strong is to be rooted in theological discussion. The Mickey Mouse problem and its solution help define the divide. The entities and beings we believe in appear to have universally similar characteristics that have persisted throughout cultures and times. These characteristics help us understand what takes hold in the collective's minds and might help us understand each other and what we value as highly as our lives.



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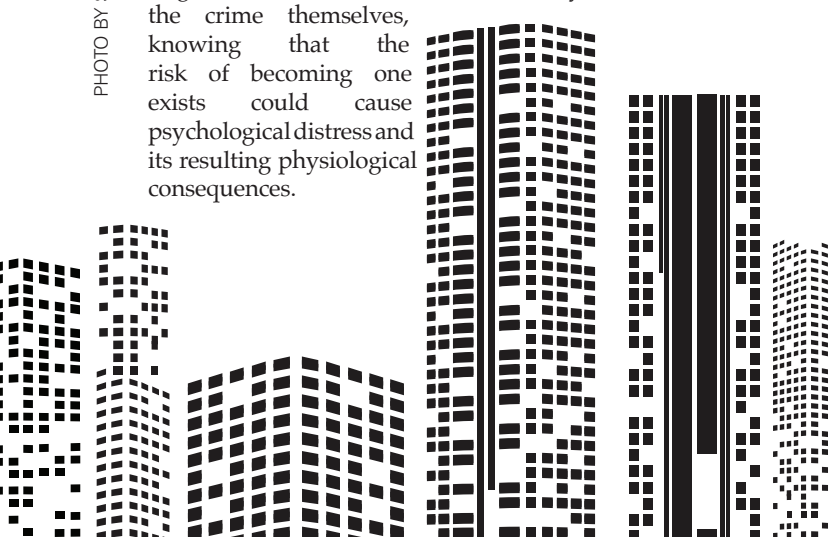
When your body chooses violence because of your community

ARTICLE & DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCES, 2025

Living is hard. The sensitivity of human health to a variety of factors often makes it easy for the body to deteriorate in the face of threats. Unfortunately, individuals do not just have their diet and exercise to worry about when it comes to maintaining their health. They must also consider the crimes committed in their communities, which can inadvertently harm non-victims. Especially prominent in cities where the population density and crime rates are high, many studies conducted over the decades continuously find similar results: a decline in physical and mental health from exposure to violence and crime.

This physical deterioration could unfortunately begin as early as childhood. Links to psychological effects may seem more obvious than those to physical health, though the close ties between these factors make it easy for mental health problems to cause physiological issues as well. According to pediatricians Dr. Shonkoff and Dr. Garner, toxic stress manifests itself through weaker immune systems with downstream consequences including, but not limited to, cardiovascular disease, hepatitis, and liver cancer. Direct physical effects have also been noted. A 2015 meta-analysis conducted by the Department of Epidemiology at Columbia University found that childhood exposure to violence increased resting blood pressure, which puts individuals at particular risk for stroke and ventricular hypertrophy.

Racial and gender differences also play a role in an individual's crime-related health. Researchers from the University of Maryland and the National Institute on Aging noted that African American women, as compared to African American men and white women and men, were the most vulnerable to health consequences resulting from crime exposure; these parameters included higher blood pressure and glucose levels. This likely results from differences in social experiences rather than any prominent biological differences. Because women and racial minorities are more likely to be victims of crime, such exposures would be of greater concern for them. Even if they are not the victims of the crime themselves, knowing that the risk of becoming one exists could cause psychological distress and its resulting physiological consequences.



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Crime affects one's physical health in roundabout ways as well, such as influencing behaviors. Researchers from RAND Corporation found that the use of outdoor public parks decreased following violent crimes, particularly in adults and the elderly. Without this space, people have less access to physical activities. Removing exercise from an individual's routine would also remove the physical and mental benefits it provides to their well-being. Furthermore, some may develop unhealthy coping mechanisms in response to crime exposure, including drug usage, risky behavior, and worsening diet. Both lead to negative consequences for physical and mental health. In particular, low exercise, bad diet, and substance use are known to increase the risk of developing cardiovascular diseases, according to researchers from Columbia University.

Criminals hurt more than just their victims; communities of people around the crime end up suffering consequences alongside them. However, the complexity of the issue makes it difficult to resolve. Between attempts from the police and political figures to reduce crime and various public health authorities' programs to address individuals' health, continuous efforts have been made for decades to improve the situation. The growing mass of data accumulated from all these attempts may help bring us closer to a solution. As said by the Office of Disease Prevention and Health Promotion, "addressing exposure to crime and violence as a public health issue may help prevent and reduce the harms to individual and community health and well-being."

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OPINION:
KEVIN MCCARTHY AND HUMILIATION POLITICS

BY LILLY SCHAR; HISTORY, CULTURE & LAW; 2025

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING & DESIGN, 2024

If your name is Kevin McCarthy, your 2023 began with utter humiliation. McCarthy endured a brutal 15 rounds of votes to attain the title of speaker of the House — the longest battle for the speakership since 1859. This was the product of a small faction of extremist Republican House members of the Freedom Caucus who firmly proclaimed "never Kevin," rather than support a member of their own party. Yet, McCarthy was never deterred and continued to negotiate with these members until a path to speaker of the House was cleared. Humiliation served as a particularly interesting motivator throughout this grueling process. McCarthy was willing to suffer a certain amount of public humiliation for the victory and honor of winning the speakership. How might negative emotions and experiences, such as humiliation, influence our politics?

A 25-year-long study analyzing the effects of persistent humiliation amidst political violence concluded that exposure to such humiliation had a definite negative effect on human functioning. Associated emotions like injustice, outrage, and powerlessness are detrimental to personal identity, and these emotions can manifest more intensely than general anger or sadness. The study also found that humiliation of a collective can have the potential to create more social cohesion, but, unsurprisingly, humiliation deriving from the ingroup towards one of its own members has the potential to further divide that group. At a time of intense partisanship in America, it is essential to understand how we reject and ostracize individuals or groups in order for bipartisanship to prevail.

A different study focusing on ingroup rejection by Tinka Veldhuis and her colleagues narrows in on subsequent behaviors of the rejected. Particularly, feelings of inferiority or the feeling of being controlled by a third party are prevalent and force the person rejected to be acted upon. In McCarthy's case, he eventually won the speakership only after conceding integral powers to the group of extremists holding him back, illustrating the claims of the study in real life by presenting as powerless and at the will of others. Among these concessions, McCarthy agreed to place members of the Freedom Caucus on important House committees and agreed to empower members of the House to call for a vote to oust him as speaker at any given time. These concessions further diluted McCarthy's power as speaker, and instead returned that power to those responsible for his humiliation.

In total, enduring humiliation can be consequential to all involved, both the rejected and the rejectors. Although there are, at times, residual positive responses to this humiliation, the example of McCarthy's humiliation spells a turbulent forecast for his future and the future of his party. Today, when working and reaching across the aisle is necessary for progress, McCarthy's concessions only serve to prove the extremists in the House have a strategy that works to give them the political power they desire. Who can say how much further humiliation McCarthy will endure to remain speaker of the House, even if that role is only a title, given the power he was forced to fork over? When our leaders seek titles for the sake of the title, we should question their motivations and discourage ingroup humiliation as a means of manipulation.

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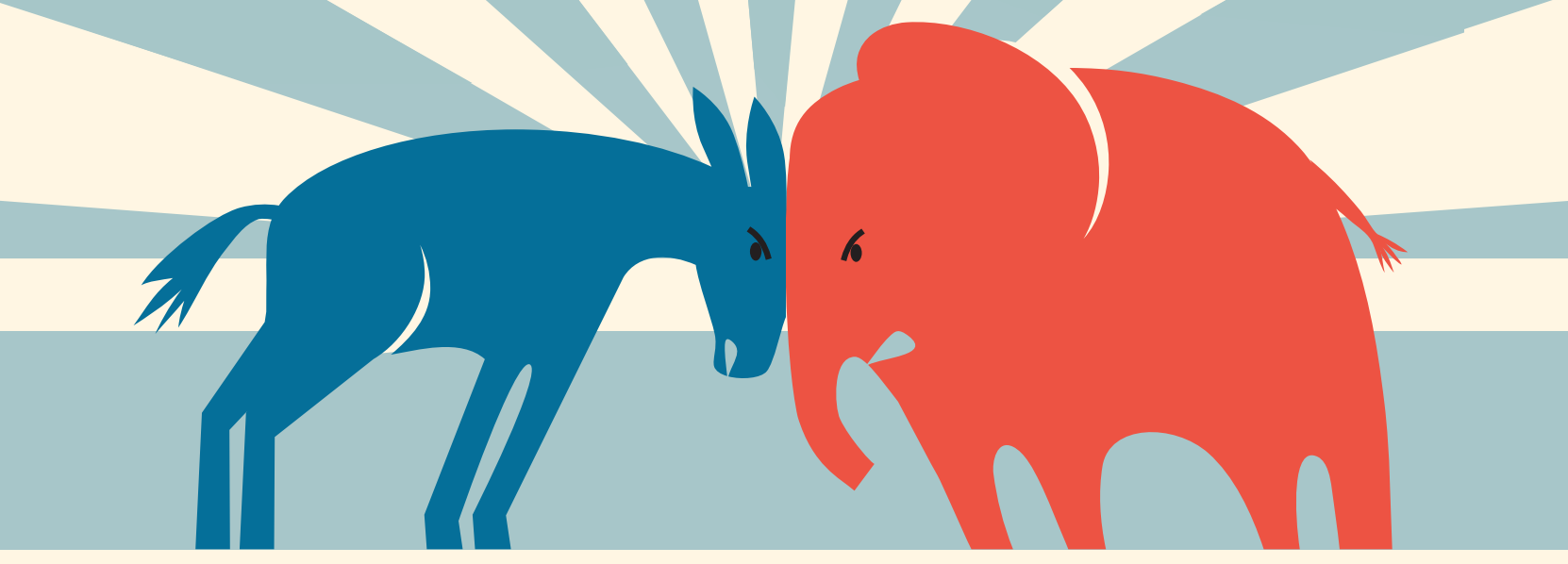


PHOTO BY SHUTTERSTOCK

NEW TRENDS IN SPACE TOURISM

Can we actually reach the stars?

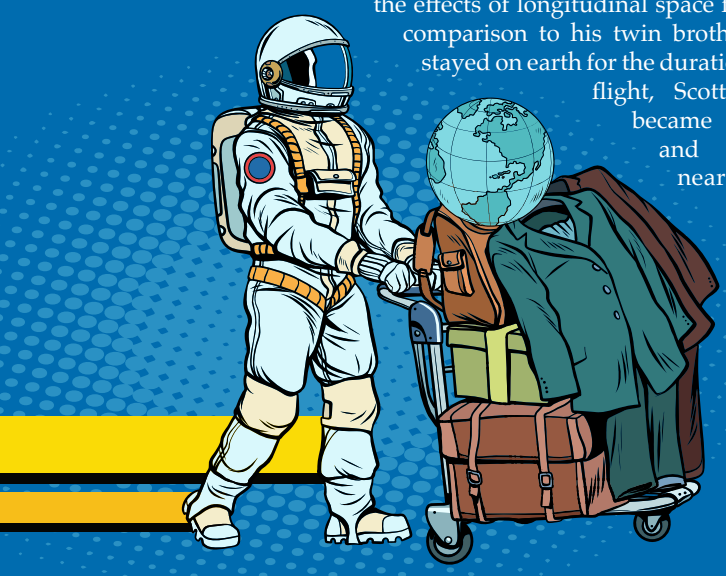
BY ALEENA JACOB, HEALTH SCIENCES, 2025

DESIGN BY PARKER HITT, BIOLOGY, 2023

For many, the idea of going beyond the boundaries of Earth's atmosphere is exhilarating. Curiosity has propelled human development, allowing us to reach the stars. From inventing the airplane to landing on the moon, humanity has an obsession with what lies above. To explore the stars and be launched into the midst of a tenebrous abyss is a nightmare to some and a dream to many.

Children often dream of one day going into space. When asked what their dream career is, some reply of wanting to be an astronaut, for they were taught it was the only way to go beyond our sky's horizon. Even if one is not inspired to be an astronaut, children are always encouraged while growing up to "reach for the stars!" In recent years, people besides astronauts have taken the common phrase and made it into a reality by going to space. In 2021, Jeff Bezos, the founder of Amazon, coordinated a program to launch himself into space. He was able to start Blue Origin, a company focused on bringing people to space as a tourism program. In November 2022, the YouTube group Dude Perfect published a video called "Dude Perfect Goes to Space," showcasing how a member of their team was able to join others who paid for a 10-minute flight being launched into space by Blue Origin. With the idea of space travel becoming more of a reality, "reaching for the stars" has been taken literally as people have the opportunity to pay for the experience.

Space travel might soon be a recreational activity, but for years, scientists have researched the safety of such endeavors. Though astronauts have routinely gone to space to explore the science behind what is out there, many suffer from the consequences of their travels. Astronaut Scott Kelly was examined after his year-long trip in space to visualize the effects of longitudinal space flight. In comparison to his twin brother, who stayed on earth for the duration of his flight, Scott Kelley became shorter and more nearsighted, and developed symptoms of heart diseases that were not present before his journey.



Other studies of astronauts found a number of other physiological and emotional damages exhibited by the human body after spending a long duration of time in space. For example, space motion can cause lingering nausea and dizziness post-landing. Another event that can occur is "puffy face bird leg phenomenon." The low gravity in space causes blood and other fluids to rush to the upper body, where they stay and swell in the body. Blood volume drop is an additional problem that can occur. This condition can lead to problems in how the heart pumps blood to the rest of the body, which leads to explain why Scott Kelly observed problems in relation to his heart.

> "Scientists have identified one possible way to combat this complication: exercise."

With space tourism becoming more relevant, how will companies like Blue Origin address the physiological damage that space travel can cause? Though they limit the travel time to 10 minutes, not much is known about how much time is needed to affect the body. However, scientists have identified one possible way to combat this complication: exercise. A recent study published in 2023 analyzed how certain exercises such as running on the treadmill and lifting weights go a long way to help reduce the effects of space travel on astronauts.

Even though organizations like NASA have been conducting extensive research into improving space flight, there is still no long-term solution to prevent the damage that Scott Kelly and other astronauts faced while in space. So when considering the wonders of space tourism, one should consider how developed this trend is. After all, we only know about 5% of the universe, so how far can we travel to discover the rest if not much is even known about its effects?

PHOTO BY SHUTTERSTOCK

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Are ghosts real?

Ghost particles definitely are

BY KYLE KIRSHEN, BIOCHEMISTRY, 2025
DESIGN BY PARKER HITT, BIOLOGY, 2023

Human understanding of the universe is not extensive. What is known, specifically at the atomic level, would not be possible without the use of neutrinos. Known as "ghost particles," neutrinos are the most abundant particles in the universe, even more so than electrons. While that might be the case, they are extremely difficult to find and study because of their ability to pass through matter undetected. They also do not interact with atoms as frequently as electrons do.

In fact, neutrinos harmlessly pass through our bodies every second that sunlight is available. The sun is the largest source of neutrinos, born during nuclear fusion when atomic nuclei break apart or come together. Neutrinos are especially important when it comes to the investigation of protons. The laboratory of Steven Chu, a professor of physics at the University of Rochester, realized that neutrinos could be used to measure the size and shape of protons making up various nuclei. They describe it as "using a ghost ruler to make a measurement."

These beams of neutrinos provide a view of protons that has never before been seen. A particular point that Chu and his team clarified was that the neutrino beam is no more accurate than a beam of electrons; it is just an accessible method of gaining new information. A comparison can be made to looking at a flower in visible light versus ultraviolet light in which you can visualize different structures under different types of light.

But how does this stream work? There are different kinds of neutrino detector experiments through Fermilab; namely the Deep Underground Neutrino Experiment (DUNE), ICARUS, and T2K. This investigation gets its name from the fact that it harnesses neutrino decay in a large tube that travels over 1,300 kilometers deep within the Earth's crust. The beam travels from a source detector under one facility and through the pipe until it reaches a proton accelerator at another facility location.

The hope is that these neutrino streams will demonstrate the isolated interaction between neutrinos and protons. Until now, there has been difficulty isolating protons because the interaction between neutrinos and the atomic nucleus includes both protons and neutrons.

While this new method of proton identification works in theory, there are many obstacles that have yet to be overcome. For example, very rarely is there an interaction between two neutrinos, even with the trillions that pass through the human body every second. So the question becomes, how can the beam force neutrinos to pass through an abundant mass of protons? It turns out that the answer lies in hydrogen atoms, which contain no neutrons and only one proton and electron.

Hydrogen atoms on their own do not do enough though, largely as a result of their incredibly small size and lack of density for any kind of neutrino interaction. However, scientists figured out that by binding hydrogen to hydrocarbon molecules, the detector can sense subatomic particles. The detector was made by the Main Injector Neutrino ExpeRiment to study v-A Interactions (MINERvA), a subdivision of Fermilab. It is composed of carbon and hydrogen atoms which can be negated so the results are solely the interaction between the neutrinos and the single proton of the hydrogen atom.

Over the course of nine years, the detector was successful in its approach to uncover new information about the interactions of protons. The success of the detector was attributed to the experts in the field who thoroughly navigated the theory-based physics involved to come up with a detection solution which was not perceived to be possible at the time. The results of the research provide information about all matter composing the universe and also predict neutrino interactions for further experiments.

While the conclusive results of Fermilab will not necessarily further human understanding of the universe in any major way, it is a step forward in how technology meets physics theory. The hope is that one day, the origins of matter, proton decay, or even the formation of black holes will be known. Perhaps all these larger answers of the universe will be found as more facilities are created across the world, all because of the impact of particles as elusive as ghosts.

Nuclear Instruments and Methods in Physics Research (2015). DOI: 10.1016/j.nima.2015.04.003

PHOTO BY SHUTTERSTOCK

ROGUE STARS

Ejected stars permanently roam space in between galaxies

BY SALMA ALAWI, COMPUTER SCIENCE & BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY PARKER HITT, BIOLOGY, 2023

In 1997, the NASA Hubble telescope discovered that there existed stars without a tie to a specific galaxy, a finding that shook the scientific community. These stars were located in the region of the Virgo supercluster, an area of space containing around 2,000 galaxies. They were around 300,000 lightyears away from the nearest galaxy and lacked a gravitational tie to any regions in the area.

These types of stars, called intergalactic or rogue stars, do not belong to a certain galaxy and therefore dwell in the void between them. However, they haven't always been like this, as stars cannot be formed in intergalactic space. Instead, they were formed in a galaxy and stayed there until a major event ripped them away.

One of these events is an extreme interaction between two galaxies, like a collision or a merge. This is more likely to result in the formation of a rogue star if the star's home galaxy is lightweight. Another possible event is an encounter with a supermassive black hole. If a star veers too close to a black hole, it sends the star into a state of hypervelocity. Speeds of hyper-velocity stars can reach up to 1.6 million miles per hour; for context, that's 2,700 times the velocity of an airplane. In this state, the star rushes out of the galaxy, losing its gravitational tie.

Before, it was impossible to trace back the origins of these intergalactic stars. However, new emerging research techniques have made it possible to discover the home galaxies of rogue stars. By matching the chemical composition of the exiled star to the chemical attributes of nearby galaxies, scientists are able to accurately determine where the star originated. Since then, researchers at Vanderbilt University have discovered that around 700 rogue stars originated in the Milky Way and were ejected from the galaxy after traveling too close to its central black hole.

These researchers chose what stars to look at in depth by their red colorization, indicating that the star originated from the inner galaxy. This makes sense considering black holes are located in the centers of galaxies; as the stars made contact with this black hole, they were then flung from the center and lost the gravitational tie to that galaxy. It's predicted that one star is ejected from the Milky Way every 100,000 years. These types of stars that roam the void between galaxies may sound like abnormalities, but they are not. In fact, around half of the stars in the universe aren't tied to a galaxy. About 10% of the mass of the Virgo cluster of galaxies, the cluster where the Hubble telescope first discovered intergalactic stars, is composed of these rogue stars.

Intergalactic floating stars are not the only planetary objects lacking gravitational ties; a 2011 study from the University of Notre Dame discovered rogue planets floating in intergalactic space, also lacking a tie to a particular galaxy. Rogue planets can be ejected in a similar fashion to intergalactic stars, through a collision with a nearby entity, and they can form through the gravitational collapse of gas, similar to how normal stars form.

The discovery of these intergalactic stars shook the astronomy community due to their irregularity. Most, if not all, of the astronomical entities, up until the Hubble's discovery, were tied to another entity; each moon had a planet and each planet belonged to a star and each star to a galaxy. However, the discovery of these rogue stars has forced astronomers to think outside the box and think past previous astronomical confines. This new mindset could lead to more discoveries about the universe we live in.

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PHOTO BY SHUTTERSTOCK

The mystery of an undying star

BY DIVYA RAVIKUMAR, BIOENGINEERING, 2025

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING & DESIGN, 2024

The recent discovery of a peculiar supernova remnant has solved an 850-year-old mystery, and a new investigation is already forming in its place.

In 1181, Chinese and Japanese astronomers observed a "guest star," or the origin of a supernova, which they identified as SN 1181. It appeared as a dim expanding nebula that was as bright as Saturn and visible for six months. It was not until 2021 that astronomer Andreas Ritter and his colleagues at the University of Hong Kong were able to identify the explosion as the SN 1181 supernova remnant Pa 30.

Even before Ritter and his team connected the two events, the Pa 30 nebula had been a puzzling topic of interest. Pa 30 surrounds a Wolf-Rayet star called Parker's Star, which is a particularly rare type of old white dwarf star. It is one of the strangest stars in the Milky Way. In 2019 astronomer Vadilii Gvaramadze at Lomonosov Moscow State University discovered that Parker's Star has a stellar wind traveling outwards at 16,000 kilometers per second, which is 5% of the speed of light. It is rare for stars involved with supernovas to have winds that fast, since the explosion takes away most of their energy.

In the 2021 study, Ritter and his team first used Pa 30's rate of expansion to determine that it originated 1,000 years ago. This age corresponds with the 1811 supernova sighting. Additionally, the location of Parker's Star matched with the ancient Chinese records of the guest star's location. The alignment of Parker's star and Pa30's age and location with the events of 1181 strongly suggests that they are both remnants of SN 1181.

While analyzing Pa 30, the team also noticed that its emission spectrum had a particular line for the element sulfur, which led them to theorize that two white dwarfs collided and merged to produce Pa 30 and Parker's Star. If one star was made mostly of carbon and oxygen and the other of oxygen and neon, they would produce the high amount of sulfur present in Pa 30 upon collision.

PHOTO BY SHUTTERSTOCK

The merging of two white dwarfs is a rare supernova explosion of type-Iax, which is a subcategory of the familiar type-Ia supernova. Type-Ia occurs in a binary system, where a white dwarf star extracts hydrogen and helium from a companion star until it grows too large and implodes quickly, leaving behind a web of gas and dust. In type-Iax, however, the star survives the explosion and becomes a zombie star, or a massive white dwarf like Parker's Star. Although much remains to be understood about type-Iax supernovae, the description of SN 1181 appears to fit this category.

In 2023, Robert Fesen, an astronomer at Dartmouth College, and his team conducted a study in which they ran an optical filter, which transmits a specific wavelength of light, over an image of the remnant that showed how much of the sulfur was in the Pa 30 nebula. The results displayed very high amounts, which supports the theory that Pa 30 was the remains of SN 1181. The filter also returned an image of a supernova unlike any other that has been photographed. Numerous thin filaments appeared to be flying outwards from the center star of Pa 30, similar to a fireworks display. This unique image unlocked a new path in determining the mechanism of type-Iax supernovae, and it corresponds with Ritter and his team's theory that Pa30 was a result of the collision of two white dwarfs. This type of collision would be explosive enough to cause the fireworks of Pa 30 while leaving behind a zombie star.

Another fascinating aspect of SN 1181 is its proximity to Earth relative to other rare explosions that occur in distant galaxies. Currently, scientists are working with the Hubble Space Telescope and the James Webb Space Telescope to capture detailed images of Pa 30 that will hopefully shed more light on its origin. For now, SN 1181 is the only remnant where researchers can study the nebula and the merged star along with the historical account of the event. Its unique existence holds promise in unraveling the mystery of white dwarf mergers and type-Iax supernovae.

Nature (2023). DOI: 10.1038/d41586-023-00202-1
Nature (2019). DOI: 10.1038/s41586-019-1216-1
The Astrophysical Journal Letters (2021). DOI: 10.3847/2041-8213/ac2253

CONGRATULATIONS TO OUR GRADUATES

NU Sci proudly congratulates our graduating class of 2023! Throughout their time at the magazine, these editors and e-board members have gifted us with countless hours of tedious hard work, constant wisdom and insight, and the humor and kindness in their hearts. They've given *NU Sci* its secret power: not the ink on the page, but the tight-knit, supportive community of classmates, friends, and mentors that brings love and dedication into the practice of science communication. As they look out on horizons of endlessly-exciting and well-earned possibilities, they leave an impact that will echo through the students of *NU Sci* for many, many years to come. We wish them joy, fulfillment, and prosperity in all of their next steps. No matter where life takes them, they'll have the *NU Sci* extended family behind them.

ABIGAIL POTTER

As a physics and philosophy major, Abigail is no stranger to merging the qualitative with the quantitative. They found *NU Sci* in their second year and quickly took to writing articles about physics and math. After a semester, they became an editor to help newer writers share their passion for science and improve their writing. As Abigail became more comfortable with their role, they realized how much more vibrant and diverse science communication could be, writing articles about experimental philosophy and data ethics and encouraging their writers to explore science in pop culture. With these goals in mind, they were elected president of *NU Sci* in their final year at Northeastern. After graduation, Abigail plans to take some much-needed time to themself at home and travel through East and Southeast Asia before starting a full-time position.

LILY WEBER

After joining *NU Sci* as a writer during her first year, Lily was able to foster her love for the intersection of science and the humanities. As a biology and English major, Lily has continued to merge her passions for medicine and social sciences, writing articles on a variety of topics from psychedelic medicine to physician burnout. After applying to become an editor a whopping three times, she was finally successful on the third attempt and is now a senior editor and head of communications for *NU Sci*. Outside of *NU Sci*, Lily is on the executive board of *Spectrum Literary Arts Magazine* and loves to write poetry in her free time. After graduating in the spring, she plans to apply to medical school (and hopefully still have time to write).

SAM KLEIN

Science is cool, eh? Sam joined *NU Sci* his freshman year, and he found that NU Sci was a great place for him to merge his passions for science and design. Throughout his time at *NU Sci*, Sam has worked on the photography, design, and marketing teams. He has led the marketing team since December 2019. Sam cherished his time with *NU Sci* mainly because of the amazing people he got to work with. At Northeastern, he has also worked as head of design for The Red & Black and head of design for the Doghouse, but *NU Sci* always made him feel at home. Following graduation, Sam is going to take some time off, going on a road trip across the country before starting work in the fall.

IAN HAY

At the intersection of biotechnology and artificial intelligence, Ian escapes through creative photography shoots as head of photography at *NU Sci*. He began his journey with the magazine sophomore year for the "Hindsight" issue and was elevated to the executive board the following year. Culminating in cover shoots for our "Resilience," "Polar," and "Odyssey" issues, "Decay" represents his last opportunity at *NU Sci* to bring science to life visually. When not contributing to tantalizing cover discussions at meetings, Ian pursued bioengineering and computer science degrees at Northeastern, was a key member of the club squash team, participated as a research scientist in Cambridge during co-op, and became a contributor to open-source software projects. Following graduation, Ian will begin working full-time at Factor Bioscience, an mRNA-focused biotechnology company in Cambridge. His experience at *NU Sci* will help him communicate scientific discoveries with keynote imagery and storytelling.

GUS MUELLER

Gus joined *NU Sci* freshman year to create the photography team. Gus, together with design, instated photography as a critical aspect of the magazine. Most importantly, over the past five years, Gus has crafted a large collection of issues with photography-based covers utilizing landscape, food, studio, architectural, and portrait photography. After graduation, Gus will be doing something — we don't know yet.

AMANDA BELL

Amanda started writing for *NU Sci* during her freshman year and has since expanded to leading the web team and designing pages for the design team. As a data science and behavioral neuroscience major, she's enjoyed writing about psychology, physiology, and neurology in conjunction with the various technologies that arise in these fields. Outside of *NU Sci*, she's found a passion for organizing with clubs including Huskies Organizing with Labor (HOWL) and the Progressive Student Alliance (PSA). She hopes to continue doing similar work in the future. After graduation, Amanda will take some time to do more of the things she neglected while at Northeastern — biking, rock climbing, hiking, running, sleeping — then start working full-time at a Waltham-based biotech company called Visterra.

JASON DENONCOURT

A fanatic of science, Jason used *NU Sci* as an opportunity to explore exciting advances in fields outside his academic discipline, chemical engineering. He wrote about seaweed aquaculture, phantom limbs, avalanche science, and many other topics. After a successful first year of writing, Jason joined the editing team to support newer writers in exploring cool topics of their own. Outside of *NU Sci*, Jason is passionate about public policy, community health, and the outdoors. Following graduation, Jason will move to Worcester and study at UMass Chan Medical School on the Population-based Urban and Rural Community Health (PURCH) track. Jason believes that his experience with *NU Sci* helped to prepare him for the role of science communicator as a physician. He is excited to work in community health in the near future.

ANUSHKA BISWAS

Anushka entered Northeastern as a conflicted cell and molecular biology major, worried she would have to give up her passion for writing in exchange for three-hour-long labs three times a week. Luckily for her, she found *NU Sci* and has stuck with it throughout her four years, initially as a writer and eventually as an editor. Being a part of the magazine exposed her to all sorts of fascinating discoveries in the fields of physics, medicine, and environmental science. Her favorite assignment involved interviewing Northeastern professors as they eagerly shared excerpts from their journeys and offered advice on getting through a career in science. Most of all, the welcoming community full of the kindest science enthusiasts truly made her time at *NU Sci* special. Following graduation, Anushka plans to work in biotech during her gap year as she applies to medical school.

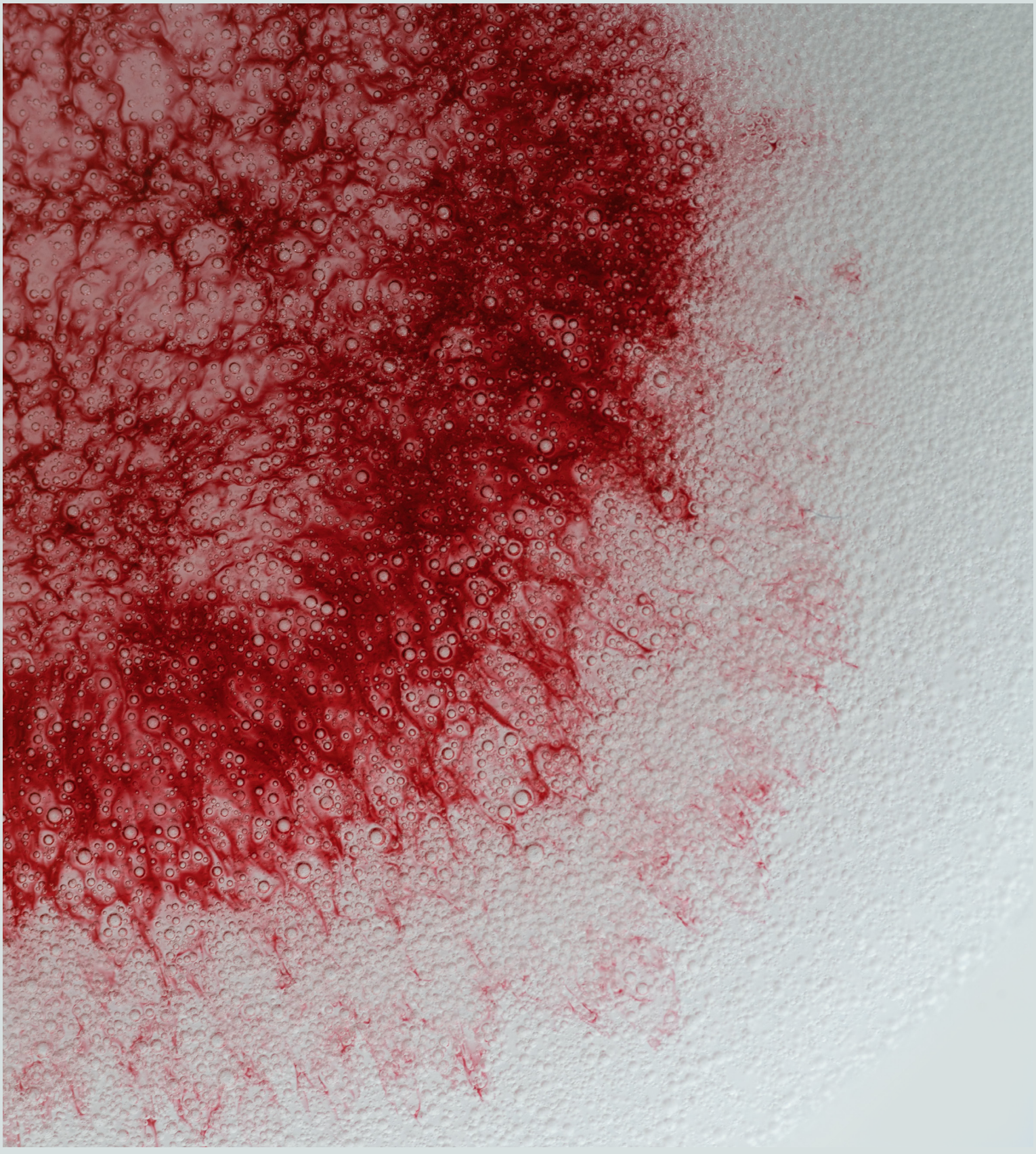
EMMA TUSUZIAN

NU Sci has been Emma's outlet for scientific exploration since her freshman year and has been a core experience as she discovered the fun of leaving her scientific comfort zone. Over her three years as an editor, Emma has built her confidence in science communication, passion for creative expression, and inspiration for connecting with science lovers of ranging disciplines. As a psychology major with minors in behavioral neuroscience and data science, Emma has also pursued her passions by leading Lean On Me, Northeastern's student-run peer support text hotline; being a peer educator for the Office of Prevention and Education at Northeastern; and being a thesis student for Northeastern's EPIC Brain Lab. After graduating, Emma will be a clinical research assistant at McLean Hospital to support the study of treatments for mood, psychosis, and cognition in bipolar disorder and schizophrenia spectrum disorders with the hope of eventually pursuing clinical PhD programs.

CATRIN ZHARYY

A behavioral neuroscience major and cultural anthropology minor, Catrin joined *NU Sci* during her first semester at Northeastern to pursue her passion for translating complex scientific concepts into accessible and informative articles. She became an editor during her sophomore year and continued to serve as one for her remaining three undergraduate years. *NU Sci* provided her with the opportunity to continuously learn about exciting new research in a variety of disciplines and explore her interest in using neuroscience research to improve our understanding of human nature, social relationships, and mental health. Beyond *NU Sci*, Catrin also devoted much of her time outside of classes to the Northeastern University Researchers of Neuroscience (NEURONS), serving on its executive board for three years. After graduating, she plans to develop a career in cognitive and affective neuroscience research with the goal of informing culturally-responsive mental health care.

THANK YOU!



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