

**ISSUE 52** Spring 2022

# NU SCI

**CLARITY**

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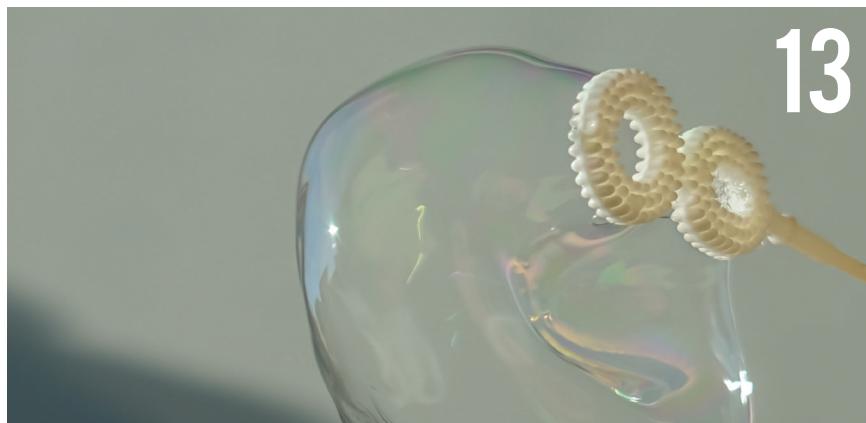
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# LETTER FROM THE EDITOR

# STAFF

I've often used the Letter from the Editor space to talk about looking back at the lessons of the past and forward to the possibilities of the future. For me, it's been a place of reflection where I could capture a moment in time and share my perspective. From the "objective" to the philosophical to the personal, I've always and only written from my perspective, placing myself and my voice at different distances between the text, you, and me. For my last Letter, I want to close that distance, be as close as I can.

My thoughts always tend toward retrospection as I write these — to make a coherent story out of all the confusing and complicated moments of the past. Yet from that story, I try to be optimistic; I try not to linger too long on what's over and look toward what's still to come. I seek what everyone else does at some point in their lives: clarity — from the past and for the future. Sometimes, I never get it in either direction. But the security of sense and the comfort of knowing are intoxicating promises. That's what makes science so great. That's what makes learning and communicating that knowledge so special. We take our observations and share them with others. We learn things about our world and ourselves, and we decide that we need to let other people know about these things. To me, that's what makes communication so remarkable, so generous.

At its core, that's what NU Sci is to me: A community of people who are passionate about learning and making sense of the world, and who want to share that knowledge with others. There are countless ways to try to understand the world, but this collection of wonderful people choose to share it in the way they know best.

For one last time from me, I thank the writers, designers, photographers, marketers, web team, outreach team, editors, e-board, and readers of this publication, all of whom make this publication possible and always phenomenal. We hope you enjoy reading Issue 52 of NU Sci, and I hope you'll choose to share your own moments of "Clarity."



A handwritten signature in cursive script that reads "Binh Dang".

Binh Dang  
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# ARE PEARLS THE KEY TO THE NEXT SUPERMATERIAL?

BY CAILEY DENONCOURT, BIOENGINEERING & BIOCHEMISTRY, 2022

DESIGN BY PARKER HITT, BIOLOGY, 2024

**T**he outsides of oysters appear rugged and dreary, but embedded inside lie beautiful, iridescent pearls. Their beauty has made them a sought-after object of vanity and aesthetics in the jewelry industry. However, this gem might be good for more than just earrings and necklaces; scientists are currently investigating its complex formation and how the organization of layers may give insight into creating the next supermaterial.

Pearls might seem useless to seawater oysters and freshwater mussels, but they have an evolutionary advantage as a defense mechanism. In response to a potential threat — like a parasite or a simple irritant, like a piece of sand or food — the sea creature will secrete aragonite and conchiolin that coat the foreign piece of matter. Aragonite is a type of mineral that is a special form of crystallized calcium carbonate, while conchiolin is a protein, but both are typically found in the shells of oysters and mussels. Together they combine to form a material called nacre, which has been deemed “the mother of pearl.”

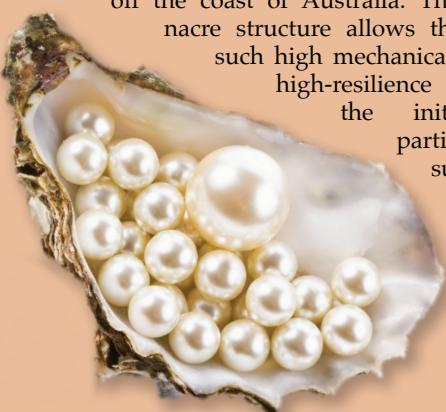
The nacre is the organic-inorganic material that forms layers that gives the pearl its signature iridescent shine. Each layer of nacre is made up of many aragonite tablets and is typically only about 50 nanometers thick, which is 2,000 times thinner than the average human hair. Between each nacre are organic sheaths. These are responsible for the patterned, organized arrangement of the crystallized structure of the pearl and for keeping all the nacre layers bound together.

In 2021 at the University of Michigan, Robert Hovden and other researchers began to investigate the formation of the pearls by observing and analyzing Akoya “keshi” pearls off the coast of Australia. They looked at how the nacre structure allows the pearls to withstand such high mechanical stresses and maintain high-resilience properties. During the initial formation, the particles of aragonite and subsequent layers of nacre are arranged in a nonuniform pattern with widely varying layer thicknesses.

Compared to the initial formation of nacre layers, the mature-stage layers have a threefold decrease in the thickness variation, which occurs when the diameter of the pearl reaches about 100 micrometers. This improvement is due to a corrective growth process that will arrange the layers over time into the proper crystalline structure. The oyster or mussel is able to achieve this by accounting for the irregularities and variability in the previous layer. For instance, if there is one layer that’s slightly too thick, the next layer will form thinner, allowing each layer to average together so the surface can become even. This process will occur again and again as multiple layers are built simultaneously with progressive thinning.

From this study, for the first time, scientists can now explain how oysters and mussels are able to create the layered, extremely durable material. Although pearls do not display perfect, long-range order characteristics — meaning that over a large set of layers, typically in the range of a thousand, the crystalline arrangement repeats itself — they do display medium-range order over the course of about 20 layers. Though not considered long-range order, the medium-range repeats still allow for the considerable durability and strength seen in the pearl layers.

Moving forward, now with a greater understanding of this structure formation, scientists can pursue further advancements in nanoscale layering materials. Previously, these incredibly small structures were extremely time-consuming to make because they were built periodically, one layer at a time, with each tablet carefully placed. But now that scientists have seen how pearls use a different strategy in which they are able to go from disorder to order through an ongoing, corrective process, they can look to nature for inspiration to hopefully improve current nanoscale materials to be stronger and lighter.



# SEEING THROUGH TREES

## TRANSPARENT WOOD AS NEXT-GENERATION GLASS

BY DESSY DESICHKA, BIOLOGY & COMPUTER SCIENCE, 2025

**G**lass is an integral part of modern buildings, appreciated for its uniquely transparent nature that provides a literal window to the outside world. Made mostly of sand, sodium carbonate, and limestone, glass resists intense weather patterns and precipitation and is recyclable and relatively inexpensive to produce. However, glass has several weaknesses — it is thermally inefficient, releases excessive carbon dioxide during production, and shatters easily. Luckily, researchers are developing a valuable alternative: a type of transparent wood that looks just like glass but improves upon many of its flaws.

One major drawback of glass is that it readily allows heat to pass through due to its high thermal conductivity, which can drive up energy demands in the winter. To combat this, most modern windows have two panes with air in between acting as insulation, but they, too, are not immune from heat loss. Fourteen percent of primary energy consumption in the United States comes from regulating temperatures within buildings. The inefficiency of traditional glass in maintaining internal temperatures causes up to 25 percent of this energy to be lost. Because of its lower thermal conductivity, double-paned transparent wood is more thermally efficient than its glass counterpart, promising to lower energy costs for buildings it is installed in.

Additionally, traditional glass production releases huge amounts of carbon dioxide. In the U.S., up to 15 million metric tons are produced annually. It is widely known that excessive carbon emissions contribute to higher global temperatures; thus, traditional glass production has harmful climate consequences. Much of this carbon dioxide comes from the large amounts of energy needed to heat materials involved in glass production. The wood-based “glass” aims to solve this problem via production methods that don’t involve large-scale industrial heating and instead rely on natural solar power.

Moreover, glass is fragile and shatters upon impact, which makes it a dangerous building material. In contrast, this wood-based glass is more durable and able to withstand impacts since it capitalizes on the natural toughness of wood. When transparent wood does break, it bends or splinters rather than fully shattering — a notably safer effect. A study in *Advanced Functional Materials* showed transparent glass has a fracture toughness of 3.03 megajoules per cubic meter as compared to glass’s fracture toughness of only 0.003 megajoules per cubic meter.

So, how can wood possibly be made transparent? Researchers have achieved this by targeting lignin, the primary component of wood that absorbs light and produces its characteristic brown color. An approach presented in a 2020 study in *Advanced Functional Materials* involves soaking balsa wood in a sodium chlorite bath to entirely remove lignin and then adding a polymer filler to improve transparency and durability. While this process produces a promising result, this method uses large amounts of chemicals and energy and ultimately produces toxic liquid waste.

A newer strategy published in *Science Advances* modifies lignin instead of eliminating it, focusing on the light-absorbing part of lignin known as the chromophore. This method still requires chemicals, but they are brushed onto the wood instead of being added to chemical baths. Thus, fewer chemicals are used, which produces less toxic waste and makes production less expensive. Next, solar power is used as a source of ultraviolet light which completes the process of removing chromophores from lignin. Relying on solar power reduces the energy demand for heat involved in the production, a significant improvement over traditional glass. Finally, epoxy is added to the wood to complete its transparent transformation.

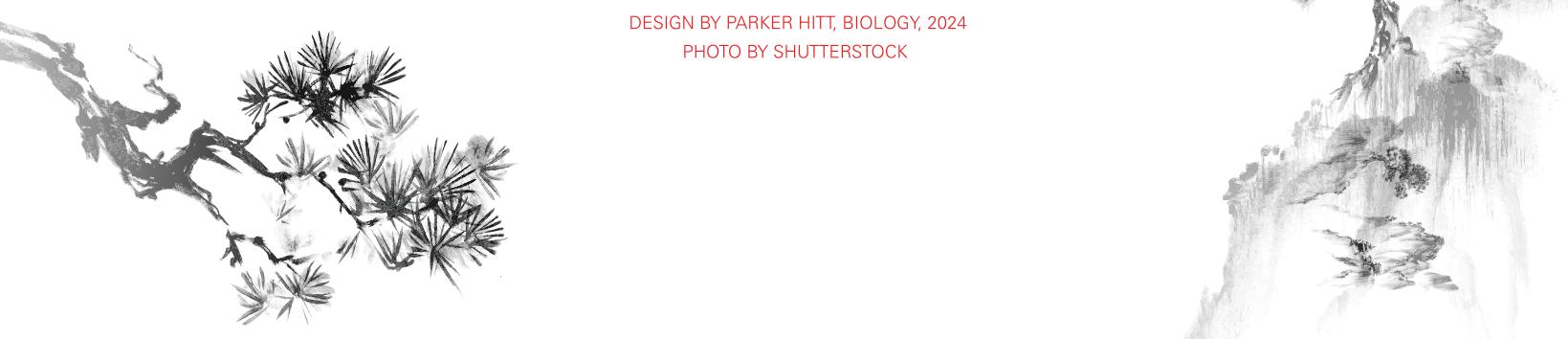
The kinds of transparent wood currently being developed have excellent optical properties, transmitting over 90 percent of visible light. The 2020 study boasts a final product that is five times more thermally efficient than regular glass, which means heat escapes less easily. Lastly, these types of transparent wood demonstrate high tensile strength and durability.

Attempting to reinvent glass has been a challenging task, forcing engineers to balance optical, thermal, and mechanical properties while being mindful of environmental and economic concerns. As shown by the continuing research, scientists are still working to determine the most efficient production process for this new material. The goal is to make this a scalable process that can be cheaply and easily implemented so that transparent wood can become widely used in buildings instead of glass. When it comes to energy-efficient buildings, one thing is clear: transparent wood is a promising solution, combining the visual benefits of glass with the eco-friendliness and durability of wood, a renewable and versatile resource.

Science Advances (2021). DOI: 10.1126/sciadv.abd7342  
*Advanced Functional Materials* (2020), DOI: 10.1002/adfm.201907511

DESIGN BY PARKER HITT, BIOLOGY, 2024

PHOTO BY SHUTTERSTOCK



# Ditch the plastic

## Eco-friendly glitter made possible

BY MILENA PEREZ-GERUS, ENVIRONMENTAL & SUSTAINABILITY SCIENCES, 2025

**G**litter embellishes anything it touches. It turns any mundane and dull poster, project, or Halloween costume into an eye-catcher. That sparkly and glistening glitter, though, ends up as litter in the environment. Although a nostalgic childhood activity, dumping excess glitter that did not stick to your mother's birthday card's glue ultimately adds up to be extensive waste. Thankfully, a sustainable alternative could give eco-conscious consumers no need to ditch glitter.

A renewable and plant-based substance called cellulose nanocrystals (CNCs) can form into the colorful and reflective films seen in store-bought glitter bottles. Cellulose is the most basic component of green plants and vegetables, and the power of this plant's abundant building block can be harnessed to create a beautiful substitute for environmentally harmful plastic glitter.

These sustainable films and pigments self-assemble through a solvent evaporation process. This first step is surface activation. This is when a liquid CNC substance is laid on a large, flat surface called a web. Confined to the web, the liquid now cannot flow elsewhere. Next, this web with the CNC liquid goes through a coating process that enhances the eye-catching properties of the substance desired for the ultimate glitter. After coating, the liquid on the web is dried and is now in a film form. The CNC is peeled off the web, put through heat treatment, and sized with a coffee grinder into pieces of glitter.

All of these steps sum up the solvent evaporation process. From being placed on the web at a liquid state to ultimately being dried, the product forms itself. After this manufacturing process, the reflective and colorful appearance gives organically-made glitter the shine that consumers love.

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

PHOTO BY SHUTTERSTOCK

**"The power of this plant's abundant building block can be harnessed to create a beautiful substitute for environmentally harmful plastic glitter."**

This large-scale process is complicated, as there are obstacles when attempting to commercially create sustainable glitter. Once only developed in small Petri dishes, the glitter is now created through utilizing roll-to-roll manufacturing, which is also used in electronics and textile industrial sectors. Through this type of production, the CNC web is continuously fed through roller machines, making this sustainable alternative an achievable commercial product. In addition to defeating this challenge, CNC films first only succeeded in making transparent films, but not colorful ones. The scientific community has now accomplished optimal color pigmentation through accelerated and prolonged heat treatments. Before grinding the film into tiny particles, heat treatments produced glitters across the entire color spectrum that would not degrade in quality when submerged in water. Continuing to research in this industry will allow for a green and guilt-free use of the widely-used party favorite.

If this new glitter hit the markets, it could further prevent micro-polluting our environment. Small plastic glitter receives copious use and disposal without thinking twice. It primarily travels through sewage systems, giving ample opportunity to reach waters from oceans to river basins. Although a pretty product to unknowing consumers, glitter can be deadly to marine life who mistake the microparticles as fueling food. This is entirely human provoked, and it is our responsibility to the planet to find safe alternatives to the accumulating plastic glitter. Cellulose nanocrystals, being organic and plant-generated, offer hope for battling micro-pollution, combating glitter as litter. Alternative glitter makes it possible to decorate birthday cards and dress up your alien Halloween costume with ethical consideration and style!

*Nature Materials* (2021). DOI: 10.1038/s41563-021-01135-8  
*Journal of Agricultural and Environmental Ethics* (2019). DOI: 10.1007/s10806-019-09785-0

# KEEP IT FRESH

Printing the organs of the future

BY TYLER LOCKE, BIOMEDICAL PHYSICS & MATHEMATICS, 2023

**A** patient desperately needs a new heart. They might wait several months for a donor organ, which may not be available before their condition worsens. Even if one is received, the body might still reject the transplant and work against the foreign cells introduced. Living with a transplanted organ means taking numerous drugs to prevent this immune response, often with a decreased quality of life or a shorter life span.

But what if it didn't have to be this way? What if, given a small sample of a patient's cells, a fully functioning heart composed entirely of their cells could be grown in a few months? While sounding like science fiction, generating functional organs like a heart is now a hot topic in biomedical research. In particular, 3D bioprinting seeks to apply technologies developed for 3D manufacturing toward printing functional organs and tissue constructs.

Traditional plastic-based 3D printing relies on a method called fused deposition modeling (FDM). In FDM, a small plastic filament is melted and deposited in a predetermined pattern. As it is deposited, the plastic hardens, and, layer by layer, a 3D object is built. This method has seen widespread success, creating strong and detailed parts with very little cost and manufacturing time. However, biological materials often do not behave like plastic. Cells and proteins can't be melted and reformed like plastics and will collapse on themselves if printed using FDM methods. This limits the complexity of bioprinted constructs to near-2D geometries, a far cry from the complexity needed for an implantable organ replacement.

Since the materials used for bioprinting cannot be changed without compromising their biological function, alternative solutions are needed. One new approach is freeform reversible embedding of suspended hydrogels (FRESH), a new method for printing biological materials where — rather than changing the material that is printed — the surroundings are changed.

As detailed in a 2015 *Science Advances* study, FRESH is a technique that involves printing biological materials into a support material rather than into the air. This support material is composed of microscopic spheres of gelatin tightly compacted in a liquid medium. When small forces are applied,

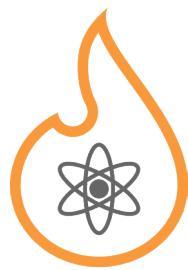
the support acts as a solid, allowing it to hold the printed constructs in place without deforming. When larger forces are applied, the material acts as a liquid, allowing penetration with a syringe for depositing print material. The print and support materials are carefully chosen so that the printed material will harden when it contacts the support. The support can then be melted and washed away, leaving just the print behind.

Researchers used this technique to 3D print a collagen heart valve, successfully replicating the structure found in an adult human heart. Remarkably, when exposed to pressure conditions mimicking the pumping motion of the heart, this valve opened and closed in a manner consistent with biological function over numerous cycles. Heart valve replacement surgery is a common procedure, usually performed with a valve from a pig, cow, or donor human heart. The prospect of an artificial valve substitute is extremely exciting as it can drastically reduce costs and increase the effectiveness of these procedures.

To further demonstrate the capabilities of FRESH printing of organs, researchers proceeded to print a full-scale model of a neonatal human heart out of collagen. This construct was created from an MRI model and accurately replicated the complex structures in the heart. Although a nonfunctional model, this construct is an amazing example of what this technology is capable of and an important step towards replicating the structure and function of human organs.

While valve and heart models are impressive, they are still only static components, lacking the movement and responsiveness present in human tissue. One of the most impressive applications of FRESH printing involves printing cell-laden ink into 3D tissue structures. Using this method, researchers created a model ventricle of human cardiac muscle cells and a collagen support structure. Over time, this ventricle exhibited synchronized contractions consistent with normal cardiac function, something that seemed impossible to replicate just a couple of decades ago. Although we may be a long way from replacing donor organs entirely, FRESH bioprinting shows great strides toward a printed-organ future.





# THE FUTURE OF ENERGY: WHY FUSION POWER IS ALWAYS '30 YEARS AWAY'

BY NOAH HAGGERTY, APPLIED PHYSICS, 2024  
DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING, 2024

**N**uclear fusion power promises to revolutionize the world's energy production infrastructure and combat climate change head-on. In the 1970s, physics researchers confidently proclaimed that nuclear fusion power was "30 years away." The phrase has been parroted time and time again, reverberating through popular science, but as time moved forward, the 30-year estimate remained constant — to the point where it has become an inside joke for scientists in the field.

In nuclear physics, the "binding energy" of an atomic nucleus is the amount of energy released, or lost to the environment, when protons and neutrons bond to form an atom. For small atoms, like hydrogen and helium, as atomic size increases, the amount of this missing atomic energy quickly skyrockets up until it plateaus just past oxygen. For larger atoms, the energy begins to decrease with size. Physicists have learned to harness this energy in modern nuclear fission power plants by starting with large elements, like uranium, and breaking them apart into smaller elements with slightly greater amounts of missing energy. Through conservation of energy, this energy missing from the atoms must go somewhere, so it takes the form of thermal energy which can be converted into electricity.

While fission plants successfully harness the energy of this process, they miss out on the elusive skyrocketing of energy released from combining smaller elements through fusion. Furthermore, fusion plants cannot meltdown like fission plants, since fusion cannot happen spontaneously in Earth-like conditions, and their radioactive waste decays in decades instead of centuries.

Fusion occurs naturally only in stars, so harnessing fusion power requires replicating those conditions on Earth: creating a plasma of free-flying electrons and ions at 150 million degrees Celsius. Fusion was first achieved in 1951, and progress toward sustained power production took off in the 1970s. This progress was fueled by a previously-niche method for creating high-energy plasma — a donut-shaped magnetic chamber called a tokamak. This bolstered the confidence of nuclear physicists, leading to the "30-year" claim. The rush of progress culminated at the end of the Cold War with the announcement of the International Thermonuclear Experimental Reactor project (ITER): a massive international collaboration between Europe, Japan, the United States, and the USSR to build an 18-story-tall tokamak. ITER set out to prove the commercial viability of fusion power by achieving fusion breakeven, getting more energy out through fusion than put into the plasma.

But by the turn of the century — the 30-year mark proclaimed by the confident '70s physicists — ITER progress was slow, and individual research groups stalled in the push to fusion

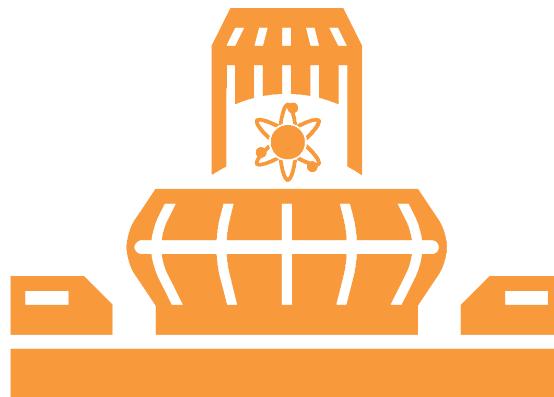
breakeven. Scientists began placing more and more of their focus and hope in ITER.

This, understandably, has many in the field worried — placing too many resources in one project and one fusion method could deliver a fatal blow to humanity's endeavor into fusion should it fail. This has sparked a new counterculture in the field to try alternative methods to ITER's tokamak approach. The United States' advanced energy research agency is pursuing new tokamak shapes and higher-pressure methods to energize plasma using lasers instead of magnets, as well as researching ways to solve some of the major engineering challenges plaguing fusion endeavors.

The Swiss Plasma Center recently partnered with an AI company acquired by Google, DeepMind, to successfully control the plasma flow in a tokamak with machine learning. The project involved feeding the AI a desired plasma shape and letting it learn how to create that shape and control it in a simulated fusion reactor, then running the developed controls on a real reactor. The program was a success and allowed the team to shift their focus to developing efficient and effective plasma shapes.

As it stands, ITER plans to begin power production in 2025 and hopes to achieve the elusive sustained fusion breakeven in 2035. A handful of nations, including Japan and China, have announced plans for domestic fusion reactors that build upon the learnings of ITER — while the US focuses on supporting private companies developing fusion technology through parallel government research programs and regulatory development.

The reality is, as with any new technology pushing the bounds of human capability, it's impossible to foresee the challenges that still lie ahead, and therefore impossible to predict how "far away" fusion really is. All we can truly analyze is physical feasibility, progress, and human determination. With deep international collaboration, renewed momentum, and stronger technology diversification, fusion is proving strong in all three.



PHOTOS BY SHUTTERSTOCK

# Rayleigh scattering

Why the sky is blue  
and other miscellanea

BY PATRICK DONNELLY, ELECTRICAL & COMPUTER ENGINEERING, 2026

**G**rowing up, we all have those big life questions that catch our interest. Those with a penchant for nature, for instance, may ask such questions as: where do the Moon's phases come from, what are rainbows, why is the sky blue? The answers to these questions, as may be given to a scientifically-inclined young mind, are reflection of sunlight, refraction of light through atmospheric moisture, and Rayleigh scattering, respectively. This last answer, however, while a popular one, often goes without further elaboration.

Rayleigh scattering, named for John William Strutt, 3rd Baron Rayleigh, is how light is scattered through air. Blue light bounces around more than red light, making the sky appear blue. However, this definition, while the most popular, overlaps several different types of scattering, rendering this explanation incomplete.

There are *many* forms of optical scattering — too many to properly explain. Indeed, even peer-reviewed publications have confused what constitutes Rayleigh scattering, but the true definition, as used in optics and scattering theory, is relatively narrow. Put formally, Rayleigh scattering is the elastic scattering of light off of fine particles with an intensity proportional to the inverse of the wavelength of the photon raised to the fourth power.

To clarify the above description, let us take it element by element. "Elastic scattering" refers to elastic interactions between the incident (approaching) photons and the molecules of the surrounding medium. In physics, "elastic" means that kinetic energy is conserved, meaning that the photon does not lose any energy in the collision. Were the collisions in question not elastic, it would not be Rayleigh scattering, but Raman scattering, named for Indian physicist Chandrasekhara Venkata Raman.

Next, "fine particles" is not a true scientific term, but a qualitative relationship. For Rayleigh scattering to apply, the particles of the surrounding medium — in this case air — must be much smaller in diameter than the wavelength of the incident photon, which they indeed are. If the particles were comparable in size to the wavelength of the incident light, the process would be Mie scattering, named for German physicist Gustav Mie. Were the particles to additionally be non-spheroidal and in suspension, the effect would be Tyndall scattering, named for Irish physicist John Tyndall.

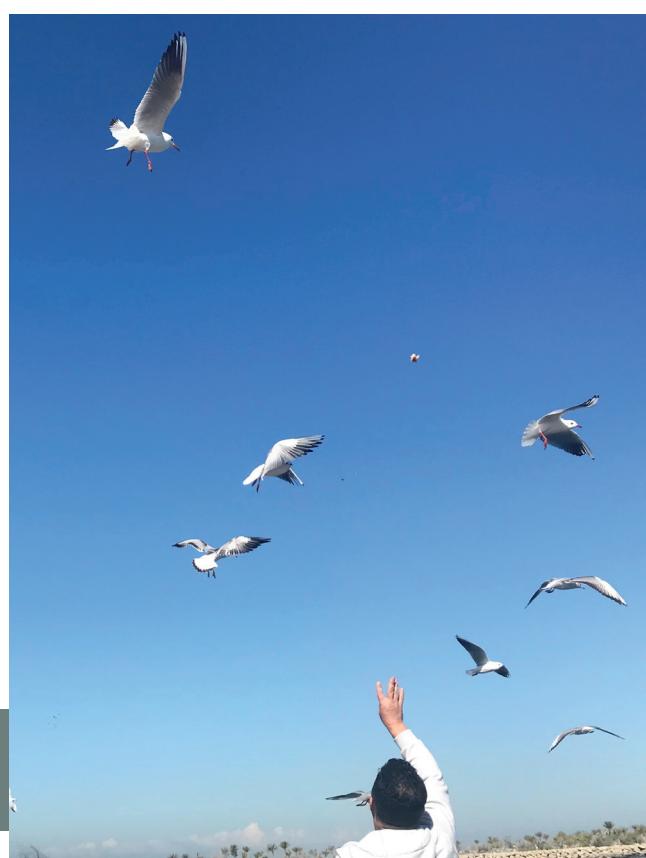
Last, the wavelength of a photon is inversely proportional to its energy; that is, the higher the energy of the photon, the shorter its wavelength, and the more it oscillates. Under Rayleigh scattering, higher-energy light scatters more than lower-energy light. Because the sun produces white light — which is a mixture of the entire spectrum of visible light — higher-energy blue light scatters more than lower-energy red light, making the sky appear bluish; the sky, however, does not appear purple because the sun produces relatively little violet light. The resulting color is a washed-out, classic sky blue.

That is, of course, looking at the midday sky. During twilight, parts of the sky will appear red. This is because the light from the sun, due to it being on the horizon, must travel through much more of the atmosphere to reach the eye. Here, Rayleigh scattering works against blue light, as, by the time it reaches the eye, it has been scattered to almost nothing, leaving the less-scattered red light to fill the gap.

This still fails to capture the breadth of Rayleigh scattering. Mathematician Rayleigh, in addition to qualifying this phenomenon, quantified it, providing basic models of light scattering in air, today called Rayleigh's approximation. This model has many practical applications, from clearing haze in photographs to facilitating various forms of gas spectroscopy.

Further still, Rayleigh scattering is responsible for the latitudinal (north-south) polarization of sunlight. This polarized light orients the internal compass of several species, most notably migratory birds. However, due to increased background noise caused by urban light pollution interfering with light polarization, such species have much greater difficulty navigating. Were there to be literal background noise (for example, resonance in the air), the effect would become Brillouin scattering, named for French physicist Léon Brillouin.

Asking why the sky is blue opens the door to so many natural phenomena that even professional scientists sometimes get them confused. Nevertheless, even if simply due to scattering, the beauty of the sky persists. So, the next time a child asks you why the sky is blue, it may be best to just tell them "light scattering."



# DOWN A HOLOGRAPHIC RABBIT HOLE

BLACK HOLES, WORMHOLES, AND HOLES IN PHYSICS THEORY

BY ANABELLE MATHERS, CIVIL ENGINEERING, 2022

**I**magine if science was scrapped and rewritten in an instant. The behavior of phenomena associated with quantum physics, gravity, and black holes has historically challenged our very perception of the universe. The scientific world potentially stands on the verge of enormous advancement through the reconciliation of Albert Einstein's theory of relativity (in part macroscopic gravitational behavior) and quantum theory (microscopic particle behavior). Different theories predict varied extents to which the scientific world might or might not change. The study of gravity and dimensions around black holes, assisted by our understanding of wormholes and string theory, facilitates this reconciliation with the proposal that the universe and reality could essentially be a hologram.

## GRAVITY: A TALE OF TWO THEORIES

First, a quick recap. The theory of general relativity explains how gravity acts on a macroscopic, universal scale throughout the universe as one of the four forces of physics. Gravity has yet to be applied to quantum theory, which, on a microscopic scale of atomic and subatomic particles, deals with the other three forces of physics: electromagnetic forces, strong interactions, and weak interactions. The universe's gravitational field is commonly represented by a tablecloth (also known as the fabric of spacetime) stretched over an opening. A large marble placed in the center causes the center of the cloth to dip downward and the rest of the cloth to curve and funnel inward. When placed on the cloth, a smaller marble will accelerate toward the large marble; this "attraction" is not from an innate force, per se, but results from the cloth's geometric properties caused by its interaction with the large marble. Unlike the physics of general relativity, the physics involved in quantum theory is based on probability and margins of error, as scientists currently cannot determine the exact trajectory of particles. Quantum theory specifically details the behavior and interactions of particles that dictate properties of matter and energy. Particle behavior is particularly useful for understanding black holes, and its incompatibility with gravity is a divide physicists have been trying to bridge. This is the long-sought realization of quantum gravity.

Some current theories of quantum gravity reconcile gravity and quantum phenomena by perceiving the universe as a hologram. This is referred to as the holographic principle. The study of black holes, which create intense gravitational fields on the scale of particles, encourages the combination of the two theories and is associated with the holographic principle. It must be noted that "holographic" refers to the representation of an N-dimensional object in less than N dimensions, similar to observing the 3D aspects of an object on a 2D television screen.

## BLACK HOLES AND WORMHOLES: PARADOXICAL DESTRUCTION

Black holes occur when massively dense stars collapse into themselves due to their significant gravity. Not only do black holes warp spacetime, they also theoretically destroy particles and particle information (the Universe's "data" of particles), violating the laws of physics and creating a paradox. Once a particle falls into a black hole, it is seemingly impossible to get back information about what that particle was. In a 1995 issue of the *Journal of Mathematical Physics*, scientists proposed that the radiation escaping from the surface of black holes, itself proposed by Stephen Hawking in a 1974 issue of *Nature*, may be related to or even relay the information of each "destroyed" particle within the black hole back into the universe.

How exactly does information escape? It is not entirely clear. Unsurprisingly, the missing puzzle piece may relate to gravity's role in quantum-level particle behavior. In a 2021 issue of the *Journal of High Energy Physics*, scientists conjectured that the interior of black holes may contain wormhole-like characteristics. Wormholes are shortcut tunnels to different locations in the fabric of the universe; black holes might act like wormholes by somehow projecting information from their interior to beyond their boundaries. For black holes, the projection of this information is facilitated by existing radiation from black holes. It is this idea of multidimensional projection that points toward the holographic principle.

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## HOLOGRAPHIC THEORY: MATHEMATICAL DUALITY

The holographic principle uses this same logic for black holes. As 3D matter falls into a black hole, the object's information is imprinted onto the 2D plane of particles on the surface of the black hole. This information can then be "picked up" by particles radiating from the surface. In other words, black holes interact with 3D gravity and matter but their visible effects exist on the 2D particle plane, meaning black holes can essentially be viewed as 2D holograms of entities with 3D properties.

Some proponents of quantum gravity consider this connection between gravity and particles to be a form of mathematical duality where gravitational phenomena mathematically correspond to particle phenomena. In the 1990s, physicist Juan Maldacena proposed a form of mathematical duality and its holographic aspects as "Anti-de Sitter space and Conformal Field Theory correspondence" (AdS/CFT). In short, this theory refers to the relationship between gravity and quantum physics when looking at the universe in terms of quantum string theory. Imagine Anti-de Sitter space as a volume of space representing the gravitational universe. This volumetric space has a surface boundary calculated using the quantum physics of conformal field theory. In geometry, a volume of space has a higher dimension than its boundary and is mathematically related to its boundary (e.g., the volume of a 3D cylinder is mathematically related to its 2D area and its boundary). Therefore, not only does this model of the universe mathematically relate gravity to quantum physics, but it shows that information of 3D space can be related to and represented on a 2D surface akin to the holographic principle. This means that, just as black holes can be visualized as 2D holograms because of their multidimensional projections between gravity and particles, the rest of the universe could be visualized as an informational hologram because of the multidimensional mathematics of a model relating gravity and quantum physics.

## RECENT ADVANCEMENTS

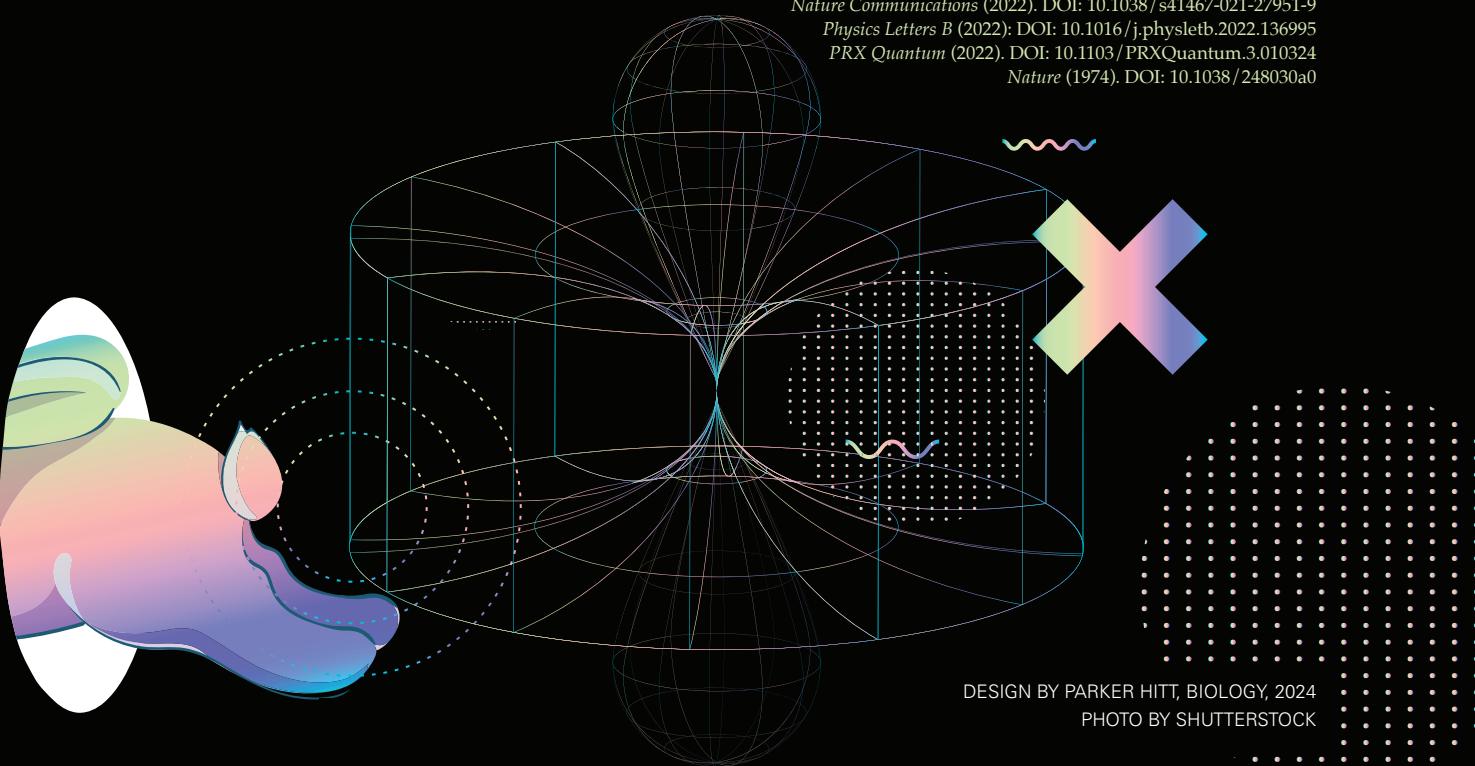
As of March 2022, papers in *Physics Letters B* and *Physical Review Letters* have produced more concrete support for the "quantum hair" explanation for how information could be projected from black holes and thus how gravity and quantum physics could be reconciled with the holographic principle. "Hair" is the term used for the imprint on the gravitational field made by a black hole's radiative and informational aftereffects. If true, this landmark discovery could eliminate the need to re-envision the foundations of physics in order to relate gravity to particles since quantum-state information is more directly related to imprints on a now quantized gravitational field without rewriting quantum theory or gravity theory. Hawking himself, doubted that *chaotic* radiation could be the exact means by which information is preserved and later considered quantum hair and its assumption of less chaotic radiation to be the missing link, but he lacked support. Scientists have finally found more mathematical evidence that black holes have this "hair," resulting in some hope that this entire phenomenon could be the true realization of quantum gravity.



## THE WHOLE PICTURE

In truth, this article barely scratches the surface of all these topics; however, the relevance of quantum gravity, particularly in light of recent developments regarding black holes, is undeniable. Holographic theory is just one of many existential theories about the Universe. True to its nature, the world of quantum mechanics is rich with possibilities that computers and artificial intelligence have only just begun to help us explore. There are innumerable caveats and nuances and holes in these discoveries, but they allow science to keep moving forward, to keep moving down the rabbit hole.

*International Journal of Theoretical Physics* (1999). DOI: 10.1023/A:1026654312961  
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*Nature* (1974). DOI: 10.1038/248030a0



# A FORCE UNKNOWN TO SCIENCE WITH INEXPLICABLE IMPACTS

BY REBECCA SCOTT, BEHAVIORAL NEUROSCIENCE, 2024

The forces dictating the physical world have always been a subject of great focus for physicists and non-physicists alike. The known laws that matter follows are accepted as absolute truth by many individuals, yet the world has been shaped only by what we know thus far. Alternatives exist, and science can completely change with just one new discovery. For many years, the physical world has been explained by the Standard Model, one in which matter is composed of quarks and leptons (the building blocks of atoms) and where forces are controlled by bosons, which can exist in many forms, such as photons. This model explains all the essential forces within the universe except for gravity, including the force of electromagnetism, the strong force, and the weak force. All these forces work together to construct an idea of our universe; however, this perception could change very soon.

Scientists at CERN, Europe's largest collaboration in physics research, have found evidence indicating there may be a fifth force of nature. Using CERN's Large Hadron Collider, researchers discovered particle decay that defied expectations. One of the six types of quarks, the beauty quark, typically decays into both electrons and muons. This decay is inevitable and can be observed in the hadron collider as a result of particles bumping into each other at extreme energy levels. Muons and electrons have similar properties, and similar amounts of each particle can be expected as beauty quarks decay. However, this was not the case for these experimenters, as illustrated by their paper released in March 2021. Instead of finding both equal amounts of muons and electrons as the beauty quarks degenerated, scientists found more electrons than muons. While electrons frequently resulted from the decay, muons only appeared 85 percent as often. One possible explanation for this difference in decay is a new force, not explained by any known standard-model forces, was causing electrons to occur more often.

While there is some evidence a fifth force may be acting on the physical world, researchers are hesitant to make any claims until there is substantial proof with limited error. Revision experiments currently undergoing publication show that this unusual pattern of decay holds true for beauty quarks paired with both up and down quarks, further backing this profound discovery. However, for all experiments conducted thus far, there continues to be large margins of error, preventing serious claims from being made. Until researchers are able to prove this decay model holds true across multiple variables and with limited error, they cannot move forward with new claims.

Recently, at a lab outside of Chicago, Illinois, investigators found muons behaving with another interesting property. According to the Standard Model, when acted on by a magnetic field, muons should wobble at a very specific rate. However, during the "Muon g-2" experiment carried out in Chicago, muons wobbled at a slightly higher rate than predicted by the Standard Model, providing more evidence that there could potentially be a fifth force acting on particles.

Although both laboratories carried out experiments halfway across the world from one another, both saw results in which the muon particles were not acting as expected according to the Standard Model. The lab in Chicago also indicated that more time and investigation are needed to truly prove that their findings were not experimental error, but the thread remains that both laboratories found muon particles behaving in a previously unimaginable way. Whether or not a new fifth force of nature is the cause of these phenomena remains unknown; however, there is an increasing possibility that these findings were indeed significant, uprooting the basis of physics and our entire current understanding of the natural world.

*Nature Physics* (2021). DOI: 10.1038/s41567-021-01478-8  
*Physics* (2021). DOI: 10.1103/PhysRevLett.126.141801

DESIGN BY PARKER HITT, BIOLOGY, 2024

PHOTO BY SHUTTERSTOCK

# SORRY TO BURST YOUR BUBBLE

New research disproves how bubbles break in turbulent systems

BY KYLE KIRSHEN, CHEMISTRY, 2025

**W**hat comes to mind when the word “bubbles” is spoken? Well, for many, they would see an image of backyard fun and a lot of empty cans of soap solution. But in the scientific field, bubbles actually play a much bigger role in environmental processes and engineering. Researchers in the areas of sea-air gas exchange, oil pollution, and bioreactions need to have a solid understanding of how bubbles work physically to apply that knowledge to the broader and more turbulent systems they are studying.

Information regarding bubbles in turbulent systems has remained the same for the last 70 years, with the well-accepted paradigm, or model, of Kolmogorov-Hinz. The paradigm says bubbles can only be broken by eddies of the same size as the bubble, and sub-bubble scale eddies will have no effect on them. Eddies are constantly swirling currents of water and air that are found within turbulent systems. A study by Rui Ni, an associate professor of mechanical engineering at Johns Hopkins University, and his team actively challenged the Kolmogorov-Hinz paradigm, hypothesizing that eddies of the same size are not the only factor that can break bubbles. Instead, through experiment, Ni and his team discovered that turbulence was somehow breaking bubbles quicker and more intensely than previously thought possible.

What Ni and his team realized was that in full turbulence, it was almost impossible to observe and differentiate what size eddies were directly breaking apart the bubbles. This was the primary reason that no one had been able to disprove the theory laid out in the Kolmogorov-Hinz paradigm. They figured if the bubble-sized eddies could be separated from the sub-bubble-scale eddies, they could expose bubbles to different-sized eddies individually. To experimentally initiate this study, a flow configuration was procured that possessed two identical vortex rings. This created a turbulent flow from the head-on collision between the rings. This was an ideal mechanism because the turbulence could be broken up into two separate parts. In the first part, the vortex rings expanded to create larger bubble-sized eddies. As the rings approached each other, they became unstable, broke down into a turbulent cloud, and created sub-bubbles eddies rather than larger-scale ones.

During the first part of the experiment, bubbles were deformed along the z-axis, in line with the vortices, until the moment of breakup. This mode was quite slow. Mentioned as

the primary breakup and occurring at the moment before the collapse of the two vortex rings, this method of interference was smooth and followed what Kolmogorov-Hinz’s theory said should have occurred. During the second part of the experiment, however, the bubbles referred to as “daughter bubbles” in the study because they came from the breakup of the parent bubble, experienced a much more violent and fast-paced breakup than what should have been expected. This directly disproved the Kolmogorov-Hinz foundation that states the bubbles would have been more difficult to break because of their smaller size and only weaker bubble-scale eddies attacking them. Labeled as the secondary breakup, the effect of the bubble-scale eddies was further studied to exactly gauge how much faster the breakup occurred. It was discovered that secondary breakup occurred in 5.1 milliseconds, compared to the primary breakup which occurred in 32.1 milliseconds.

“Bubbles actually play a much bigger role in environmental processes and engineering.”

While bubble-sized eddies were supposed to be the only factor that contributed to bubble breakup, this experiment showed that sub-bubble eddies had just as much to do with the bubble fragmentation process. While the phenomenon is still being studied to further understand why this happens, it is believed that larger energy in the sub-bubble-sized eddies is likely the result of the much faster breaking of bubbles.

What is clear, however, is that this study truly impacts how the scientific community will understand bubble breakup in turbulence and will affect future innovation. In fact, Ni believes that it will also “provide better predictive models for many applications such as pharmaceutical and cosmetic products because the size distribution of their final products are often sensitive to the turbulent fragmentation process.” Perhaps the next step is to use this research’s new application in that backyard bubble fun. Then again, that would probably ruin the simplicity of the whole experience.

*Nature Communications* (2022). DOI: 10.1038/s41467-022-28092-3

PHOTO BY MILENA PEREZ, ENVIRONMENTAL STUDIES, 2025



PHOTO BY HARRISON NG, BIOLOGY, 2023  
DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

# FREEZING PHARMA

BY KRISTINA KŁOSOWSKI, BEHAVIORAL NEUROSCIENCE, 2022

**D**ue to advances in both chemistry and technology, modern drug development is increasingly utilizing synthetic chemical compounds as the basis for our lifesaving and innovative drugs.

However, many of the pharmaceuticals we have today are still derived from naturally occurring compounds or organisms, and recently, there has been a renewed interest in looking to nature to find these novel compounds, especially to help solve certain issues such as antimicrobial resistance. This is due to the fact that not only have we significantly advanced our understanding of how naturally occurring compounds are synthesized, but natural compounds are often better at engaging their biological targets than their synthetic counterparts. Indeed, organisms are fighting a constant antimicrobial battle against the pathogens that threaten them, which allows humans to harness these compounds for our own benefit. Traditionally, the discovery of novel, natural compounds has centered on areas that were thought to contain a diverse array of bacteria, such as the soils in temperate regions of the world. However, recent discoveries are pointing to an interesting source for these compounds — the vast and largely unexplored polar regions of our planet.

“However, recent discoveries are pointing to an interesting source for these compounds — the vast and largely unexplored polar regions of our planet.”

Though both polar regions account for a generous amount of the total biosphere (about 15 percent), their unforgiving, extreme environments have given these regions a largely unwarranted reputation for being barren and lifeless. However, research has recently upended this notion with the discovery that cold environments, like warm environments, have variations in salinity levels and nutrient concentrations that result

in a diversity of microbial ecosystems. The Armi Project, run by researchers at the Finnish Forest Research Institute (Metla), isolated more than 500 different bacterial strains in Antarctica between 2001 and 2004. Subsequent research has determined that several bacterial strains lend promise as origins of antimicrobial agents, which are the basis of antibiotic drugs. However, this exciting field of research is not limited to only bacteria, nor just antimicrobial agents. Compounds have been discovered that could have activity in several other classes of drugs, such as antiviral, immunomodulation, and anti-cancer drugs. For example, the marine bacterium *Bacillus subtilis*, which was discovered in the mud of the Arctic Ocean, was found to produce peptides that inhibited the cells of human colon cancer.

However, as promising as some of these discoveries are, the impact that they will have on drug discovery is unknown. Much of drug discovery these days is done through a method called high throughput screening (HTS), which uses robotics to quickly and automatically test thousands of synthetic or natural chemicals for a biological target, and HTS has significantly accelerated the pace of drug discovery. Although this efficient technique can work for the testing of natural compounds, a multitude of issues arise with it — including uncertainty over who lays claim to the intellectual property rights of naturally occurring compounds. In addition, the overall timelines of synthetic drug discovery are much shorter, which makes them more advantageous than natural ones. Some scientists even take the position that natural compounds are not a viable source of drug discovery leads, simply because of how much the pace of drug discovery has increased.

Thus, despite the unexpected promise of these polar region discoveries, it is not certain that we will reap the benefits of these discoveries in the form of novel pharmaceutical agents. As the pace of drug discovery continues to accelerate, it remains to be seen whether nature will be able to keep up with the demand for innovative drugs — a demand that synthetic chemicals seem better able to satisfy.

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*Nature Reviews Drug Discovery* (2021). DOI: 10.1038/s41573-020-00114-z  
*Microbial Biotechnology* (2019). DOI: 10.1111/1751-7915.13351

# From rock to water

## Studying the origins of water on Earth

ARTICLE AND DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

**I**magine water seeping up from the solid ground beneath our feet. Then imagine water falling from the sky — not as rain, but as a giant rock crashing into Earth. Both seem like ridiculous scenarios, but they closely relate to real theories about what may have happened billions of years ago. The origins of water on our planet have baffled scientists for decades. The scalding temperatures of proto-Earth's surface 4.55 billion years ago prevented water from existing as a liquid. With the lack of an atmosphere, the young planet could not prevent water molecules from evaporating into space. Even today, scientists do not have a definitive theory. Popular theories speculate space as the origin of water, pointing toward asteroids as the main contributor. However, a recent study conducted by researchers from Nankai University and Skoltech found new evidence that may suggest a different story.

Meteorite impacts have long stood as a means for water to travel from space to Earth. These scientists found that carbonaceous chondrites — meteorites with large carbon stores that formed during the early years of the solar system — contained large amounts of water. One test conducted on the chondrites looked at their hydrogen isotopes, which are atoms of hydrogen that contain different amounts of neutrons. Unfortunately, when scientists compared the isotopic hydrogen ratios of these chondrites with that of water on Earth, they found these ratios do not match. This suggests that the chemical composition of the water from carbonaceous chondrites differs too much from Earth's water for meteorite impacts to be the main water contributor. However, meteorite studies may still help us understand the origins of water. Recent studies conducted by researchers at the University of Lorraine found that enstatite-heavy chondrites had a composition (including their isotopic hydrogen ratio) similar to Earth's mantle layer. They furthermore demonstrated that enstatite chondrites contained a large enough hydrogen composition to fill up Earth's oceans and more. Their findings have a large implication; Earth was formed from material similar to enstatite chondrites. If true, then the mantle layer, with its similar composition to enstatite chondrites, could have stored large amounts of water on proto-Earth. Perhaps the origins of water lay underneath the surface rather than extraterrestrially.

Earth has not always been separated neatly into its known layers (crust, mantle, and core). The moment in proto-Earth's age before the core-mantle separation was important

for water storage. Physicists from Nankai University and Skoltech discovered magnesium hydrosilicate compounds — which existed before the separation of the core and mantle — that could store water inside Earth. The magnesium hydrosilicates, alpha- $\text{Mg}_2\text{SiO}_5\text{H}_2$  and beta- $\text{Mg}_2\text{SiO}_5\text{H}_2$ , likely resided in abundance within proto-Earth, widely distributed across its inner terrain. Without the core, they inhabited a deeper level of Earth where higher pressure was present. The same researchers conducted tests on the compounds and found that both variants were stable at high pressures and temperatures similar to those found in proto-Earth at the time. These conditions would have allowed the hydrosilicates to stably store the components of water — oxygen and hydrogen — underground while the atmosphere of proto-Earth was unsuitable for liquid water.

However,  $\text{Mg}_2\text{SiO}_5\text{H}_2$  could not last forever. As Earth's core grew, it slowly pushed up the silicates from their residence underneath the ground. At shallower depths, further from the center of Earth, there was lower pressure, leading to the destabilization of both alpha- $\text{Mg}_2\text{SiO}_5\text{H}_2$  and beta- $\text{Mg}_2\text{SiO}_5\text{H}_2$ . As a result, the hydrosilicates decomposed into magnesium silicate ( $\text{MgSiO}_3$ ), magnesium oxide ( $\text{MgO}$ ), and water ( $\text{H}_2\text{O}$ ). Molecules of water would slowly diffuse to Earth's surface where it would eventually shape the biosphere—allowing the emergence, survival, and evolution of life.

While not all scientists agree with how water came to reside on Earth, with the silicate theory being one of many, they agree that water's presence heavily influences Earth's internal activities. Its ability to soften (or even break apart) rocks, lower their friction and decrease their melting temperatures helped generate magma as well as impact the movements of tectonic plates and consequent earthquakes. Deeper in Earth, water reacts with iron to form iron oxides and pyrites; dissociation of these pyrites was believed to have contributed to the oxidation of the atmosphere — an important evolutionary event for life. Needless to say, the origins of this molecule could also be considered the origins of life on our planet, shaping the terrain and the nature around us.

*Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.035703  
*Science* (2020). DOI: 10.1126/science.aba1948  
*National Science Review* (2020). DOI: 10.1093/nsr/nwz071  
*Science* (2020). DOI: 10.1126/science.abc1338

# REHABILITATING THE HARBOR OF SHAME

## Past and present solutions

BY JEFFREY PAN, ENVIRONMENTAL & SUSTAINABILITY SCIENCES, 2024

**O**riginally dubbed as the “dirtiest harbor in America” by George Bush in the 1980s, Boston Harbor was a cesspool of toxic sewage and wastewater. Large amounts of pollution were constantly dumped into the harbor, damaging marine ecosystems alongside the Massachusetts coastline and causing extremely poor water quality. If people were to swim in the water, the poor state of the harbor had the potential to cause *E. coli* bacterial poisoning. Calling for drastic change, a U.S. district judge ordered the clean-up of the harbor in 1985. This \$3.8 billion project has had profound effects on the Boston-area environment. Pollution prevention continues today, supported by purposeful water treatment engineering.

The most detrimental aspect of the harbor pollution was nitrogen within the sewage being poured into the harbor. In saltwater, nitrogen is a limiting nutrient, meaning the growth of organisms depends on the concentration of nitrogen. With increased nitrogen concentration from sewage, organisms such as algae fed and grew exponentially. This overload of algae caused algal blooms, where algae populations grew out of control and began to create hypoxic conditions within the water, choking off other organisms of oxygen. These algal blooms caused mass deaths of organisms throughout the entire ecosystem, effectively debilitating the marine environment of Boston.

Without a stable and healthy marine environment in Boston, many of the ecosystem services—or positive benefits for people provided by an ecosystem—from the harbor were lacking. Provisioning services, or benefits that can be taken from nature by humans, such as fish populations, were decimated by heavy pollution. Regulating services are processes that maintain natural ecosystem cycles. One example of the loss of these services is the stifling of plankton photosynthesis by cloudy water. Finally, supporting services, which help create other ecosystem services, such as a healthy water cycle, are all lost to the sludge being dumped into the water. Without such services, the entire environment suffers.

To restore the harbor, the City of Boston invested \$3.8 billion into the Deer Island Wastewater Treatment Plant and created the Massachusetts Water Resource Association (MWRA) to maintain it. This old island housed antique World War II bunkers and prison cells and was an optimal location for the cleanup of the harbor. Completed in 1996, the Deer Island treatment facility now

protects the harbor from the pollution of the city and 42 greater Boston communities.

Presently, the process of cleaning the sewage at Deer Island is carefully engineered. First, the plant receives the sewage and wastewater from four main underground pipes from the city and surrounding communities. It is then sifted through grit chambers to separate larger particles for off-site disposal. The remaining flow is directed toward primary treatment clarifiers, where the sludge and scum are separated from the primary wastewater. While the water is being treated and sanitized, the separated sludge is centrifuged, compacted, and “digested.” Microorganisms are employed that break down sludge into methane gas, carbon dioxide, solid organic byproducts, and water. Such methane gas is then used to heat buildings on-site. Finally, the digested sludge is sent out to become fertilizer.

After this process, about 50 percent of all pollutants are removed, including suspended solids and pathogens. The separated wastewater is then run through a series of treatment mixers, reactors, and clarifiers to remove non-settleable solids. To remove such solids, MWRA utilizes microorganisms to break down organic matter, increasing the amount of pollutants removed to 85 percent. Sodium hypochlorite, which kills the remaining bacteria, is used alongside sodium bisulfate, a dechlorinating agent, to finalize the sanitation process. This results in a completely sanitary product that is ready to be discharged into the bay. The plant uses 50 diffuser pipes to promote rapid and thorough mixing, protecting the water quality for organisms living within the harbor.

The impacts of the cleanup have been dramatic. The cleanliness and overall water clarity of the harbor has increased and wildlife has been able to thrive under these new, cleaner conditions. The initial investment of \$3.8 billion has yielded ecosystem services valued between \$30 billion and \$100 billion, according to a study run by the Woods Hole Oceanographic Institution in Woods Hole, MA. Recreational activities and cleaner beaches have made Boston a more attractive city, and the clean-up methods enacted by MWRA and the Deer Island plant have allowed many people to enjoy Boston for what it is: a gem destination of America.

*Frontiers in Marine Science* (2018). DOI: 10.3389/fmars.2018.00478

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

PHOTO BY ERIC KILBY VIA FLICKR



# MARINE SNOW: HOW DEEP-SEA SNOW STORMS COOL THE PLANET

BY NIKKI SUZUKI, ECOLOGY &amp; EVOLUTIONARY BIOLOGY, 2023

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING, 2024

**S**now falls 24 hours a day in the depths of the oceanic twilight zone. White flurries saturate the marine landscape, appearing in all different shapes and sizes. Unlike crystallized water droplets that fall from the sky, marine snow is made from a variety of different organic compounds. It sustains life in the deep ocean where sunlight doesn't penetrate and plays a key role in the cooling of our planet. What is marine snow, and why is it important to study amidst global oceanic change?

Microscopic plankton species play a key role in marine ecosystems, and we can look to them to understand more about the marine snow phenomenon. From absorbing carbon dioxide through photosynthesis to providing a foundation for the marine food web, plankton are vital to maintaining the health of the ocean. When they die, they fall down the water column and combine with other decomposing plants, animals, fecal matter, dust, and sand in the top layers of the ocean. As this debris accumulates, it aggregates into larger "snowflakes" that can reach up to several centimeters in diameter. When it hits the shallow ground of coastal habitats, bottom dwellers like crabs and mollusks quickly use it for food. In the open ocean, fish and other filter-feeders dine on the organic material they separate from the waste. The last consumers of the 'snowflake' leftovers include deep-sea marine life, such as sea cucumbers and vampire squids.

**“Even small changes in the sequestration of carbonate carbon into this enormous sink are important for understanding net changes in atmospheric carbon dioxide and climate.”**

However, this doesn't mark the end of the marine snow's journey. After weeks of falling, the remaining snow reaches the bottom of the deep-sea and accumulates into thick sludges of carbon-rich "ooze." In some parts of the ocean, this ooze is hundreds of meters thick and millions of years old. The pressure of the deep ocean compacts this ooze into stiff carbonate structures that lock in carbon and prevent it from cycling back into the ecosystem. The 350-foot tall White Cliffs of Dover in the United Kingdom reveal what this buildup can create over millions of years.

In 2018, researchers at the University of Sydney developed a computer model of marine snow accumulation over the past millennia. They found that carbon sequestration by these colossal structures have played a key role in cooling the planet to a hospitable environment for life to thrive. Lead researcher Adriana Dutkiewicz says that "even small changes in the sequestration of carbonate carbon into this enormous sink are important for understanding net changes in atmospheric carbon dioxide and climate." They estimate

that over 200 million tons of marine snow are deposited and stored in the deep sea annually.

However, this long-standing phenomenon is now being threatened by a variety of harmful human activities. In recent times, marine snow has carried down more than just oceanic waste. Research from the University of Exeter found that marine snow is a primary route for the introduction of microplastics into deep sea ecosystems. Additionally, as carbon dioxide emissions have caused a 30 percent increase in oceanic acidity over the past 200 years, the capabilities of marine snow to suppress atmospheric carbon have been greatly stunted. Greater oceanic acidity can dissolve calcium carbonate structures and reduce the abundance of plankton and marine species at the ocean's surface, which are key elements in the formation of marine snow. Learning more about how the changing climate affects the carbon-capturing abilities of marine snow are important next steps in this field.

Scientists around the globe are working together to learn more about the composition of marine snow, how it impacts the carbon cycle, and its exact ecological functions. The answers they find will help us to preserve the health and longevity of our oceans amidst a changing climate.

*Geology* (2019). DOI: 10.1130/G45424.1

*Science* (2019). DOI: 10.1126/science.aau5153

*Environmental Science and Technology* (2018). DOI: 10.1021/acs.est.8b01000



PHOTO BY SHUTTERSTOCK

# Predicting weather with machine learning instead of traditional numerical methods

BY AANCHALIKA CHAUHAN, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY KAI GRAVEL-PUCILLO, ENVIRONMENTAL SCIENCE, 2022

**E**veryone has experienced the unmistakable first drop of a rainstorm that no one expected in

the middle of a bright and sunny day. While the weather app mentions nothing but clear skies, people suddenly find themselves running to find cover before the downpour ensues. The truth is that hour-to-hour weather is notoriously difficult to predict, which can sometimes lead to inaccurate forecasts, due to constant changes in atmospheric variables.

Modern-day weather forecasting began in 1922 upon Lewis Fry Richardson's publication of "Weather Forecasting by Numerical Process" in the *Cambridge University Press*. In his work, Richardson theorized that meteorological variables, such as atmospheric pressure, measured at certain latitudes, could be used in differential equations to predict weather change. However, Richardson's idea of using mathematical models to forecast weather was initially dismissed due to the long hours it would take just to predict one day's weather. According to "Encyclopedia Britannica," "the main drawback to his mathematical technique for systematically forecasting the weather was the time necessary to produce such a forecast." Calculating 24 hours of a weather forecast usually took three months.

After the introduction of computers in the 1940s, Richardson's idea was revisited since now computers could almost instantaneously solve these mathematical equations. Today, this method is known as

traditional Numerical Weather Prediction (NWP) and is the basis for almost all weather predictions. NWP is known for its strong accuracy in broad long-term predictions, but when it comes to specific hour-by-hour forecasts, NWP is limited in predicting the weather.

With recent development in artificial intelligence, meteorologists are looking at a technology called Graph Neural Networks (GNNs). GNNs are groundbreaking as they have the potential to develop accurate hour-to-hour forecasts for the following six hours. The system accomplishes this by first collecting specific data about the current weather and then analyzing similar past weather patterns to make a prediction. GNNs can use over five million physical variables relating to atmosphere pressure levels to define a weather pattern. Additionally, GNNs can take into account the specific shape of the Earth and produce multi-resolution models.

Well, how exactly do GNNs work? First, meteorologists and researchers train GNNs under two main sets of data so the machines know past weather patterns. The first set is

known as the ERA5 analysis. The ERA5 is a fifth-generation reanalysis of the weather that provides an hourly estimate of weather variables across a range of climates for the past 40 years. The ERA5 can provide a variety of data, but the main extracted variables are temperature; geopotential height; specific humidity; and the eastward, westward, and vertical components of the wind. To maximize efficiency, GNNs download every 3 hours of ERA5 data from 1979 to 2021. The second set of data GNNs use is NOAA's Global Forecast System (GFS) data from 2021. This data set is simply the collection of weather forecasts from the year 2021. Like the ERA5, the same six variables that were obtained from the ERA5 are extracted from GFS for every three hours.

Once GNNs have been trained, three components of the GNN model — the encoder, the processor, and the decoder — process this information to make weather predictions. The encoder begins the prediction by translating current weather measurements from a latitude-longitude grid and placing them onto a spherical grid. Next, the processor reads the spherical grid and compares these measurements to data from the ERA5 and GFS to pinpoint instances where past weather variables were similar to the current weather variables. The decoder then places past variables onto a latitude-longitude grid and analyzes how these past weather patterns under similar conditions played out to predict a six-hour weather change. Compared to the equations Richardson solved in the mid-1900s, GNNs perform this process notably quickly, averaging 0.04 seconds to create a six-hour model and 0.8 seconds to create a five-day forecast.

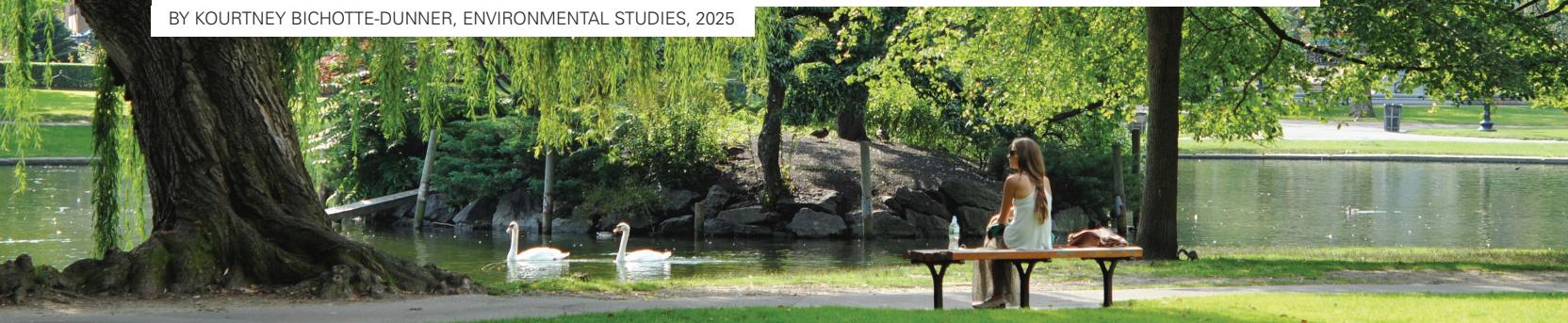
GNNs have a promising future beyond creating weather forecasts and have the potential to create predictions in climate change. With rising temperatures and changing climates, GNNs could potentially warn us of dangerous effects regarding global warming. And who knows? The weather outside today could predict the weather 10 years from now.

*International Journal of Environmental Science and Development* (2010). ISSN: 2010-0264. *Physics.ao-ph* (2010). arXiv: 2202.07575v1

# Could there be indigenous sovereignty for plants?

Problems of urban greenspaces from the overuse of cultivated and nonnative plant species

BY KOURTNEY BICHOTTE-DUNNER, ENVIRONMENTAL STUDIES, 2025



**A**s spring comes around, the Boston Public Garden boasts eye-catching colors of roses, tulips, and daffodils. Some of these plants, however, are not native or have been manipulated by humans for centuries to achieve their distinctive traits.

These plants are cultivars. Cultivars are variants of wild plants, meaning they are not naturally occurring and require human intervention in order to exist. One way of producing cultivars is by using selective breeding — artificially choosing desirable traits in the plant species — and rapidly reproducing them through asexual reproduction, or cloning. Another way is cross-breeding two plant species, also known as hybridization, then cloning them. Cultivars are so abundant that wild plants seem to be rare.

Take the rose for example. Unlike modern roses, wild roses tend to be smaller with a single layer of five petals and light pink colors. Originating in China, they were cultivated after the Han Dynasty 1,500 years ago based on ancient paintings and artworks.

From then on, roses were further cultivated and spread to Europe and the Middle East, ultimately making their way across the globe. Today, there are tens of thousands of varieties of roses including hybrids. The terms “North American wild roses” or “native roses” refer to naturalized varieties, meaning they have the ability to grow and reproduce new generations without human aid, even though they are not native to the area.

While these cultivars attract humans, they do very little to attract pollinators and other insect species. A University of Melbourne urban greenspace study found that indigenous and native plants support native insect communities better than nonnative plants. Within the study, indigenous plants produced the highest species richness to plant ratio because they promoted more biodiversity.

Combining the terms “native” and “cultivar,” nativars are cultivated varieties of wild native plants. Studies from botanical gardens have looked at pollinator preference of different traits in nativars. Nativar shrubs with purple or multicolored leaves are not as attractive to caterpillars as native shrubs with green leaves. In other observational studies, researchers found that accessibility of the pollen is predicated on the shape of the

flower and can deter or allure pollinators. For example, bees love open bowl-shaped flowers, like daisies, because they can quickly and easily collect nectar and pollen versus the tightly packed ruffling petals of double flowers.

Many urban green spaces and street plantings do not support native insect populations nor reflect indigenous plant species. Instead, there is overuse of exotic plants. For example, trees in Boston Public Garden are composed of 25 exotic tree species, two of which are cultivars and others originating in Europe and China. There are only 15 indigenous and native tree species.

When determining the source of these urban plantings, many plant nurseries specialize in exotic plant species. Native plant nurseries are niche and harder to access. Even though there has been a recent increase in demand for native plants, the market value is not reflected in plant nurseries. Furthermore, the majority of plant nurseries use cloning as their primary plant propagation method, leading to decreases in genetic diversity.

**Biodiversity is needed to make Boston and other cities climate-resilient by adapting to ongoing climatic changes.”**

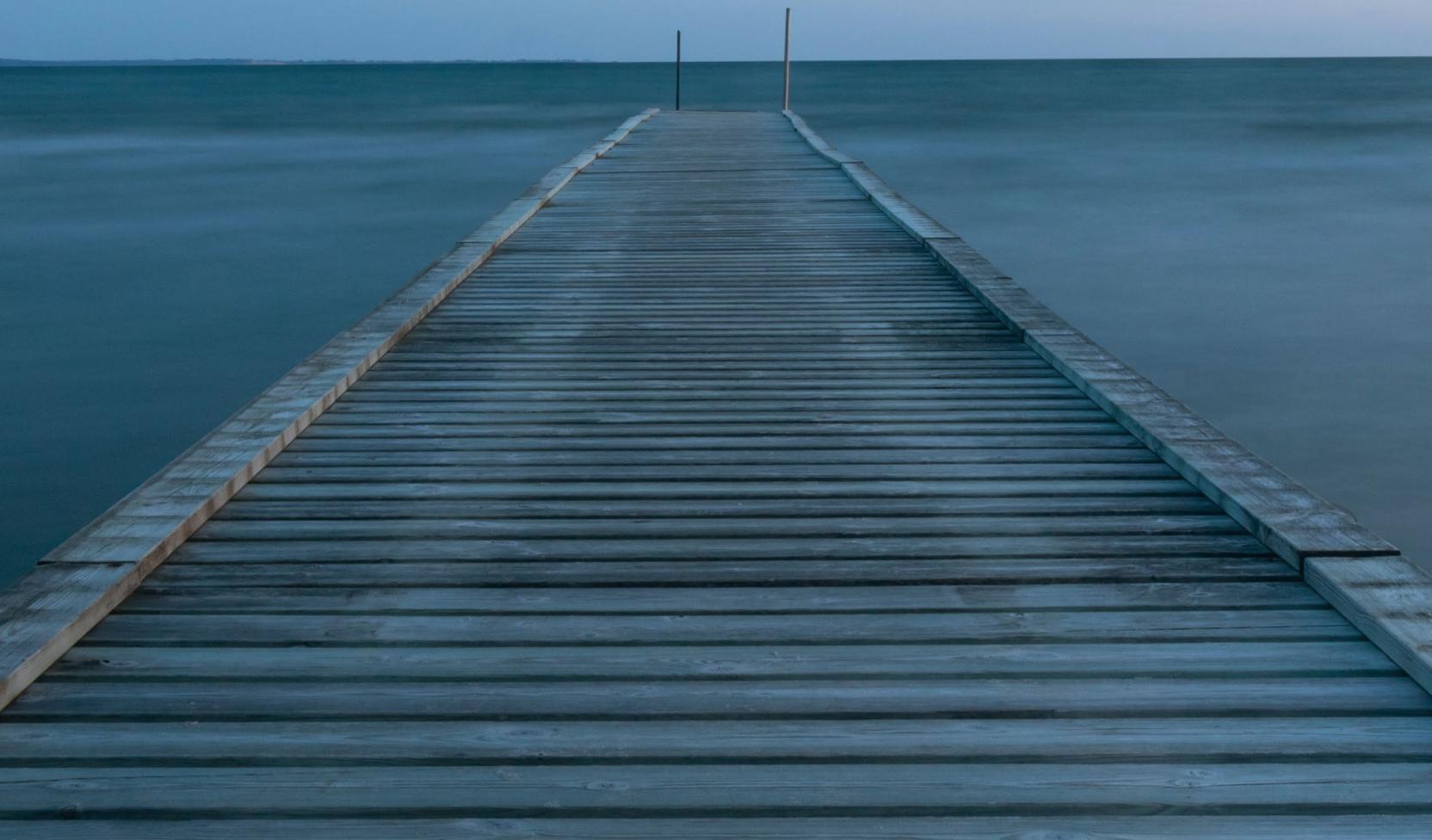
Coupled with the overplanting of single tree species, all of this contributes to our lack of biodiversity within urban green spaces and street plantings, making our communities susceptible to disease and climate change. These results are seen with Dutch elm disease — the global spread of a fungus that killed numerous elm trees — and currently, the emerald ash borer, an invasive insect species infecting North American ash trees.

With more genetic and biodiversity in urban landscapes, this would be a different story. Biodiversity is needed to make Boston and other cities climate-resilient by adapting to ongoing climatic changes.

This is not to say, though, that we should become native purists. There are times when cultivars are better adapted to our changing environment than native plants. However, instead of cultivating plants solely for ornamental purposes, we should consider their nutritional value and ability to support insect populations, which will improve urban landscaping for us and for the environment.

Docks such as this one in the Danish countryside not only provide access to water-related activities for humans, but they also can provide habitats by acting as artificial reefs. Current research is looking into documenting the ecological impacts of human-made structures and adapting them to better support ecological communities.

PHOTO BY GUS MUELLER, MECHANICAL ENGINEERING, 2023



# SPLEEN OR SCUBA TANK?

## How we hold our breath for longer underwater

ARTICLE AND DESIGN BY LILY GARRETT, BIOCHEMISTRY, 2025

**T**he Bajau people of Southeast Asia spend 60 percent of their workday underwater. Commonly known as the Sea Nomads, the Bajau population has survived for over 1,000 years collecting and hunting food through underwater diving. Their extraordinary breath-holding capabilities seem almost humanly impossible. When the brain experiences hypoxia — the deficiency of oxygen in bodily tissues — it will eventually cease to function, and the body will move dangerously further away from a stable state. It seems logical to assume that Sea Nomad divers who spend their days submerged in water would face physical damage from hypoxia, and yet they don't. The reason why? The diving reflex.

The diving reflex is a set of physiological responses in mammalian species induced by water submersion. The bodily reactions that follow submergence underwater include bradycardia, apnea, increased peripheral vascular resistance, and contraction of the spleen — terms that describe the body's methods of reducing non-essential oxygen consumption or providing an oxygen boost. These processes are vital, as they protect the body from entering a threatening hypoxic state. When a human begins to hold their breath underwater, the diving reflex kicks in instantly. The body is keenly aware of its entrance into an aquatic environment — a capacity demonstrated magnificently by endurance divers like the Bajau people, whose underwater lifestyle is complimented by an uncommonly excellent diving reflex.

Spleen contraction, one of the major oxygen-boosting physiological reactions of the diving reflex, has been studied in diving seals such as the Weddell Seal. In this mammalian species, larger spleen mass correlates with the seals' abilities to dive and hold breath for longer. Splenic mass is a genetic human trait that seems to logically correspond with diving reflex capabilities, but there are minimal scientific studies that establish a genetic basis of the diving reflex. Hence, a compelling question is raised: is the diving reflex purely a result of environmental factors, or can it be traced to human genetics?

"Mammals are obligate air breathers but have evolved to exploit many different environments," shared Donald O'Malley, associate professor of biology at Northeastern University. The Sea Nomads' livelihood has evolved to rely on their ability to dive, hunt, and gather under the sea. They have lived this aquatic lifestyle for over 1,000 years, "which is a great amount of time for small adaptations to occur," O'Malley said. "Random gene changes occur

constantly, and when a favorable gene change occurs, it will propagate through a population [and] provide some sort of competitive advantage."

For endurance divers, genetics must play a role in their enlarged spleens. The Sea Nomads have significantly larger spleens than humans in non-diving populations, including nearby populations in Southeast Asia. In 2018, a comparative genomic study of the Bajau with a neighboring population named the Saluan identified genetic variants associated with spleen size and found that genes that increase spleen size are naturally selected for in the Bajau population. It is possible that the Bajau's diving lifestyle may instigate a plastic response and cause their spleens to enlarge, yet, the statistically significant results of the study suggested a major physiological difference between the Bajau and Saluan that is not explained only by environmental influence. "It's tempting to make a connection to genetics," O'Malley said. The Sea Nomads have spent their days diving underwater for over a millennium, hence, it can be inferred that their diving reflex is attributed to both genetics and learned behavior. The average human may be capable of prolonging their underwater breath-holding with practice, but not to the masterful level of the endurance divers. "This fits with the idea that there is some genetic contribution to the diving reflex," O'Malley said.

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The nuances of the diving reflex demonstrate the fascinating capacity for the human body to protect itself and conserve vital resources.”

The nuances of the diving reflex demonstrate the fascinating capacity for the human body to protect itself and conserve vital resources. For Sea Nomads adapted to an underwater existence, their large spleen, plentiful red blood cells in their bloodstream, and readily-available oxygen reserves all kick in to supply ATP and oxygen boosts when immediate oxygen resources are expended. In return, the degree of hypoxia that the Sea Nomads will face is intermittent to mild: their diving reflex allows their tissues to remain oxygenated. For the rest of humanity that isn't as adapted to tolerating low oxygen levels, mammalian physiology still impressively works to maintain oxygen levels through complex, regenerative diving reflex reactions.

# Love-bugs and toxic relationships

BY REBECCA MCCONNELL, HEALTH SCIENCE & COMMUNICATION, 2024

**I**t's February — meaning relationships are on display everywhere. They're seen on your Instagram feed, in campaign ads for your favorite brand, and even in the Curry Student Center. But whether you have a significant other or not, you, too, are in quite the intimate long-term relationship.

As you're reading this, there are trillions of microbes teeming in your stomach and gastrointestinal tract. These bugs are working diligently to digest your last meal and up your immune defenses, and they have been for quite some time. In fact, your gut symbiosis has been in the works from the day you were born.

But what happens when this relationship turns toxic? When a relationship once marked by mutual benefit becomes a source of constant agony?

Dysbiosis — a change in microbiota composition that has harmful effects on the host — can happen for a number of reasons. According to Jason A Hawrelak and Stephen P Myers of the University of Tasmania, "factors such as antibiotics, psychological and physical stress, and certain dietary components [have all been found to] contribute to intestinal

dysbiosis," but there's still much to be discovered. Ok, we all get it, gut health matters. Each day, we pop probiotics or eat some yogurt hoping to nourish our guts so that we might live happily ever after. But what if your gut is too far gone? What if — like a crummy high school boyfriend — you and your gut were just built to fall apart?

For individuals with a *Clostridium*

**"**Each day we pop probiotics or eat some yogurt to nourish our guts so that we might live happily ever after."

*difficile* infection (*C. diff*) or inflammatory bowel disease (e.g., Crohn's and ulcerative colitis), gut relationships can't be fixed with an 'I'm sorry I love you' or a kombucha.

With that said, fecal transplantation — which is still emerging and, might I add, very unorthodox — could serve as a possible solution. During the procedure (which might also be referred to as "bacteriotherapy"), a healthy donor stool is transplanted into a sick patient via colonoscopy. For your sake, I'll spare the details, and, because it's February and

I'm feeling festive, I'll opt for a timely analogy instead. Think of fecal transplantation as a fresh start with a new boo — or, might I say, a new poo.

Ed Yong, a science journalist and Pulitzer Prize winner, refers to fecal transplants as "ecosystem transplants" because of their unique capacity to reset the microbiota and purge the gut of harmful bacteria. The procedure has proved especially promising with respect to the treatment of *C. diff*; results from a randomized trial done in the Netherlands concluded a cure rate of 90 percent for donor feces infusion, compared to 60 percent for antibiotic therapy. Experimental research is still being done to determine if fecal transplants might provide similar relief to other patients with serious gastroenterological issues — including Crohn's disease and certain forms of colitis — but only time will tell.

Whether it be a new match on Tinder or Facetime calls to a long-distance significant other, technological advancements have enabled new relationships to form and old ones to flourish. So why not our relationships with our guts?

DESIGN BY EVELYN MILAVSKY, CELL & MOLECULAR BIOLOGY, 2025

PHOTO BY SHUTTERSTOCK

# Toxoplasmosis

Can you catch crazy cat lady syndrome?

BY EMMA TUSUZIAN, PSYCHOLOGY, 2023

DESIGN BY PARKER HITT, BIOLOGY, 2024

**P**opular culture has birthed an archetype of the crazy cat lady: a middle-aged woman with more cats than people in her life, unable to properly care for them and her home. Seen as both offensive and humorously affectionate, this often disheveled or reclusive image has brought into question the legitimacy of these behavioral patterns. As science intervened, news stories of “crazy cat lady syndrome” became used to refer to links between a parasite, psychiatric disorders, and behavioral changes in humans. Could they reveal the truth about this long-held stereotype?

The single-celled parasite *Toxoplasma gondii* (*T. gondii*) is one of the world’s most common parasites, infecting warm-blooded animals including humans and cats. *T. gondii* does not usually impact healthy adults unless immunodeficiency or pregnancy is involved. Still, the Centers for Disease Control and Prevention considers toxoplasmosis, a disease resulting from *T. gondii* infection, as “one of five neglected parasitic infections of people,” with more than an estimated 60 million in the U.S.

According to the Cornell Feline Health Center, *T. gondii* cycles through definitive hosts, where the parasite reproduces and forms eggs (oocysts); and intermediate hosts, where it clones itself. These clones cluster inside cysts, or sac-like pockets of membranous tissue. Notably, felines are the only definitive hosts for *T. gondii*, becoming key in their life cycle. Upon a cat’s ingestion of contaminated raw meat, the parasite is released from the meat’s cysts into the cat’s digestive tract, where it produces millions of oocysts. Eggs are shed through feces as early as three days after consumption with the ability to survive for over a year in their environment. Some of the *T. gondii* released can penetrate the host’s intestinal wall and multiply as a tachyzoite, a faster-growing form, after which they take the dormant bradyzoite form, a slower-growing parasite found in tissue cysts of muscle and central nervous system cells. In *Foodborne Parasites in the Food Supply Web*, researchers write that this form allows *T. gondii* to maintain its infection until eaten by their next host.

Humans and other animals are intermediate hosts of *T. gondii*, becoming infected by eating cysts or oocysts. *T. gondii* most often calls a human “home” when one consumes undercooked contaminated

meat or is exposed to infected cat feces. This is much more likely in an unkempt home overwhelmed with cats, especially if they roam outdoors. Within a few days, contact with areas like litter boxes or gardens may lead to ingestion of infectious oocysts, leading to the creation of further cysts within the host’s body. These cysts become permanent residents in intermediate hosts and are infectious to cats, people, and other intermediate hosts consuming the tissue. For someone with many cats, their likelihood of exposure is greater than that of an average cat owner, which could be the speculated cause of the “crazy cat lady” stereotype.

This stereotype may originate from the behavioral changes toxoplasmosis has been observed to produce in rats, especially since parasites can also affect human brains. In 2000, researchers at the University of Oxford suggested *T. gondii* manipulated rats’ perception of risk in the face of predators, sometimes even turning this instinctive avoidance into attraction. Infected rats in the study became drawn to the smell of cat urine, compromising their safety but likely allowing *T. gondii* to continue reproducing in its definitive host when inevitably eaten by a cat. However, a more recent study published in 2020 analyzed *T. gondii*-induced changes in mice and provided evidence that the parasite “lowers general anxiety in infected mice, increases explorative behaviors, and surprisingly alters predator aversion without selectivity toward felids,” defying the idea that they only lose fear of cats.

Since the release of the first study linking human behavior to toxoplasmosis in 1994, over 200 papers have been published on the topic, producing results as heterogeneous as those of rodent behavior studies. As a 2020 literature review reflects, *T. gondii* is unique for its ability to cause “long-term latent infection in the [central nervous system] of humans and rodents.” With many study differences and limitations, underlying mechanisms of the *T. gondii* infection are still unclear. This review concludes that “if *T. gondii* influences human behavior or disease, the effect is likely subtle” and that genetic background plays a role, opening potential markers for those at higher risk of behavior change. Despite this parasite’s invasive nature, science is ultimately hesitant to call *T. gondii* the reason for “crazy cat ladies.”

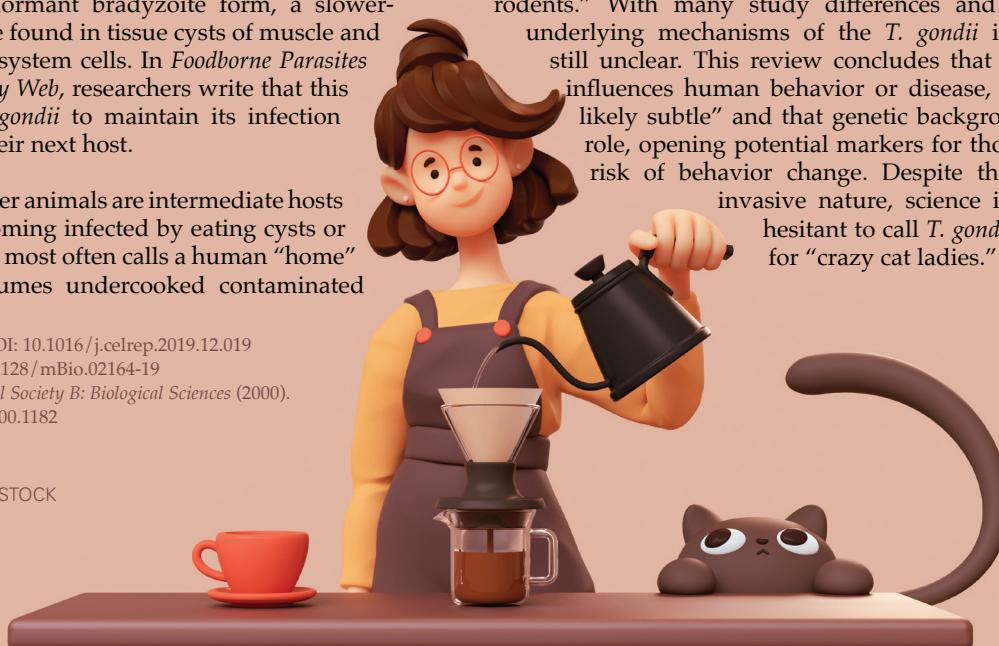
*Cell Reports* (2019). DOI: 10.1016/j.celrep.2019.12.019

*mBio* (2020). DOI: 10.1128/mBio.02164-19

*Proceedings of the Royal Society B: Biological Sciences* (2000).

DOI: 10.1098/rspb.2000.1182

PHOTO BY SHUTTERSTOCK



A black racer snake raises its head to peek above the grass. There are many misconceptions made about snake vision, like “they have poor eyesight” or “they see with their tongues.” In reality, snakes have extensive diversity in eye anatomy. Some species have a sensitivity to ultraviolet light, which allows them to see in low-light conditions. Others have a built-in set of sunglasses — an extra lens on the eye that filters sunlight and sharpens images during the day.

PHOTO BY IAN HAY, BIOENGINEERING, 2023



# Communicating through (waggle) dance

BY ANNA DUCROSET, BIOCHEMISTRY, 2025

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

If someone were to ask you the directions to a store, you may be able to explain the directions verbally, point to the general location, or even show them the location on a map. These abilities are largely restricted to humans, but other organisms have developed the ability to communicate in unique ways — notably, the honeybee.

The honeybee's unique style of communication is well known, as most that have had contact with members of the honeybee's genus, *Apis*, have seen the distinct "waggle dance." The characteristic shaking and dancing and spinning of bees, the figure eights, and vibration of wings is recognizable to many as the way in which bees communicate. Despite familiarity with the waggle dance, there is still plenty unknown about the science behind this movement.

University of Munich researcher Karl Von Frisch proposed the idea of a complex bee language and communication system in 1973. Prior to his experimentation, it was commonly believed that insects were colorblind. Von Frisch refuted this with the idea of adaptation: Why would flowers develop beautiful flowers if not to attract pollinating insects?

Von Frisch's first experiments with bees tested their "color sense." He placed a colored sheet of paper among gray papers, and he placed a syrup on the colorful paper. The bees he experimented with learned to associate the color with syrup, showing that bees have some sort of color sense. Interestingly, he also observed that if a singular bee noticed there was syrup on the plate, they would return to the hive, and a swarm of bees would arrive to enjoy the syrup. This observation introduced the idea of bee colony communication.

After further observation, Von Frisch noticed bees dance to communicate the location of food and other resources. Modern scientists have built upon this foundation and have researched the intricacies of this discovered waggle dance. The waggle dance is modified depending on the abundance and location of the food source. If there is a rich food source, the dance is more likely to occur and with more fervor. The observed dance is substantially shorter when the food is closer and much longer if the food is further.



Bees also use the odor of a feeding site to pinpoint the precise location, as without the odor details, bees would not know where they were truly looking. This odor information is communicated through the scent that remains on the bee after they visited the food site. Over time, members of a colony begin to recognize and even prefer specific scents. Odors within the colony may lead to young bees growing up to seek out foraging areas with a specific scent.

Bees don't always use the information provided from the bee dance, but instead sometimes rely on their own past experiences. In a paper published in *Molecular Ecology*, researcher Anissa Kennedy and her team aimed to elucidate the factors that determine if bees will use the information provided in the waggle dance. This paper describes that age and experience determine if a bee will use social information to forage, with more experienced foragers relying more on their past forages. The paper goes on to summarize that the differences in methods of foraging can be explained by various molecular signals.

Kennedy and her team compared the genes of bees that use social information from bee dances versus bees that rely on their own prior experience. They predicted there would be differences in RNA transcripts among bees that forage with different methods. While the study found that there were no recorded transcript differences in the brain, they found there were genetic differences in the antennae. This indicates that variation in sensory perception determines if the bee will use social information or their own private information.

Despite the growing body of research pertaining to bee behavior and communication, there are still many uncertainties regarding the true cause. For now, it seems that the combination of intricate dance moves and a strong odor clinging to the bee's body allows for bees to communicate. Imagine if you asked someone where the train station was and they started making figure eights ... maybe now you would know what they're trying to say.

*Journal of Experimental Biology* (2017). DOI: 10.1242/jeb.142778  
*Molecular Ecology* (2020). DOI: 10.1111/mec.15893



# This new screen may promote better outcomes for hypertensive diseases during pregnancy

BY CHRISTINA CURRAN, BIOCHEMISTRY, 2023

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

**T**his year in the United States, between 5 and 10 percent of pregnant people will face a hypertensive disorder related to their pregnancy. Although these conditions will often subside after giving birth, the most severe complications can lead to death of the fetus or the mother, according to *Contemporary Ob/Gyn*. The most common of these disorders is called preeclampsia, which presents as elevated blood pressure and protein levels (proteinuria) both during pregnancy and for some time after giving birth. If this isn't monitored, it may lead to eclampsia, a more severe progression of the disease characterized by frequent seizures in addition to worsening of the preeclampsia symptoms.

At times, it has been difficult to diagnose these diseases in a timely manner. Symptoms may not present until late in a gestational period, and it is also necessary to receive consistent and reliable clinical monitoring. It is crucial to make a diagnosis as soon as possible so that patients can be monitored and treatment can be administered accordingly.

**“**This potential molecular diagnostic may enable doctors to diagnose this disease well before symptoms begin.”

Another challenge to diseases like preeclampsia is that there is no guaranteed treatment. The general consensus among medical providers is that the best treatment option currently available is delivery of the baby. Symptoms can be monitored, diet and lifestyle changes are recommended, and in more severe cases, magnesium sulfate may be administered to alleviate seizures. However, these are generally the only options, and treatment research is difficult given the obvious ethical constraints of testing therapeutics on pregnant people, as stated in a 2016 paper from *Advances in Clinical Chemistry*.

Enter: RNA. The once overlooked sibling of DNA has recently been involved in key biomedical developments, including gene editing therapies and the COVID-19 vaccines. It may also extend a hand in providing more accurate diagnoses and monitoring of hypertensive diseases. Already, RNA plays a key role in developmental pathology, identifying fetal blood genotypes and common chromosomal abnormalities. Now, a 2022 *Nature* transcriptomic study, using an RNA library of over 1,800 patients, reveals that cell-free RNA (cf-RNA) displays signature patterns of normal and abnormal pregnancies. In other words, the researchers discovered the RNA patterns of pregnancy progression by analyzing the cf-RNA from a single, noninvasive blood draw.

This potential molecular diagnostic may enable doctors to diagnose this disease well before symptoms begin so that they can advise at-risk patients. Consequently, this tool has the potential to alleviate a facet of racial and socioeconomic disparities within maternal healthcare. Many Black patients and those with lower socioeconomic status are less likely to be accurately diagnosed, according to the American Academy of Family Physicians. As a result, they are more likely to suffer from worse complications during their pregnancies. This *Nature* study included the most diverse maternal cohort population to date and found that the pregnancy profiles and cf-RNA signatures are highly generalizable to all races and ethnicities. This means that an objective diagnostic is available for those who are most vulnerable to the severest disease.

In addition to the diagnostic tool, this transcriptomic study also uncovered some potential biomarkers for the onset of disease. Some confirmed previous speculations and genetic analyses, like the upregulation of *PAPPA2*, which is a key regulator of placental development. Other genes like *SNORD14A*, *PLEKHH1*, and *MAGEA10* are still being explored to determine their function. They likely hold key information about how maternal and fetal genetic material collaborate during pregnancy.

In exploring RNA data from early stages of gestation, this study took a novel approach in mapping preeclampsia disease pathology. It exposes new molecular mechanisms that previous analyses of confirmed cases failed to discover. This model gives hope for reduced mortality, as well as a better and more equitable diagnosis paradigm for this disease. There's promise that RNA transcriptomics can elucidate other diseases in the future.

*Advances in Clinical Chemistry* (2016).

DOI: 10.1016/bs.acc.2015.12.004

*Nature* (2022). DOI: 10.1038/s41586-021-04249-w

PHOTO BY SHUTTERSTOCK



# VETERINARY FORENSICS: SENDING CRIMINALS TO THE POUND

1



BY RACHEL LINES, BEHAVIORAL NEUROSCIENCE, 2022

DESIGN BY KAI GRAVEL-PUCILLO, PSYCHOLOGY, 2022

**N**earby a municipal landfill in Oregon, several witnesses discovered the bodies of eight incapacitated eagles. Flightless and convulsing, these animals appeared near death and were retrieved by National Fish and Wildlife Forensics Laboratory staff. One eagle was confirmed dead, while the others were moved for supportive care. What was the cause of this loss of life and illness? The answers could be sought by a specific expert of veterinary medicine: a veterinary forensic pathologist.

Veterinary forensics is used for many circumstances involving animals. With growing awareness of animal cruelty, public pressures for the investigation of animal abuse crimes have increased. Due to these pressures, veterinary forensics is a growing field. In 2016, the National Incident-Based Reporting System used by the FBI created a new category to track violence and abuse against animals in the same way they track homicide. Wildlife crime is also a concern, including animal trading and smuggling, illegal possession, abuse, habitat destruction, and illegal hunting.

A specific forensics expert is needed for animal crime because other scientists who study animal physiology and disease may rarely encounter abuse or crime-related pathology. The first step for this expert is crime scene investigation. In their review of veterinary forensic science, researchers from the University of Florida stress the importance of an in-person analysis of the scene by a forensic veterinarian. These experts are familiar with animal crime and could identify, for example, wash tubs used to clean dogs prior to dogfighting that a law enforcement officer could overlook. At the scene, animals are triaged: victims in critical condition are identified and subsequently sorted by medical condition. Deceased victims and their environment are documented as well, and all relevant physical evidence is collected and preserved.

Following crime scene investigation, scientists examine the bodies of the victims through forensic necropsy, the animal equivalent of a human autopsy. First, the body is externally examined for injury. Typically, tissue, blood, and urine samples are collected, along with DNA samples from the animal or the surroundings. Other samples can be taken for toxicology, such as stomach contents and liver or kidney samples, revealing the presence of drugs or chemicals.

Finally, imaging technologies are used to investigate skeletal and internal injuries.

Using samples collected at the scene and from the necropsy, DNA analysis can be performed to determine the identity and species of the DNA source. This

methodology reveals if humans were in contact with the animal. Furthermore, DNA present in the digestive system indicates what the animal last consumed. This material evidence and photos of the scene are pieced together to unveil the story behind the crime.

Through the establishment of clear protocols for necropsy, sample collection, and digital media documentation, scientists can reduce compromising evidence. By explaining the protocols used to collect evidence in a legal setting, forensic veterinarians can secure a jury's understanding of the evidence collection process.

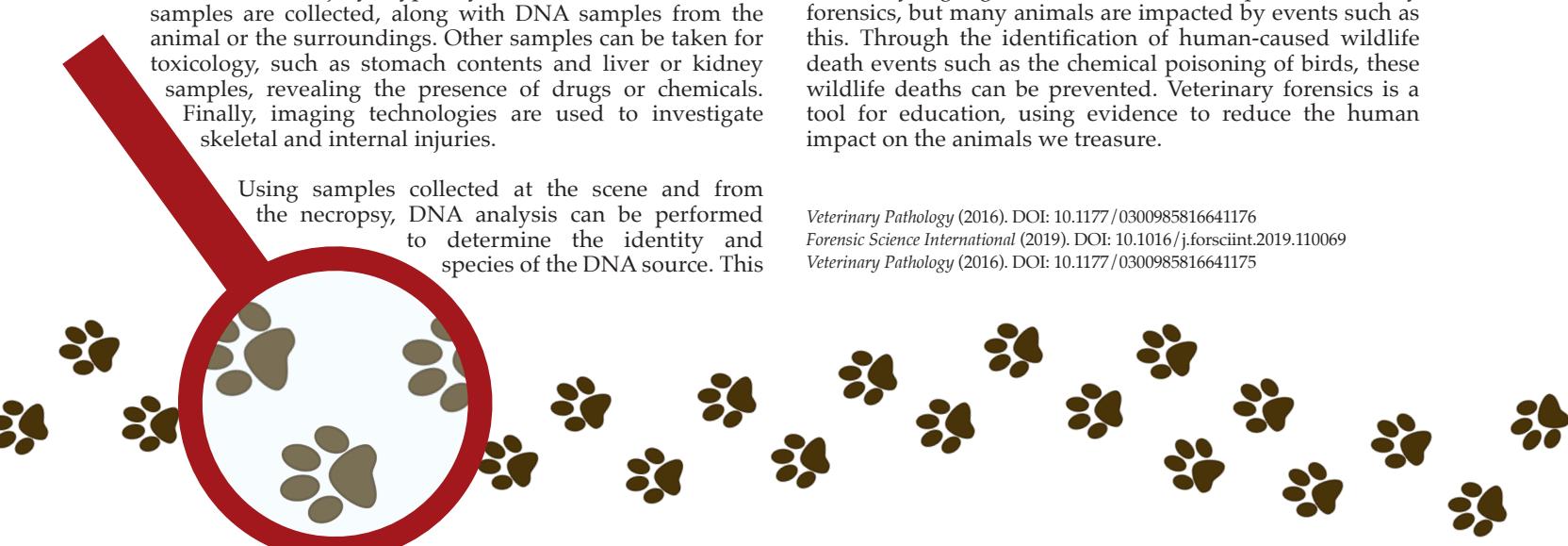
These veterinary forensic techniques can reveal human crimes and prevent unfortunate accidents. Importantly, natural wildlife deaths can be noted as well — necropsy of stranded Florida manatees revealed that over 50 individuals died of natural causes, like algal bloom, in 2020. Necropsy can reveal how wildlife populations are changing from natural events and inform research. In this example, concerns about marine mammal health and algal bloom have directed research regarding nutrient pollution of the Florida coast.

However, the eight eagles discovered in Oregon were not incapacitated due to natural causes. After forensic veterinarians recovered the bald eagle corpse, a necropsy was performed, revealing that the lungs, liver, heart, brain, and kidneys were healthy. No trauma was indicated, no gunshot wounds were present, and there was no evidence of electrocution.

With many possible causes of death eliminated, the eagle's ventriculus — a digestive organ — was chemically examined. A DNA sample of the stomach contents identified that the bird had eaten a domestic cat laced with pentobarbital and phenytoin. This chemical cocktail is used for euthanasia, and an improperly disposed euthanized cat was revealed to be the cause of the incapacitated birds. The remaining seven eagles were treated until they fully recovered.

This story highlights one successful example of veterinary forensics, but many animals are impacted by events such as this. Through the identification of human-caused wildlife death events such as the chemical poisoning of birds, these wildlife deaths can be prevented. Veterinary forensics is a tool for education, using evidence to reduce the human impact on the animals we treasure.

*Veterinary Pathology* (2016). DOI: 10.1177/0300985816641176  
*Forensic Science International* (2019). DOI: 10.1016/j.forsciint.2019.110069  
*Veterinary Pathology* (2016). DOI: 10.1177/0300985816641175



# TAMING THE PSYCHE

Mindfulness meditation  
as neurological process

BY TENZING BRIGGS, ENGLISH, 2022

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

**I**n traditional Buddhist philosophy and training, taming the mind through meditation is part of achieving spiritual wellbeing. In recent decades, however, Western Science has looked to meditation as a novel clinical practice for improving mental health. In the process, research has begun to study how meditation can positively impact an individual psychologically and neurologically.

Due to the fairly recent nature of such neurological research, there are a wealth of problems within existing studies, covered by an extensive literature review in *Nature Review Neuroscience*. The authors explain that because neuroscientists are still in the process of formulating theories about how meditation induces change within the brain, often studies of meditation utilize a low-quality methodology. That is, stemming from assumptions of what constitutes meditation, experimentation may invite ambiguity or be difficult to reproduce. Namely, there are many ways of conceptualizing meditation, as well as several key components working together within the practice (each described later in this article) that must be considered and isolated within the study.

In evaluating studies across such a literature review, of primary importance is to establish, in a thorough way, what challenges there are in studying meditation neurologically.

First, research is limited both by the sparsity of studies conducted and of meditation practitioners, especially expert practitioners. Sample sizes in essentially all current studies on meditation have been incredibly small, with none of the studies reviewed having more than 50 practitioners and many having far fewer, more often in the range of 15 to 25 persons for both meditator and control groups.

Furthermore, the difference between cross-sectional versus longitudinal studies must be considered. As stated in the review, the vast majority of studies on meditation have been cross-sectional, meaning they investigated neurological differences between meditation and control groups at a single point in time. In general, for more definitively showing how meditation changes practitioners neurologically *over time*, longitudinal studies are required — studies where subjects are studied across a longer time span, such as several months of development. The literature review covers various reasons why this second kind of study would be more effective.

A cross-sectional study might show differences between an experimental and control group, but because of the lack of a

Often studies of  
meditation utilize  
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methodology.”

temporal aspect — namely a close examination and isolation of the variables factoring into subjects' development over a long period of time — data might be skewed by unknown variables. For example, personal experiences or other non-meditation types of therapy might have affected neural development alongside mediation. In other words, cross-sectional studies fail to account for other aspects of subjects' lives that may have caused incidental differences between practitioners and non-practitioners. Rather than meditation *creating* difference, it might simply *reflect* difference, where pre-existing differences factor into practitioners seeking out and maintaining meditation practice.

In this comparison between cross-sectional and longitudinal studies, another underlying challenge in studying meditation is revealed: that meditation, as a cultural and taught practice, may contain multiple variables, some of which are unconnected to the meditation itself. Meditation may, for example, accompany a differing lifestyle and diet, other psychological practices like relaxation training and stress management, or amounts of exercise. Studies, therefore, should have *multiple* control groups, where each of these other variables is introduced, to differentiate between their effects and those of meditation, and, for good measure, studies should also include “sham meditation” where individuals are led to believe they are practicing meditation but given incorrect instruction, as a way of isolating the teaching environment itself as another variable in practitioner outlook.

Finally, the review points out something key that should be considered in studies going forward, which is that learning meditation is a process that incorporates multiple psychological components, specifically attention control, emotion regulation, and self-awareness. Because each of these must be mastered, then, studies should look to include both new and expert practitioners. And because studies have correlated mindfulness meditation with multiple regions of the brain, scientists should also consider how these three components each represent specific, different neural activities, suggesting meditation's compositeness helps cause subtle neuroplastic changes that encompass multiple neural networks.

Scientists, then, should seek to break down meditation's intertwined, both through extensive experimental structure and through novel hypotheses concerned with how meditation functions as a series of psychological processes.

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PHOTO BY SHUTTERSTOCK

# MOURNING LOVE

## The overlap of heartbreak and grief

BY DIVYA RAVIKUMAR, BIOENGINEERING, 2025

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022



**F**or all of its dramatics, heartbreak is a chaotic, overwhelming experience. From having a frustrating tangle of emotions lodged inside to even feeling physical pain, people often feel like their heartbreak controls them more than they can handle.

Science shows that it just might.

Florence Williams, a prominent science writer, went through a sudden divorce after a long marriage. To better cope with her pain, she set out to investigate exactly how the body and mind react to heartbreak, as recounted in her book, *Heartbreak: A Personal and Scientific Journey*. In her search, she found that heartbreak has a more severe impact than people might expect.

In a 2010 study by Helen Fisher, author and biological anthropologist at the Kinsey Institute, she scanned the brains of 15 people who weren't over their recent breakup. As they looked at a picture of their ex-partner, the subjects' activated brain regions were those needed to experience romantic love. At the same time, these regions are linked to drug addiction, creating a feeling similar to withdrawal when that love is taken away. There was also activity in the insular cortex and anterior cingulate, areas linked to physical pain, and subjects showed a lack of emotional control that continued for weeks or months. This can grow into more serious issues, such as depression and suicidal tendencies.

In an article Williams wrote for *The Atlantic*, Fisher explained that these results line up with the two main neurological stages of a breakup. The first stage is protest, where people try to win back their partner. Caused by extra dopamine and norepinephrine, people feel threatened and agitated because they think they're missing something, which can lead to insomnia, weight loss, and other consequences. The second stage is resignation, where people start to give up as the dopamine and serotonin wear off. Lethargy takes over if they retreat to various unhealthy coping mechanisms.

These two stages are similar to the five stages of grief, and that isn't a coincidence. In a separate study by Zoe Donaldson, a behavioral neuroscientist at the University of Colorado, she studied how heartbreak affects prairie voles' neurochemistry by stimulating yearning, an important aspect of grief. Prairie voles exhibit the same social habits as most humans, preferring to be devoted to a single partner for life, and they are often greatly impacted by partner loss. One

experiment separated a group of vole couples, some of them paired as siblings, in half. Their neurochemistry changed; voles who were separated from their partner produced more corticosterone, a stress hormone, than those separated from their siblings. They also exhibited behaviors representative of depression and anxiety as the male voles became more passive and withdrawn after separation.

However, regardless of whether the voles were separated, their brains produced more corticotropin-releasing factor (CRF), a stress hormone, than voles who were never partnered, but CRF never activated unless they were separated. According to Oliver Bosch, a colleague of Donaldson, the same phenomenon happens in our bodies when we fall in love and is why we feel miserable after breaking up. Our brains produce the stress hormones in advance as an adaptive response to compel us to find our partners when they leave or feel relieved when they return.

Health issues arise when those stress levels increase excessively.

An extreme example is takotsubo cardiomyopathy, or broken-heart syndrome. A large influx of stress hormones stuns your heart, reducing its ability to pump blood efficiently, causing heart attacks in otherwise healthy people. It's common in women who have experienced a tragic emotional event, such as a spouse or a pet passing away. Beyond this condition, people who have lost a lover in some way face a higher risk of medical issues. A little after William's own divorce, she was diagnosed with type 1.5 diabetes, a condition in which the immune system attacks the pancreas, despite not previously having shown any symptoms.

This isn't uncommon. As our body sustains high-stress levels, our brain thinks we are in danger, so neurotransmitters prioritize sending resources to systems like respiration rather than those that fight off disease. In the long term, this can lead to failing immune systems, mental disorders, and cognitive decline.

While there's no escaping the pain of heartbreak, time seems to be the most effective form of recovery. Research shows that it takes about a few months to a couple of years to stabilize emotionally and physically after a separation, depending on the person's individual experience. As Williams writes in her *The Atlantic* article, "We are built for heartbreak just as we are built for love."

*Journal of Neurophysiology* (2010). DOI: 10.1152/jn.00784.2009

*The National Center for Biotechnology Information* (2020). DOI: 10.1016/j.yhbeh.2020.104847

# HOW TO HAVE MORE LIGHTBULB MOMENTS

BY AMANDA BELL, DATA SCIENCE & BEHAVIORAL NEUROSCIENCE, 2023

We've all had moments of indecision, moments where we're trapped in a certain way of thinking and can't find the answer to the problem we're solving. Whether it's a question of how one phrases what they're thinking, what one should major in, or what job offer one should take, we all face difficult decisions daily. Suddenly, a solution emerges that changes everything: a moment commonly known as an epiphany or lightbulb moment. While there is no guarantee that one can have an epiphany with each problem, research suggests a couple of ways to induce them, including learning through trial and error, eliminating external distractions, and boosting one's mood.

Research shows that people have epiphanies when they learn from their own experiences, but how do scientists know this? A study published in the *Current Directions in Psychological Science* tracked the eye movements of participants playing a two-person game. In the game, each player picked a number between 0 and 10 with the goal of selecting a number closer to the average of the two numbers picked multiplied by 0.9. The average of the two numbers picked will always be closer to the lower number since the average is multiplied by 0.9. Therefore, the optimal strategy would be picking 0 because it is the lowest possible number to choose in the game. To more easily determine whether participants learned the optimal strategy through epiphany, researchers paid participants who committed to picking the same number for the remainder of the study. Nearly all the participants who committed to 0 did so because they had epiphanies, and they spent more time looking at their numbers than the numbers of their opponents. This suggests that they learned from personal mistakes and

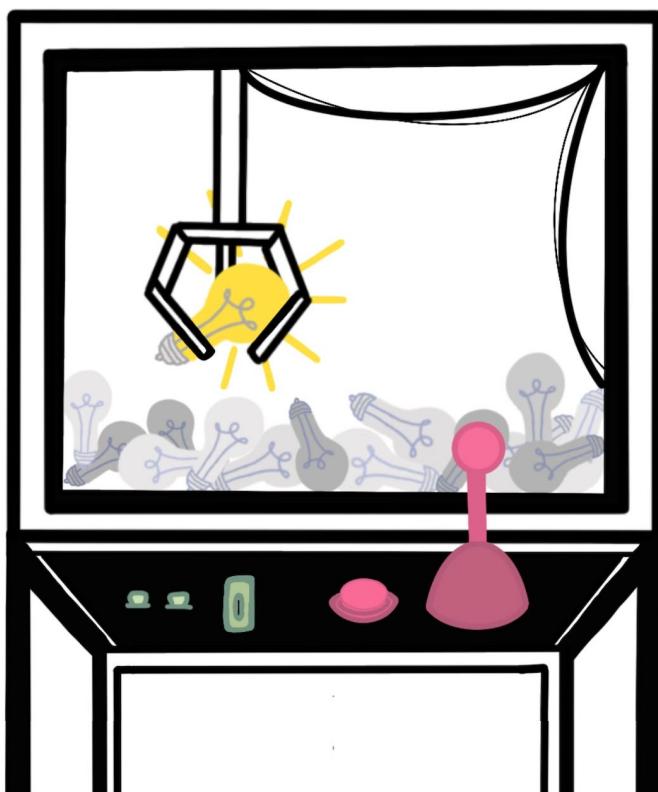
successes. If someone wants to have an epiphany, they should focus on their own experiences and try out possible solutions to receive greater benefits from the learning process.

Another study published in *Sage Journals* found an association between reducing visual input and having epiphanies using electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). Participants in the study played a game where they were given three words and had to find a word that formed a compound word with each of them. Once they thought of a word, they pressed a button indicating whether they found the word through insight or methodically. EEG showed that immediately before a lightbulb moment, there was a slow alpha-band of activity followed by a high-frequency burst of gamma-band activity indicating the aha moment. Alpha-bands are associated with an inhibition of activity, while gamma-bands are associated with higher cognitive functions. This appeared in the scans as activity in the right occipital lobe, which manages vision, followed by activity in the right anterior temporal lobe, which deals with the processing of language. Because alpha-bands are associated with inhibition, a reduction in visual processing occurred before an aha moment followed by an increase in word processing when the participant found a solution. In practice, someone could close their eyes or move their gaze away from the task at hand to induce an aha movement. This often happens naturally when one is faced with a difficult problem as a way to avoid distractions and concentrate on finding a solution. It could also be beneficial to eliminate surrounding distractions like one's phone to avoid disrupting the problem-solving process.

Within the same study, researchers found a connection between mood and having epiphanies. fMRI showed activity in the anterior cingulate cortex, a region of the forebrain involved in regulating mood, immediately before participants saw the problems. To test the connection between mood and solving problems, the researchers showed the participants comedy videos before they solved problems, which allowed them to not only have more epiphanies but also solve more problems overall compared to when they watched neutral or horror-themed videos. Consequently, people could have more aha moments if they boosted their mood as it increases activity in the anterior cingulate cortex. This could include things like spending time with a pet, talking to a friend, listening to music, or anything else that someone might enjoy.

So the next time you find yourself experiencing writer's block, grappling with a major decision, or needing some inspiration, take note of your previous mistakes and act accordingly, remove external distractions, and find a way to improve your mood. Although this isn't a foolproof method to induce a lightbulb moment, it doesn't hurt to try.

*Current Directions in Psychological Science* (2009). DOI: 10.1111/j.1467-8721.2009.01638.x  
*PNAS* (2017). DOI: 10.1073/pnas.1618161114



# IS SEEING REALLY BELIEVING?

An investigation into how humans process optical illusions

ARTICLE AND DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

**A**t any given second, the human eye is processing billions of visual stimuli — trees changing color, flashing sirens, people in the distance — and turning them into understandable information. This means that what is seen is only understood after it has been processed by the brain. In other words, perception defines reality. But what if that reality isn't as clear as it seems?

Take a look at the image in the center of the page. There appears to be a grayscale gradient going in one direction, with an inner rectangular gradient going in the opposite direction. Or at least, that is what the brain thinks. In reality, the inner rectangle is evenly-shaded throughout. This is an optical illusion.

To investigate why the brain perceives a gradient in the inner rectangle, a basic understanding of how vision is processed in the brain is first needed. Light reflects off objects and into the eye. It enters the eye through the pupil, a hole in the eye's outer layer. The light travels through the lens, where it is focused, and onto the retina where various cells and photoreceptors process the light information. Now, the information regarding the visual stimuli translates the image so that it is seen upside-down and horizontally flipped. It is the brain's responsibility to correct the orientation of the image so it is seen right-side up. The eyes are responsible for seeing, but the brain is responsible for perceiving. Past the retina, information from each eye travels through the optic nerve and converges inside the brain at the optic chiasm. The information then travels to the lateral geniculate nucleus, where the brain decides how to separate the information and sends it to the primary visual cortex. The primary visual cortex is where the initial steps in making sense of the information occur. Then, the information travels to other areas of the brain for further processing based on the type of visual information. For example, there are different neural

pathways for perception of what something is versus where something is.

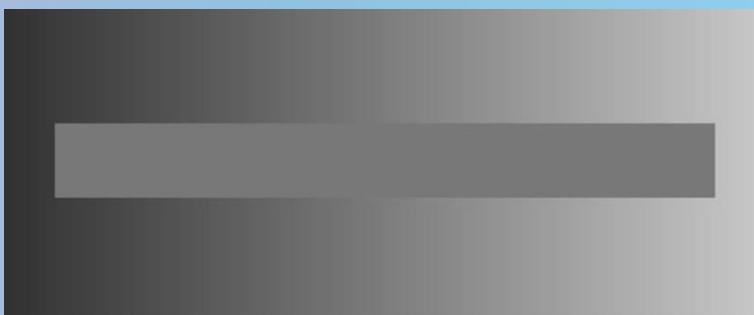
Based on this understanding of visual processing, it is clear that the brain is truly in charge of what is perceived. Although the pupil may receive light to form a certain image, the brain is where that information is defined. It is the brain's control over human perception that allows optical illusions to take place.

The human brain is constantly trying to make sense of the world. The world, on the other hand, is not always a logical place; some things simply do not make sense. For the brain, however, this is a reality that is hard to face. Instead, the brain works extra hard to make sense of discrepancies. This is what the brain does when it interprets the image at the center of the page. This is a "perceptual illusion," or a misinterpretation of an external sensory experience. The human perceptual system has the ability to alter perception in order to help detect certain objects faster.

As a solid shade of gray, the inner rectangle is hard to differentiate and recognize in the context of the gradient behind it. In order to make the inner rectangle pop against the gradient background, the brain perceives the solid shades of gray as a gradient going in the reverse direction. Elements of

color contrast theory are also seen here. In this optical illusion, the brain works to create better figure-ground relationships and alters perception to a useful advantage. Although it may seem as though the brain is lying or creating a false reality, the brain is functioning with survival-based reasoning.

Perceptual illusions are just one of many types of illusions that affect the human mind. Optical illusions are not confined to games, carnivals, and magic tricks. They can be found everywhere because the brain is constantly trying to make sense of the world. Although this can lead to false reality, there is comfort in knowing that your brain has your best interests in mind.



# A heated debate

## CLEARING UP THE CONFUSION ON SUNSCREEN AND SPF

BY JOSEPHINE DERMOND, UNDECLARED, 2025

DESIGN BY PARKER HITT, BIOLOGY, 2024

**E**veryone enjoys the summer days when the sun shines and there isn't a cloud in the sky. Some choose to soak in the sun, many use sunscreen, and others, well, burn. Clothing, sun-avoiding behaviors, and sunblock are methods that offer sun protection, yet many individuals fail to implement any. Various scientific studies reveal data on consumer sunblock use, SPF effectiveness, and concerns over sunscreen ingredients and their health effects. Although the controversy surrounding SPF has presented opposing opinions, following scientific data is key to making informed decisions on skin protection.

Those who choose not to administer sunscreen or reapply may be unaware of the severe damage the sun inflicts on the skin. The sun emits ultraviolet (UV) radiation invisible to the human eye in two forms, UVA rays, and UVB rays. UV light is attracted to melanin — a pigment in the skin that darkens to protect cells. This results in a tan if sufficient melanin is present or an inflammatory response turning the skin red if absent. Although UVA is responsible for tanning, it is also responsible for skin aging and damage. On the other hand, UVB damages cell DNA and primarily contributes to sunburn. Nevertheless, both wavelengths contribute to skin cancer.

To build a protective layer from the sun and its rays, sunscreen containing sun protection factor (SPF) — a barrier that measures the amount of UVB required to inflict a burn on protected versus unprotected skin — is applied. When applied as directed, wearing sunscreen with an SPF of 30 will protect your skin from sunburn 30 times longer than without sunscreen. Higher SPF results in a lower percentage of UV rays radiated on the skin. The SPF value refers primarily to the amount of protection given from UVB rays. Nevertheless, UVA contributes to sun damage and is blocked by sunscreen labeled as "broad spectrum." Therefore, broad-spectrum sunscreen is most effective when trying to evade skin damage if applied as directed.

Confusion surrounding SPF is prevalent among consumers. A paper in the *British Journal of Dermatology* offers clarity to users by presenting a comprehensive look at SPF efficacy, how to measure it, and inconsistencies in SPF data that contribute to confusion. Results from SPF testing in Europe and the United States are incongruent and reveal an over-exaggeration

of SPF in American sunscreens. The use of two different methods to test SPF — *in vivo* and *in vitro* — also accounts for data discrepancies. SPF can be categorized by general protection levels starting at SPF 5 to 10 with low protection and maxing at SPF 50 with very high protection. According to the paper, UV transmission is a much better indicator of SPF efficacy than UV radiation filtered. The UV dose transmitted in the skin, measured in photons, reduces from 6.7 at SPF 15 to 3.3 at SPF 30. Therefore, contrary to common belief, SPF 30 is twice as effective than SPF 15 even though the percent of UV dose filtered decreases by only 3.4 percent between the two SPF values. Misinterpretations of SPF data and inconsistencies fuel consumer distrust.

Climbing SPF values in the market leave users reaching for the "best" product on the shelf; however, concerns over SPF legitimacy leave many believing that the race to the top is a classic marketing scheme. Although SPF 50 is more effective than lower SPFs, individuals don't apply sunscreen frequently or thick enough to achieve complete protection. Human behavior is a huge factor driving the problem. Unease over SPF values, no matter how high, is futile if sunscreen is not applied correctly. The directed usage establishes a 2 milligram per square centimeter layer of sunscreen evenly distributed to achieve the promised protection. Although SPF concerns are a prominent factor hindering sunscreen application, it is also vital to pay attention to other barriers to sunscreen use, like concern over ingredient toxicity and the damage it inflicts on health and the environment.

SPF values instill a sense of security in users who feel less inclined to reapply or avoid the sun. The hyperfocus on SPF values overlooks proper application and the importance of incorporating other methods of sun protection like avoiding the sun or wearing long-sleeve clothing. Additionally, it neglects the importance of using broad-spectrum sunscreen to achieve uniform sun defense. In the end, there should be less emphasis on SPF value and more on proper usage and broad-spectrum technology to prevent skin cancer, early aging, and sunburn.

PHOTOS BY SHUTTERSTOCK



# FAKE NEWS AND VACCINE HESITANCY

BY JASON DENONCOURT, CHEMICAL ENGINEERING & BIOCHEMISTRY, 2023

In 2020, the World Health Organization declared an “infodemic,” demanding attention for the dangerous over-abundance of COVID-19 information. Circulating extensively since the onset of the pandemic, fake news has weakened the trust of health officials and undermined the global pandemic response, including mask and vaccination mandates, contact tracing, and stay-at-home orders.

Health misinformation has emerged as an immediate public health threat. Throughout the pandemic, health officials have worked around the clock to refute numerous claims and conspiracy theories. In April 2020, over seven hundred people died in Iran following false claims that ingesting methanol cures COVID-19. In June 2020, a statement surrounding disinfectants by President Trump led many people to suggest injecting or consuming bleach to treat COVID-19. Similarly, at the height of the pandemic, politicians made unsubstantiated claims that the anti-malarial drug hydroxychloroquine or the antiparasitic drug ivermectin were “wonder” treatments. In fact, the use of the over-the-counter, high-dose horse ivermectin sent demand and calls to poison control soaring. This surge led the Food and Drug Administration to warn with the now viral tweet, “You are not a horse. You are not a cow. Seriously, y'all. Stop it.”

All these unconfounded claims can, in part, be attributed to the scarce COVID-19 knowledge at the beginning of the pandemic between politicians and health officials. However, even as science caught up, the initial conspiracy theories continued. Currently, COVID-19 vaccine misinformation is particularly concerning. Several studies have identified a correlation between fake news perception and vaccine hesitancy, defined as the delay in acceptance or refusal of vaccination despite availability and recommendation by health officials. Despite several studies proving the Pfizer and Moderna mRNA vaccines safe for most, the Mayo Clinic estimates that only 65 percent of eligible Americans are fully vaccinated with two or more doses as of March 2022.

Vaccine misinformation is nothing new. The “anti-vax” movement started in 1998 after Andrew Wakefield published a paper in the well-respected, peer-reviewed journal *The Lancet*. In his paper, Wakefield made unsubstantiated claims that the measles-mumps-rubella vaccine causes developmental disorders, such as autism. The paper was quickly refuted and eventually retracted from *The Lancet*, and Andrew Wakefield was stripped of his license to practice medicine. However, the paper had already sparked a new movement of “anti-vaxxers,” who have since carried

their ideas into the global pandemic. In fact, according to a YouGov survey, about a quarter of Americans and half of Fox News viewers believe that the COVID-19 vaccine could be a ploy by Bill Gates to insert microchips in people.

A study published in the *Journal of Public Health* explored the relationship between COVID-19 vaccine hesitancy and the ability to detect fake COVID-19 news. In this study, a cohort of more than 1,000 participants was asked whether or not they would be willing to get a vaccination against the coronavirus even if the vaccine has not yet been fully proven effective. The participants were given the options of “yes,” “no,” or “I don’t know.” From there, the researchers asked participants to consider several statements to establish the ability to detect fake news. Some statements included were true, such as “the virus survives on inert surfaces such as doorknobs or bars in public transportation,” and others were false, such as “only people over 70 years of age can die from COVID-19.” Ultimately, the findings were not surprising; the risk of being vaccination hesitant or anti-vaccination was higher among individuals who struggled to pick out false statements, or fake news. These conclusions were not unique to this one study. According to another study conducted in Germany, people who endorsed the conspiracy that the virus was bioengineered were less likely to get the COVID-19 vaccine or follow public health guidelines, like mask mandates and stay-at-home orders.

Health literacy is a measure of a person’s ability to obtain, process, and understand basic health information and services needed to make appropriate health decisions. The sheer volume of misinformation in the media presents a health literacy disaster, leaving medically-uninformed people to assess and interpret COVID-19 information. Ultimately, people do have the right to refuse the COVID-19 vaccine for religious, health, or any other reason. However, the concern is whether fake news is influencing those decisions, which current research suggests. Making an informed decision is impossible without discrimination between facts and misinformation. Even as the pandemic slowly wanes, public health officials must continue to refute fake news while presenting the facts to reach most Americans.

*Journal of Public Health* (2021). DOI: 10.1093

*Health Information and Libraries Journal* (2020). DOI: 10.1111

*Frontiers in Psychology* (2020). DOI: 10.3389

PHOTOS BY SHUTTERSTOCK AND FREEPIK  
DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

# Sensitivity, soreness, suicide:

## The unseen complications of Lasik eye surgery

BY LILY WEBER, BIOLOGY & ENGLISH, 2023

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

If, like 75 percent of the population, you were blessed with less than perfect vision, you are likely well aware of the inconvenience presented by glasses or contact lenses. For this reason, many choose to undergo Lasik eye surgery, the best known and most popular procedure to correct one's vision. For eyes with normal vision, the cornea is able to refract light onto the retina, located in the back of the eye. However — in those afflicted with nearsightedness, farsightedness, or astigmatism — light is bent incorrectly, and vision is subsequently blurred. Lasik eye surgery effectively reshapes the cornea using a specialized cutting laser to ensure this refraction is carried out correctly.

Around 700,000 of these procedures are performed annually. Furthermore, since Food and Drug Administration approval in 1999, over ten million Americans have undergone Lasik surgery, making it one of the most common elective surgeries on the market. Most consumers also appear pleased with their results; one literature review reports an average satisfaction rate of 95.4 percent worldwide. Overall, public perception tends to view Lasik as a simple procedure with favorable outcomes. Though the data appears to support this perception, the exceptions to this rule may not be well known.

Possible unintended negative effects of Lasik may include dry eyes, cornea damage, light sensitivity, double vision, astigmatism, worsened vision, or even vision loss. In addition, these effects can be permanent. In short, Lasik surgery is capable of causing some of the afflictions it's designed to correct. According to the American Refractive Surgery Council, the chances of these side effects occurring are rare — less than one percent, in fact. However, there have been some cases where the advent of these complications was devastating — and even deadly.

There are several notable cases of Lasik patients having catastrophic complications which change their lives irrevocably. Most people who undergo the surgery typically resume normal activities within a few days. Tragically, for Jessica Starr, a meteorologist from Michigan, it was only two months after her procedure that she ultimately ended her own life. Her husband said in an interview with Fox Two Detroit that she did not struggle with depression prior to her surgery. However, it wasn't long after surgery that Jessica knew something wasn't right. Though she sought advice from numerous medical professionals, her husband explained that she felt that her eyes and brain weren't communicating like they used to. In her note to her family, she explicitly stated that her decision to end her life was connected to her Lasik surgery.

Jessica is unfortunately not the only documented case of suicide following Lasik eye surgery. According to the *Journal of Ophthalmic and Vision Research*, literature reviews using popular research databases revealed six other people also found to have died by suicide following the surgery. In one case report in the *Open Journal of Ophthalmology*, a young man who underwent the surgery to correct nearsightedness in both eyes developed dryness and irritation after the procedure. He attempted to seek help for his symptoms and burgeoning depression, though weeks later he took his own life.

**“**In short, LASIK surgery seems capable of causing some of the afflictions it's designed to correct.”

To bring awareness to this issue, a multitude of online support groups have become forums for discussion. One such example is lasikcomplications.com, on which the researchers found 34 patients who reportedly either attempted or completed suicide following the surgery. The website contains many categories of issues, from dry eyes and infection to more debilitating symptoms such as cataracts, nerve damage, depression, and even suicide. The possibility for exaggeration or misinformation on such websites is obviously abundant, though the confirmed cases of suicidality are hard to ignore. The website contains an abundance of stories from patients experiencing debilitating consequences from their surgeries, many ending in attempted or completed suicide.

Regardless of one's own view on Lasik eye surgery, there appears to be a clear disconnect between the advertised complication rates and the personal anecdotes of those who have had the procedure. Debates on the truthfulness of these testimonials aside, more investigation should be done to uncover why this gap exists. As with any other medical procedure, potential complications should be clarified and broadcasted accordingly.

*Ophthalmology* (2009). DOI: 10.1016/j.ophtha.2008.12.037

*Journal of Ophthalmic & Vision Research* (2020). DOI: 10.18502/jovr.v15i3.7464

*Open Journal of Ophthalmology* (2015). DOI: 10.4236/ojoph.2015.53022

PHOTO BY PIXABAY

Opinion:

# Climate change, the Anthropocene, and the Plantationocene

BY BINH DANG, ENGLISH, 2022

**A**s we grapple with the consequences of climate change, some scientists and researchers have tried to nominalize the cause of today's environmental degradation. The term "Anthropocene" has been used to emphasize humanity's impact on the environment, suggesting that humans are the major force of environmental change in this geological epoch. In 2016, the Anthropocene Working Group made a binding vote to treat the Anthropocene as a formal chronostratigraphic unit, but its parent organization, the International Commission on Stratigraphy — which is responsible for establishing the geological time scale — has yet to formally recognize the Anthropocene as the current epoch and still refers to the present as the Holocene, the epoch proceeding the last ice age. Although the Anthropocene is unofficial, anthropologists and literary scholars have taken an interest in playing with periodic designations to understand the origins of our current environmental crisis.

The start of the Anthropocene is contested, ranging from the invention of agriculture 12,000 to 15,000 years ago to the Industrial Revolution in the 18th and 19th centuries. However, in the context of climate change, scientists typically refer to the latter as the start, as most of the instrumentally measured data sets of global temperature begin around 1850. Furthermore, the data show that after the Industrial Revolution, Earth's average global temperature increased drastically throughout the 20th century.

If we view the designation of the Anthropocene as a way to understand the climate crisis, then it follows that we should understand how and why humans began to and continue to affect Earth's climate, so we can address the

processes that harm our environment. By entertaining this logic, anthropologists Donna Haraway and Anna Tsing coined the term "Plantationocene" to more accurately pinpoint the beginning of the ideological and socioeconomic systems that have engendered our current environmental degradation. They argue that the term Anthropocene is too broad and does not address the root of climate change, which is capitalism. Humans are not all equally responsible for climate change: The Industrial Revolution itself only refers to the developments of the economies of Europe and the United States, and the famous 2017 "Carbon Majors Report" by the CDP, a global nonprofit supporting the disclosure of data on companies and governments' impact on the climate, revealed that 100 companies are responsible for 71 percent of carbon emissions since 1988. These facts concentrate the blame onto the Western world and corporations specifically. While the term "Capitalocene" has been suggested to reflect this, Haraway and Tsing assert that the logic of capitalism can be located back to the creation of the plantation — hence, Plantationocene.

The theoretical conception of capitalism arose in Adam Smith's writings in the 18th century. At a basic level, capitalism is the private ownership of the means of production in a market economy. Private individuals control the resources and labor needed to produce goods and services, and these individuals, capitalists, are driven by the profit motive — that is, they seek to maximize profit, which is the economic value produced after accounting for the costs of materials and labor.

This same logic of working on profit margins emerged in practice on plantations in the 17th century. Take the example



of Barbados: During the 17th century, the British set up colonies and sugar plantations on the island. Plantation owners used indentured servants and enslaved people to grow and harvest sugarcane on the island; enslavers bought land, resources, and labor to transform the sugarcane plant into sugar and sell it as a commodity. Private landowners on the island maximized profits by exclusively growing sugarcane and transitioning from using indentured servants to primarily slave labor.

Plantation owners opted for slave labor because it was more cost effective to subject Black people to work and to keep their children as slaves than to import labor from indentured servants, who would ultimately be freed after a set period of time. Sugar became such a profitable commodity that it was more cost effective to import food from the New England colonies than it was to grow food on the island. Therefore, Barbados' arable land was only used to grow sugar, resulting in a sugar monoculture that was emulated across colonies. Scientists have long argued that monoculturing is an unsustainable agricultural practice that results in disease and pest outbreaks, soil degradation, and ecological instability due to the reduction in biodiversity and consequent changes in the biogeochemical cycles of the local environment. Just like the transition to slave labor, the logic of crop production justifies exploitation and degradation to reach the end of maximizing profits.

The structure of the plantation and its society, with enslavers who exploited natural resources and enslaved labor to become wealthy, precisely reflects capitalism's structure: an elite class owns most of the wealth and uses other people's labor to make money. Today, we see how corporations harm the environment, whether by polluting water sources, lobbying for and building new oil pipelines in protected wilderness areas, or clearing forests for land development. The Plantationocene reminds us that the consequences we see today aren't new but logical conclusions to a system set in motion centuries ago.

Beyond the economic effects of capitalism and the plantation, the term also emphasizes the racial nature of this exploitation. Communities of color are disproportionately harmed by environmental degradation: A September 2021 EPA report found that, at 2 degrees Celsius of global warming, Black Americans are significantly more likely to currently live in areas with the highest projected increases in childhood asthma diagnoses and extreme temperature related deaths. Even though we've moved past racialized chattel slavery, the consequences of the socioeconomic systems that constructed plantation society still reverberate in the modern day.

In terms of solving climate change, that means that we have to look at how the plantation and capitalist systems that have built society today are not only the foundation of our world but also part of the processes that continue to shape it. Over the past few years, there have been more public reckonings with systemic racism and the economic inequalities embedded in our society, but these problems have existed for centuries. These conversations have opened space for new ways of understanding our world and the problems in it, with new vocabularies to make sense of things. The designation of the Plantationocene is no different. It's a diagnosis. It frames the conversation around our problems, so we can look in the right places for the right solutions. In February 2022, professor of economics Hoesung Lee, the chair of the Intergovernmental Panel on Climate Change, ended his remarks at a press conference by saying, "Half measures are no longer an option." If we have a system whose logic condones the exploitation and extraction of resources and people — and whose logical conclusion has resulted in our current environmental crisis — then any solution within that logic will always be a half measure.

*Ethnos* (2015). DOI: 10.1080/00141844.2015.1105838

PHOTOS BY SHUTTERSTOCK

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022



# Open access

## A new age of research publication

BY MAYA KRAUSE, ENVIRONMENTAL SCIENCE, 2022

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

**T**ransparency is a critical element of science. A fundamental principle of any experiment is reproducibility, or the ability for an experiment to be reproduced by any researcher, which is impossible without researchers being transparent about the conditions of the initial experiment. But transparency is also important to ensure that policymakers, healthcare providers, and members of the public have access to current, peer-reviewed scientific research.

One method of increasing the public's accessibility to science is through opening access to scientific research. Historically, scientific research has been published in physical academic journals that relate to specific scientific disciplines. Scientists send their research to one of the journals, which manages communications between editors and scientists and eventually accepts a version of the scientific work that is published in the journal and distributed to research institutions and libraries, which pay subscription fees to receive the journals. This method of publishing research is still used by many scientists, as it is estimated that there are more than 30,000 academic journals in publication today.

However, with the advancement of the internet, more researchers are turning to open access publication to increase the public's accessibility to their work. Open access publication involves publishing research in digital journals that do not charge subscription fees; the authors and their institutions absorb the costs associated with publication. There are different ways to publish open access, distinguished by color codes: gold open access indicates that the final article is freely available directly from the journal website, and green open access indicates that an earlier version of the article was posted on the author's personal website and in an institutional repository. Both of these models break down financial, legal, and technical barriers for the public to access research for personal or academic use.

The main benefit of open access publication is increased accessibility and visibility of a researcher's work. Journal subscription prices are extremely high, with the average price per journal ranging from around \$2,200 per year for math and computer science journals to more than \$6,500 per year for chemistry journals. This restricts broad access to academic research to those connected to institutions who pay for many journal subscriptions.

By publishing their

research in an open access journal, researchers can broaden their audience, increasing the visibility of their work and contributing to improved public education and enrichment. Many rely on knowing current science for their professions, and open access publications benefit them and the general public. For example, physicians use journals to keep their clinical work updated based on the latest medical research, so broadening access to research would help their patients and public health.

**"Open access publications can increase the accessibility of science to the general public."**

Open access publishing can come with downsides for the researcher. One disadvantage is that researchers rely on the reputation of the journal where they choose to publish their work to boost their credibility. Journals utilize the impact factor ranking system, which is a measure of the frequency with which the average article in a journal has been cited in a particular time period. The value of individual papers are often judged on the impact factor of the journal they are published in. While most open access journal articles are peer reviewed to the same standard as paid journal articles, it takes time for a journal to develop a high impact factor, which can negatively impact the perception of the researcher's work if they publish in an open access journal. Additionally, predatory open access publishers who charge excessive fees for publishing in their journals while providing little to no services to the researchers have appeared in recent years. Researchers must use caution when choosing open access journals to ensure they are selecting reputable publications.

Open access publications can increase the accessibility of science to the general public, improving transparency in science and assisting those in fields that rely on recent publications. As open access publications build up their reputations, it is likely that more and more researchers will choose to publish their research for free. The internet has revolutionized many aspects of society, and access to scientific research is no exception.

PHOTO BY SHUTTERSTOCK



# Unforeseen consequences: A look into data storage and usage

BY ABIGAIL POTTER, PHYSICS & PHILOSOPHY, 2023

**W**e are in the midst of the information revolution. Where oil or coal were once used to propel advancement, today data is the leading resource. However, unlike oil and coal, data is unlimited. It can be reused an infinite amount of times and be possessed by an infinite amount of people. We have no way of knowing what data will be used for in the future or how it will be linked with other data. We have no way of knowing which data should be publicly accessible and which should not. Ergo, few restrictions exist on what data can be gathered and what it can be used for. Unimpeded, companies around the world gather and store millions of people's data.

According to a 2017 study conducted by Ghostery, a database on web trackers, approximately 79 percent of websites track users' data. Through the use of cookies (small pieces of data used to identify a computer network) and other trackers, websites gather information about a user's behavior and interests. User data can look like anything, whether it be Wordle tracking an IP address to keep track of a streak or Netflix calling out the 53 people who watched a Christmas movie 18 days in a row. This data is used to determine website performance and ensure ad reach. However, some websites store this data and send it to other companies. Oftentimes, this information is used to create personalized advertisements. For example, if someone has been looking at baby clothes, they're likely to get ads about diapers. This practice is fairly common, with 10 percent of websites with trackers sending user data to 10 other companies or more. Five years and a pandemic turning a significant portion of daily life digital later, that percentage has only grown.

Unfortunately, data tracking doesn't stop at websites. "Smart" devices track user information daily as well. For example, Roomba maps the homes of its users to maximize efficiency. Robot vacuums have sensors that enable them to memorize the location of every object in a home. It tracks where the walls are, where furniture is, and what areas require more cleaning, among other things. While this data might simply seem as if it improves Roomba's function, it can improve other companies' products as well. Knowing more home floor plans and layouts could help speaker companies improve audio performance using a room's acoustics. Similarly, knowing the spatial mapping of a room

could help improve air conditioners' airflow and increase cooling. The knowledge of home layout can even be used to (again) improve advertising, recommending a user furniture ads when it tracks an empty room in their home.

The primary problem with this data collection is that most people don't even know what information is being collected. While terms and conditions are easily accessible for apps, most people do not take the time to read what they are agreeing to. However, this behavior becomes quite dangerous when purchasing products because, many times, the terms and conditions are implied to be accepted when the object is bought. As such, people are completely unaware that their in-home smart devices could be keeping greater tabs on them than the device's functionality implies it does. In the worst-case scenario, this means people are completely unaware of what information about them can be published or stolen during company data breaches. With personal data exposed, people become more vulnerable to new and improved phishing campaigns built off of data that they were unknowingly exposing to the world.

Currently, few protections exist for consumers when it comes to data gathering. The only U.S. law that protects against what companies track, store, and sell about consumers is the California Consumer Privacy Act (CCPA). The law mandates that any company doing business in California must post their digital privacy notices, honor Do Not Track privacy settings, clearly explain what information will be collected and how it is used, and allow consumers to opt out of personal information sales. CCPA protects citizens of California but does not apply to the rest of the United States (or even the world for that matter).

A lack of regulation means companies are responsible for moral practice. Unfortunately, many will not do so without pressure. As such, increasing public knowledge about personal data and its usage is imperative to keeping consumers safe. Knowing what information can be gathered about you can encourage safe internet habits and ensure that you know what information about you is made available.

*Big Data* (2018). DOI: 10.1089/big.2018.0083

PHOTO BY SHUTTERSTOCK

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022



# HE SAID, SHE SAID

The importance of linguistic differences in attributing blame and memory

BY CELESTE CANZANO, PSYCHOLOGY, 2023

DESIGN BY RESHIKA SAI DEVARAJAN, HEALTH SCIENCE, 2025

**D**o you solemnly swear to tell the truth, the whole truth, and nothing but the truth, so help you God? But what if something so natural as the language you speak affects the way you remember and report events? Simple things, like the verbs you use and the locations of nouns in a sentence, can have an impactful role in the way your brain encodes and recalls even the most mundane of experiences.

Anyone who has ever taken a Spanish or French class in high school knows that verbs can be tricky. With a multitude of conjugations and spelling variations, learning verb tenses requires memory tricks and plenty of practice. Reflexive verbs can throw a wrench in this system, especially considering how common they are in romance languages. As the name suggests, reflexive verbs directly and identifiably reflect back on the subject who is performing the action. For instance, in Spanish, "la ventana se rompió" directly translates literally to "the window broke itself" in English. English has its own variation of reflexive verbs but are less common and are used in very specific contexts, such as in "I washed myself".

This reflexive quality in Spanish and English can be attributed to agentive language. Agentive sentences follow a very basic format: the subject, followed by the verb, and then ended with the noun on which the subject is performing the verb on. For instance, "John broke the window" uses John as the agent which performed the action. Conversely, non-agentive language lacks the agent. For instance, "the window broke," implies the window magically broke, and there was no

agent present who actively broke it. While agentive and non-agentive language are present in both English and Spanish, the context in which it is used can have powerful implications on eye-witness accounts.

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Reflexive verbs directly and identifiably reflect back on the subject who is performing the action.”

With the rise of social movements like Black Lives Matter and #MeToo, eye-witness testimonies have never had more importance. It is crucial that events are reported with accuracy, especially in who receives the blame for the criminal action. This is where agentive and non-agentive language come into play. A study performed by Fausey and Boroditsky at Stanford University found that while both monolingual English and Spanish speakers can properly identify who was to blame for intentional actions, English speakers were more likely to use agentive language when reporting accidental events. When English speakers were shown a clearly accidental event, such as someone knocking over a mug of coffee with their elbow, they reported the incident as "the person knocked over the mug" rather than "the mug was knocked over." Spanish speakers did the opposite, instead preferring a non-agentive description of the event.



So why does the way we report incidents matter? It's theorized that the type of agentive language used in internal cognition influences how memories are encoded. If a language predominantly uses non-agentive language, then speakers' attention would visually orient to the object and not the action. The inverse is likely for predominantly agentive languages, where the speaker orients on the agent and not the object. This fixation can be reflected in the way people remember events. Fausey and Boroditsky discovered that Spanish speakers had a more difficult time remembering the individual involved in accidental events. When shown an accidental action twice with different actors, Spanish speakers had a more difficult time identifying who did the action first, as they encoded the event in the context of what happened to the object and not who did the action.

This internal bias from naturally generated thought could lead to serious implications in real-world situations. Fixating on objects rather than agents could lead to incomplete or false memories of an event, which is something that could impact the availability and validity of eye-witnesses. In situations where the attention is ambiguous, will the ambiguous nature and tendency to use non-agentive language lead to false testimonies? The same goes for over-attributing blame. Are English speakers more likely to believe that someone did something intentionally if the accidental event is encoded agentively?

*Psychon Bull Rev* (2011). DOI: 10.3758/s13423-010-0021-5.

PHOTO BY PIXABAY



# Overcoming cross-cultural confusion

Foreignization and domestication of translated literature

ARTICLE AND DESIGN BY EVELYN MILAVSKY, CELL & MOLECULAR BIOLOGY, 2025

**W**hen translating texts between languages, translators often run into the challenge of balancing the literal and figurative elements of the work. Though denotation is essential for staying true to an original plotline and concept, connotation is extremely significant in conveying nuanced aspects of a story's deeper meaning to readers. Perfecting connotation is made more difficult by the fact that languages and cultures have different allusions, references, and idiomatic expressions which often necessitate variations between the original and target language of the translation for readers' understanding.

To assess the level at which translators aim to eliminate or incorporate these cultural differences into translated texts, Lawrence Venuti of Temple University identified two methods of translation: domestication and foreignization.

Domestication of a foreign work entails the modification of culturally specific information to include references widely understood in the target language. For example, a French book likening someone's attitude to cold January weather may be switched to reference a different month if the book were being translated into Spanish for distribution in Argentina, where it is warm in January. This would allow readers to still understand the insinuation that the character is being unwelcoming and stiff whilst utilizing their pre-existing notions of weather within their own environment. Proponents of this method believe that changing the specific content of a work can enhance the audience's ability to comprehend greater themes within the text by not forcing them to align their mindsets to an unfamiliar culture. This strategy also operates on the assumption that readers have little knowledge of the original language's society, which can be a benefit if true. Critics of this method argue that complete cultural context is necessary for maximum accuracy in a translation and that attempting to make concessions for cultural neutrality weakens the work. For instance, an ancient Greek play may make a quick joke about a politician who was in power at the time. Though modern audiences may not be aware of who that politician was or their reputation, replacing their name with that of a current politician would arguably damage the authenticity of the piece, even though it would aid in comprehension, since knowledge of present leaders is far beyond the scope of ancient Greek playwrights and could not possibly be included in their original writing.

Critics such as these may prefer the method of foreignization. Foreignization seeks to retain most of the source material from the original language throughout the translation process despite cultural discrepancies that may arise. An example of this may be a novel in which a high school student discusses a prestigious university in their home country even though it may not be highly recognized in the readers' culture rather than swapping it out for the name of a college in the target language. Advocates for a foreignized approach say that maintaining cultural authenticity in translated texts pays respect to the author by acknowledging the significance of the original culture regardless of international knowledge. Forcing readers to confront and overcome the initial barrier presented by foreignness is seen as a learning opportunity that doesn't compromise the readers' deeper comprehension of the text at large rather than a feature that would disincentivize continuation of the text. Though proponents of foreignization embrace the discomfort that may come with a lack of cultural understanding, critics of this method believe that literary works should meet their audiences' perceptions of their everyday world to limit confusion and focus more on larger thematic messages. To illustrate this, perhaps a character likened the texture of something to that of a mango. If the text were to be translated into a language of a region where mangoes aren't available, the target readers would not have a basis to understand that described texture. Foreignization supporters would believe that more description of the texture and inclusion of the mango would suffice to make this understandable, but critics would say that it is not relevant to maintain the specific fruit when it could be interchanged with a food that the audience may be more familiar with. They are concerned that prioritizing the inclusion of these critical features reduces overall interpretation of major abstract concepts.

Ultimately, most translated works rely on a mix of both foreignization and domestication to pay homage to the origins of the translated content and make it digestible for a different audience than was originally intended. Acknowledging the cultural context of translated texts allows individuals to expand their realms of knowledge, while making concessions for thematic precision creates a greater appreciation for overarching moral themes that transcend cultural barriers. Literary translation is an imperfect art that still manages to connect humanity through the written word.

# Celebrating our graduates

## A NU Sci farewell

**N**U Sci is proud to present our Class of 2022! We strive for exceptionalism and innovation at our magazine, and these individuals represent those goals through their contributions to the practice of science communication. Their perseverance allowed NU Sci to flourish through the incredible disruptions, challenges, and distresses of the past three years. More importantly, they've acted as role models, mentors, and friends within our community, bringing out not only the best in our magazine but the best in our people as well. Their positive impact and legacy will forever resonate with us all. Whatever their paths forward may be, we thank them for their dedication and wish them the best of luck in their bright and promising futures. They will always be a part of the NU Sci family.



### Lillie Hoffart

After joining NU Sci her freshman year, environmental science major Lillie has fallen head over heels for science communication. She enjoyed sharing her love of weird creatures in her articles, and the magazine even inspired her journalism minor. Serving as a head of design, editor, and the club's president over her five years at Northeastern, she has spent countless hours pouring over journals, designing pages, or searching for missing magazines in the depths of the mailroom. One of her favorite memories is swabbing items in her apartment to grow bacteria for a last-minute page. This magazine has provided her with an outlet to share her love of science as well as gain many friends. After graduation, Lillie will be continuing her science education in a PhD program at the University of Nebraska studying trees and ecosystem stress.



### Binh Dang

Science and writing have always stuck around in Binh's life, and NU Sci was the perfect place to engage with those interests together. Through the four years Binh has been a writer for NU Sci, they've also been an editor and the editor-in-chief. Parallel to that journey in the club, Binh has changed majors from behavioral neuroscience to environmental science to English. Their transition to the humanities was reflected by their approach to the magazine, writing about science within the context of broader philosophies and epistemological methodologies. Binh is grateful to have been part of such a vibrant and talented community, which has always offered them the opportunity to learn from a diversity of disciplines. After working as a technical writer in the future, Binh plans on pursuing a PhD in rhetoric and composition to explore their interest in epistemology and the construction of new forms of knowledge.



## Katie Green

At 14 years old, Katie joined her high school's newspaper and got her first introduction to design. After choosing bioengineering as her major, she picked up a graphic and information design minor at the start of her second year because she missed the creative outlet. Then Lillie (the then-head of design and Katie's roommate) introduced her to NU Sci's design team. Combining both her love of science and design, Katie was excited to get involved. She designed for a year and a half before joining NU Sci's e-board as co-head of design. Now finishing up her second year, her favorite moments are still seeing each issue printed for the first time and flipping through everyone's designs. After graduating, Katie plans to visit Australia for a couple weeks before joining the Takeda Pharmaceutical's vaccine unit in their process development team.



## Kristina Klosowski

Kristina found NU Sci during her sophomore year of college as a behavioral neuroscience major and quickly fell in love with being involved in the magazine. She joined the e-board team as the head of communications the following year and has been in the position ever since. Aside from seeing the finished product of her fellow students' incredible design, photography, and writing every semester, her favorite part has always been the people she has met through NU Sci. After graduation and some long-awaited international travel, Kristina will be making the great state of Colorado her new home when she moves to Denver to work for a healthcare consulting firm, and she plans to apply to law school in the next couple of years.



## Annabelle Mathers

The humanities have always been an important part of Annabelle's life and, as a civil engineering major, she found NU Sci to be the means by which she could combine her passions for STEM, reading, and creative writing. After joining as a freshman, Annabelle quickly realized that she could also explore her other interests more deeply through NU Sci, not limited to architecture, quantum physics, astrophysics, and music. She has been a writer, editor, head of communications, and treasurer for NU Sci; however, her favorite part about her experience with the magazine has been the opportunities to learn about completely new and unexpected topics through editing, writing, and researching articles. After graduation, Annabelle will work in structural engineering at LA Fuess Partners Inc. in Boston, but hopes that she will continue to enjoy and explore reading, her side interests, and future interests yet to come.



## Tenzing Briggs

Tenzing has only been a writer and editor for NU Sci during his last year at Northeastern, but he has greatly enjoyed writing and editing for the magazine in that limited time. In the past a biochemistry major, Tenzing rediscovered through the magazine his interest in science writing, especially neurology, such as in articles about the psychological science behind perfect pitch and meditation. As an English major, he loved getting to help other writers improve and hone their writing skills, and found his brief stint as editor for the magazine incredibly rewarding. He plans to pursue technical writing and editing after graduation, returning to work with previous employers in his home state of Arkansas and freelance editing, while building his application for a grad program in technical writing.



## Cailey Denoncourt

After browsing through all the magazines at admitted students day, Cailey knew this was a club she wanted to be a part of. She finally joined as a writer starting her second semester freshman year, but unsure of her writing ability, she didn't become an editor for another year. Her articles covered a wide variety of topics ranging from capsaicin as a lung cancer treatment to unsinkable fire ant rafts, despite being a bioengineering and biochemistry major. She is currently on the pre-med track but plans to take a gap year before hopefully starting medical school. After graduation, her plan is to work as a clinical research assistant at Beth Israel studying the effects of environmental factors on chronic lung diseases!



## Louise Holway

Coming from an architecture and civil engineering background, Louise has always craved learning about new discoveries in the industry. Louise joined NU Sci during her freshman year as an outlet for both creative running and research. During her time, she explored topics mostly relating to sustainable buildings, but also explored various topics that interested her like GMOs, the science behind the perfect running shoe, and the golden ratio. Wanting to improve her writing skills and be more involved in the magazine's production, Louise became an editor her junior year. After graduation, she will be getting her masters in architectural computation from University College London in the fall and working part time as a Sustainability Engineer.



## Maya Krause

As a freshman, Maya joined NU Sci after her RA suggested it, and she's never looked back, becoming an editor in her sophomore year. An Environmental Science major, Maya has enjoyed writing about environmental topics for NU Sci, but her favorite article she's written was about how humans still go into heat, just like cats and dogs. She also has enjoyed editing for NU Sci because it has allowed her to read about many different topics, and she enjoys seeing the progression of an article from first draft to publication. Outside of NU Sci, Maya is involved in environmental activism through Sunrise Northeastern. She has no solid plans for after graduation but is looking to work for a few years in Boston and then apply to law school.



## Rachel Lines

Reflecting on her numerous articles about animal behavior research, Rachel has realized her interests in animals are undeniable. NU Sci has enabled Rachel's pursuit of animal knowledge and her curiosity about how all creatures experience their world. Her favorite article to write was "Moo-ving about: The transitional lives of dairy cows," because she loved considering her personal experience working with these charming animals. Through her role as an editor, she has enjoyed reading about other fields, learning bizarre phenomena, and serving as a writing mentor. Following her graduation in August, Rachel will be exploring animal health and behavior through several gap year internships before applying to veterinary school. She is incredibly grateful for the friendships she made through NU Sci, and she will miss this curiosity outlet very much!



## Cara Pesciotta

Coming into college with a communications background, Cara found NU Sci to be the perfect place to integrate her passion for journalism with that for science. Her favorite thing about the magazine is the opportunity to learn about topics she typically would not see in her physics major, although she has most enjoyed writing about astronomy and quantum physics (spoiler: we are probably not living in a simulation). Cara started writing for NU Sci her sophomore year and wrote for one year before becoming an editor, thanks to encouragement from previous editors. She has loved getting to know fellow editors and team members and looks forward to using the skills she learned in NU Sci in the future. After graduation, Cara will be pursuing an astrophysics PhD to study exoplanet chemistry.



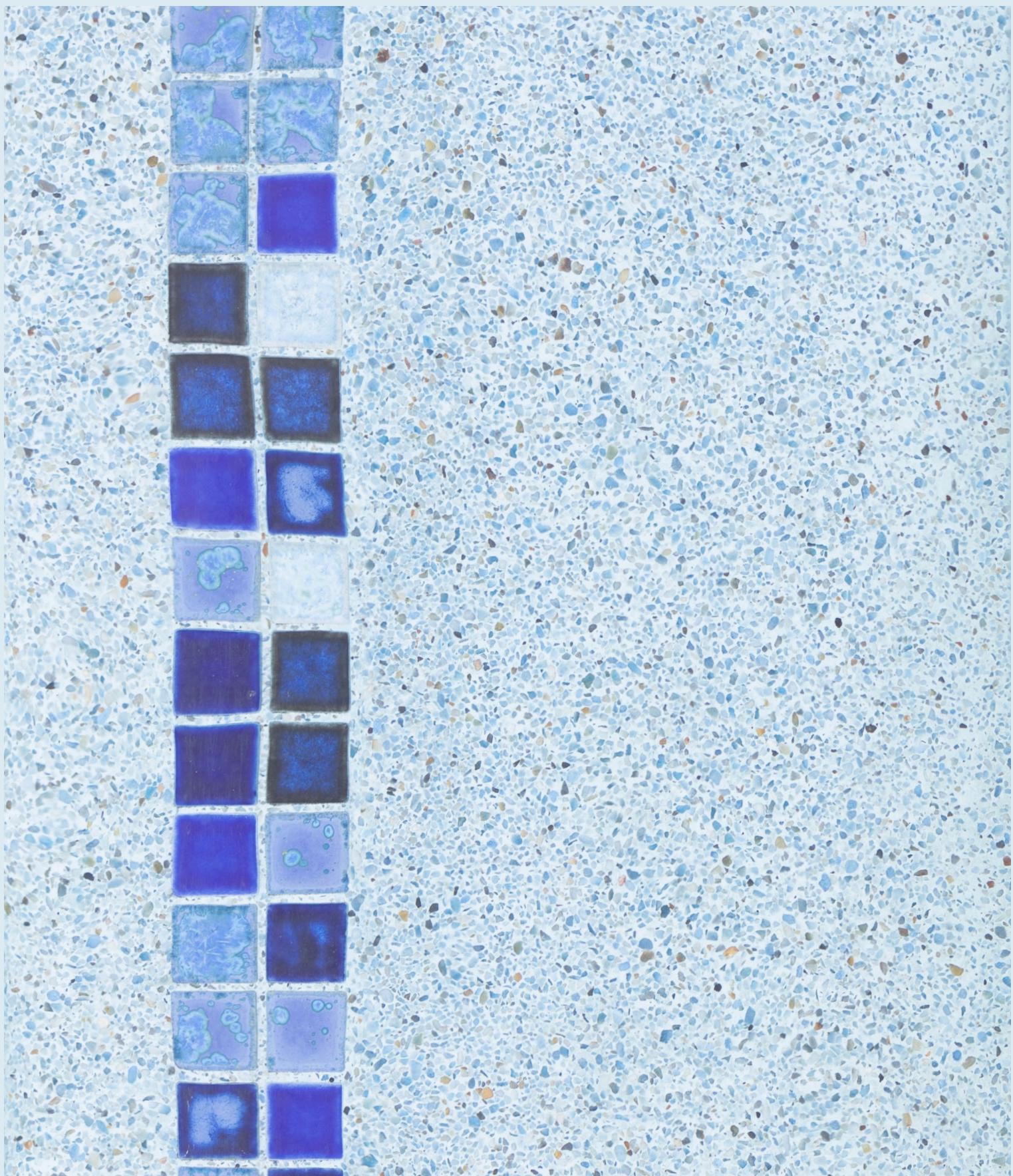
## Ian Proulx

Ian is a bioengineering major who has been an article designer for his four years at NU Sci. He joined NU Sci freshman year because of his love of science. Over his time at NU Sci he has learned a ton about how to make a design pop, as well as how to better use Photoshop and InDesign to bring a design idea to life. One of his favorite parts of being in NU Sci has been reading and learning from all the different articles and then being able to come up with a design to enhance the article. After graduation, he plans to work at a biotech in Boston, and although his job won't be design work, he hopes to use his skills to make some pretty graphs.



## Yechan (Ben) Yang

As a behavioral neuroscience student with a background in graphic and layout design, Yechan (Ben) joined NU Sci his freshman year in hopes of exploring interdisciplinary works of STEM and art. During his five years with NU Sci, Yechan was able to explore various fields of studies ranging from zoology to theoretical physics through numerous designs he worked on. Although Yechan's design work often emphasizes minimalism and modernity, NU Sci not only pushed him intellectually but also encouraged him to venture into design styles he has never explored. Yechan is currently working at the Sabatini Lab at Harvard Medical School where he will continue his position as a laboratory technician after graduation to further explore the field of neuroscience before applying to medical school. While Yechan is extremely sad to end his career with NU Sci, he is looking forward to seeing the future works of NU Sci.



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