

ISSUE 59 SPRING 2024

# NU Sci

fractal

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# LETTER FROM THE EDITOR

One of my favorite peculiarities of college is the “Where did you grow up?” conversation, often had over solo cups at 1 a.m. I especially love listening to two East Coasters who take the Amtrak Northeast Regional home for Thanksgiving strike up the conversation: The closer they grew up, the deeper they’ll talk about their individual towns (probably both somewhere in Jersey) to identify all of their shared cultural quirks and mutual acquaintances.

Scientists have even quantified this effect — albeit for the contour of the coastline itself, not the culture. The closer you look, the more detail you see. The shape has another interesting property: It’s almost impossible to tell looking at one mile or a thousand miles of rugged beach. It’s created by a simple process: The ocean erodes the beach on every scale — from large tidal motions to tiny waves in the surf. And this pattern exists far beyond the coastline. In this issue, we share the stories of scientists who have identified the pattern over and over again in the world around us, in trees, weather, computer science, and math.

In the 1970s, it finally got a name. The Polish-French mathematician Benoit Mandelbrot developed the Mandelbrot set, a pure mathematical example of the pattern. It looked fractured and broken to Mandelbrot, which inspired the name he gave it: *Fractal*.

It's almost ironic that a natural method for creating structure, by simply repeating a process on multiple scales, was named for how it appears broken — it's a reminder that even when something appears broken, there can be incredibly clear and precise dynamics creating it. In this issue, we explore the dynamics of pseudoscience allegations in consciousness science, the United States and South African healthcare systems, and the sudden disappearance of a snail species from its tropical island habitat.

I thank our editors and e-board members — from along the Northeast Regional and beyond. I thank all of our writers, designers, and photographers; our social media and outreach team; and our web team for bringing this issue to life. As you travel through this issue, take notice of the complexity at every turn. I bet the closer you look, the more you'll see.



A handwritten signature in black ink, appearing to read "Noah Haggerty".

Noah Haggerty  
Editor-in-Chief

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# A simplified guide to charging your phone with a black hole (theoretically)

BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

DESIGN BY ANJANA BALAKRISHNAN, STUDIO ART, 2027

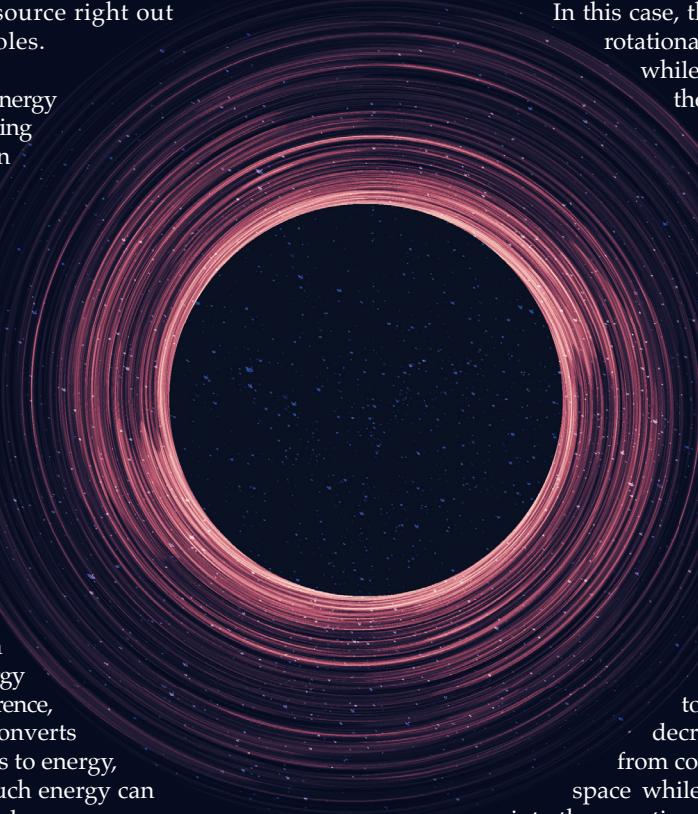
The race to find sustainable energy has quite literally led us out of our world. Earth harvests energy from the sun to keep itself alive, but for the ever-growing human species, even this massive star is not enough to satisfy our high energy needs. Ergo, scientists have been searching further into space for other sources to tap into, which brings us to a source right out of science fiction: black holes.

The first step in harvesting energy from a black hole lies in picking one. Contrary to common logic, larger black holes emit less energy (through Hawking radiation). On the other hand, smaller black holes rapidly emit large amounts of Hawking radiation, though this causes them to rapidly destabilize and evaporate. Another consideration to factor in when picking the black hole is its spin. Rotating black holes, known as Kerr black holes, increases the conversion efficiency of mass to energy from 6% to 32%. As a reference, nuclear fission technology converts approximately 0.1% of mass to energy, demonstrating just how much energy can be extracted from a black hole.

The next step is to feed the black hole. Mass captured by the black hole does not directly get swallowed into the event horizon, but instead falls into orbit along the black hole's accretion disk — a magnetic field surrounding the black hole — due to the conservation of angular momentum. As the object approaches the center of the black hole, it speeds up and interacts with other particles within the disk, radiating this energy out of the black hole. Hawking radiation also causes black holes to emit energy as well — where mass converts to energy via an emission of black body radiation (heat and light) within the accretion disk. Two scientists from Columbia University and Universidad Adolfo Ibáñez also

suggested using the magnetic field of spinning black holes to utilize its rotational energy. Their research proposed using magnetic reconnection, which allows parts of plasma in the ergosphere to accelerate and obtain infinitely high energy while the other part of the plasma accelerates against the black hole's rotation and obtains negative energy.

In this case, the accelerated plasma extracts rotational energy from the black hole while the latter plasma feeds into the event horizon.



Once energy leaves the black hole, it has to be transferred and collected for use on Earth. One suggestion for this challenge would be to build a Dyson ring, a modified Dyson sphere. Dyson spheres were suggested by physicist Freeman Dyson as a means to collect energy from a planet's star. In the case of black holes, there would be a fleet of satellites surrounding it in a ring that would collect and direct the emitted energy back to Earth. This ring formation decreases the likelihood of damage from collisions with objects moving in space while also allowing masses to fall into the accretion disk for energy.

Unfortunately, tapping into black holes is a project for the world far into the future. Limitations in space travel, current material technology and availability, and the sheer cost of such a project prevent this idea from leaving theories on paper. It is an idea that would push on the limits of humanity when realized, allowing us the capability to achieve more than allowed in modern society.

*ArXiv* (2023). DOI: 10.48550/arXiv.2210.10587  
*Physical Review D* (2021). DOI: 10.1103/PhysRevD.103.023014  
*Physica Scripta* (2022). DOI: 10.1088/1402-4896/ac9e78

PHOTO VIA SHUTTERSTOCK

# Home away from home

## NASA's newest ocean-covered exoplanet

BY ROHAN GUPTA, CELLULAR & MOLECULAR BIOLOGY, 2024

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING & DESIGN, 2024

**W**hat makes Earth feel so much like home? For some, crisp fall mornings and hot coffees make this planet the place to be. Others might argue in the name of our endless collection of island beaches and piña coladas that Jupiter just can't offer. At the root of it all, though, there's one thing that we can all agree makes Earth the comfiest destination for humanity's lifetime residence: water.

Where water can be found on Earth, we can almost always expect to find life thriving alongside it. It is the pinnacle of this planet's attention to detail in supporting life; water exists as a stable compound in all three states of matter and acts as a nearly universal solvent in its liquid form, aiding in the distribution of other invaluable nutrients critical to existence. Water's multifaceted chemical characteristics are so ingrained in the processes that facilitate life on Earth that NASA dubbed "follow the water" their motto in the search for extraterrestrial life. So when liquid water is detected on any planet that isn't ours, it tends to be a pretty big deal—and new results from NASA's James Webb Space Telescope, or JWST, are no different.

**“**Water's multi-faceted chemical characteristics are so ingrained in the processes that facilitate life on Earth that NASA dubbed 'follow the water' their motto in the search for extraterrestrial life.”

In early September 2023, University of Cambridge astronomer Nikku Madhusudhan and his team of scientists presented their results on the JWST's findings while exploring the dwarf star K2-18 and its exoplanets—planets that orbit a star outside of our solar system. One of the exoplanets, named K2-18b, has been a target of NASA's hunt for water among the stars since as early as 2015 when it was first discovered by the Kepler Space Telescope. The planet took the spotlight again in 2019, this time capturing the attention of a much greater audience, when the Hubble Space Telescope discovered the presence of water vapor in its atmosphere. Given Hubble's relative limitations at the time, the astronomers from the University College London responsible for publishing the novel findings were unable to confirm whether the atmosphere also contained nitrogen and methane.

Fast-forward through a multitude of exploratory advancements and the successful launch of JWST as a complement to Hubble, infrared astronomy capabilities have provided insight into this previously unanswered question. Both methane and carbon dioxide were detected in Webb's transmission spectrum of K2-18b, and although the presence of these compounds is plenty exciting, the lack thereof of another compound, ammonia, leads to even more enthusiastic speculation. In 2021, a team of researchers led by Renyu Hu from NASA's Jet Propulsion Laboratory published a theoretical study outlining characteristics that qualify exoplanets to be considered "Hycean worlds," planets potentially possessing an ocean-covered surface. Their work showed that planets with liquid water oceans would have increased abundances of carbon dioxide and either water or methane in their atmospheres—and importantly, a lack of ammonia. K2-18b completely satisfies these requisites.

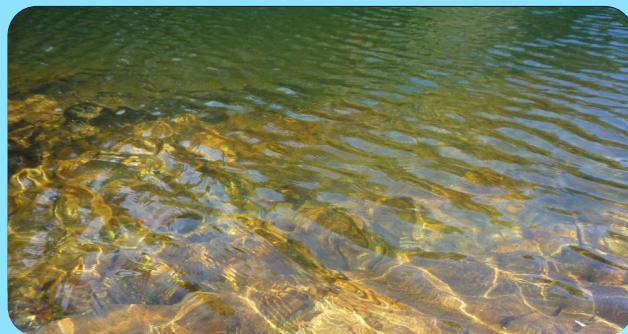


PHOTO BY CLARA BARSOUR; POLITICAL SCIENCE, COMMUNICATION STUDIES & PHILOSOPHY, 2025

To bolster the buzz around this planet further, the telescope's results point to the potential presence of dimethyl sulfide, a molecular byproduct that, on Earth, is excreted only by marine phytoplankton.

Humanity's search for habitable grounds outside the comfy confines of Earth continues to progress with discoveries and detections like those of K2-18b. These most recent findings have been reported to us just two years after JWST was initially launched and represent only the start of a new era of planetary exploration. The discovery of a world potentially covered in oceans beneath a hydrogen-rich atmosphere, similar in description to our very own planet, is just the first drop in the ocean.

*arXiv Preprint* (2023). DOI: 10.48550/arXiv.2309.05566  
*The Astrophysical Journal Letters* (2021). DOI: 10.3847/2041-8213/ac1f92  
*Nature* (2019). DOI: 10.1038/nature01096

PHOTO VIA SHUTTERSTOCK

# THE FOUR FUNDAMENTAL FORCES

## A BRIEF HISTORY OF NATURAL PHILOSOPHY

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

DESIGN BY KATHRYN FURMAN, COMPUTER SCIENCE & MATH, 2025

**P**hysics — from the Latin *physica* (“natural philosophy”), itself from the Greek φύσις (“nature”) — is the study of matter, energy, and the interactions between them. All such interactions fall into one of four categories, known as the **four fundamental forces of physics**, the combinations of which explain with great accuracy the majority of known phenomena.

The first fundamental force, **gravity**, is perhaps the most obvious as it pertains to our lives. The study of gravity began with the first formal descriptions of matter in the fifth century BCE by Democritus of Abdera. From this came Archimedes’ theories on mass in the third century BCE, John Philoponus’ theory of impetus — a precursor to momentum — in the sixth century CE, and Johannes Kepler’s three laws of planetary motion in the early 17th century. These two millennia of progress culminated in Isaac Newton’s *Philosophiae Naturalis Principia Mathematica* (“The Mathematical Principles of Natural Philosophy”) in 1687, which laid out his three laws of motion as well as his law of universal gravitation, one of the first quantitative descriptions of gravity.

The second fundamental force, the **electromagnetic force**, was originally described as two separate forces, electricity and magnetism. Both have been observed since antiquity, with philosopher Thales of Miletus attributing the static charge of rubbed amber (from whose Greek name, ἥλεκτρον, we get the word “electricity”) and the invisible pull of lodestones (from whose source, Μαγνησία, we get the term “magnet”) to deific action, though the two phenomena were pursued separately.

Magnets found utility early on in navigational instruments, with manufacturing methods being discovered as early as 1064 by Chinese scholar Zheng Gongliang. Meanwhile, electricity went almost completely unobserved beyond lightning and triboelectricity, due in large part to the difficulty of studying it.

The first rigorous experiments on magnets would not be done until 1600 by English physician William Gilbert in his treatise *De Magnete* (“On the Magnet”), where he also discussed electricity, though again as a separate phenomenon. The two fields were finally combined in 1820 by Danish scientist Hans Christian Oersted who, during

II That is,  
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universe.”

experiments with voltaic cells and coiled wires, noticed that the current produced by the battery deflected the point of a compass. His observation established the phenomena as two manifestations of a single electromagnetic field. The Scottish experimentalist James Clerk Maxwell then aggregated and quantitatively described the body of research between 1861 and 1862.

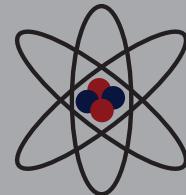
The last two forces — the **strong nuclear force** and the **weak nuclear force** — were discovered much later than the first two, due in large part to the scale of their interactions. While gravity and the electromagnetic force are capable of interacting at a seemingly infinite distance, the strong and weak nuclear forces extend only about as far as the diameter of a single proton.

In 1896, French physicist Henri Becquerel accidentally discovered radioactivity, and what would later become known as beta decay, when working with samples of uranium salts. Italian physicist Enrico Fermi later theorized a mechanism for beta decay in 1933, a first attempt at describing the weak nuclear force.

Following New Zealand physicist Ernest Rutherford’s discoveries of the atomic nucleus and proton in 1911 and 1917, questions arose as to how nuclei could remain stable given that, under electromagnetic theory, their protons should repel each other. With the eventual discovery of the neutron, German physicist Werner Heisenberg put forth the so-called neutron-proton model of nuclear interaction in 1932 to explain nuclear stability, a first attempt at describing the strong nuclear force.

The first formal description of a unified nuclear field model came from Japanese physicist Hideki Yukawa shortly thereafter, laying the groundwork for what would eventually become the Standard Model of Particle Physics. That is, even two millennia following the first formal inquiry into φύσις, we are developing more accurate descriptions of the universe. Still, despite the complexity of our chaotic world, we have distilled physics into four fundamental components, and may yet simplify it still.

*American Journal of Space Science* (2013). DOI: 10.3844/ajssp.2013.33.45  
*Encyclopedia of Condensed Matter Physics* (2024).  
DOI: 10.1016/B978-0-323-90800-9.00155-4  
*The Origin of the Concept of Nuclear Forces* (1996). ISBN: 0-7503-0373-5  
*Journal of Chemical Education* (1929). DOI: 10.1021/ed006p1726



# 2021 PHYSICS NOBEL

## LAUREATE KLAUS HASSELMANN'S INVALUABLE CONTRIBUTION TO CLIMATE SCIENCE

BY SASHI NALLAPATI, CHEMISTRY, 2026

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

The 2021 Nobel Prize in Physics was a notable one, recognizing discoveries that constituted the beginnings of climate science for the 20th century. With scientists measuring record-high temperatures last summer, the research provides a basis for understanding climate change, namely anthropogenic climate change, which demands our attention.

The prize was split in two, with half awarded to Syukuro Manabe and Klaus Hasselmann, and the other half to Giorgio Parisi. Manabe contributed momentous findings regarding interactions between radiation balance and vertical transportation of air. He eventually demonstrated the relationship between increased carbon dioxide levels in the atmosphere and surface temperature. Meanwhile, Hasselmann developed a model that connected weather and climate, attributing increased surface temperature to human emissions of carbon dioxide.

Hasselmann's extensive career as a theoretical physicist began in 1957. While completing his PhD thesis, he detailed a method for understanding a specific facet of wave interactions. Klaus was especially interested in wave mechanics and, at the time, its physical manifestation in ocean wave dynamics. This work led to his first publication where he developed sea state prediction equations.

As his career progressed, Hasselmann founded the Max Planck Institute for Meteorology in 1975. Here, he developed his career-defining "stochastic climate model." Up until the development of this model, it was generally believed that climate change could be traced to one or more external drivers. However, in Hasselmann's model, climate was presented as a combination of internal random variability as well as external drivers. He described climate as being composed of various mathematical dimensions of noise and signals.

Noise refers to variability in climate systems — the pure randomness of weather occurrences. This is contrasted by the signals present within a climate system, which indicate a singular direct contributor to certain weather patterns. The term "noise" highlights the complex nature of climate systems characterized by disorganization and difficult interpretability. It is considered to be probabilistic, or only able to be described by probabilities, eliminating the possibility for a determinate mathematical solution to describe this physical process. In this way, the noise resides in higher, mathematical dimensions governed by probabilistic dynamics while the signals live in the lower

dimensions, governed by deterministic dynamics. This contribution shifted the consideration of climate in the scientific community.

In tandem with this research, mathematical dimensions of space in climate were conceptualized in Hasselmann's multiplex publication titled "PIPs and POPs: The reduction of complex dynamical systems using principal interaction and oscillation patterns." Here, Haseelman sets forth a solution for separating the confusing and distorting noise from the external drivers of a climate system. By considering the deterministic qualities of a climate system, it was possible to separate signals from the random fluctuations characteristic of this climate model. He derived a set of differential equations to describe the low-dimensional system, which includes explicit external drivers affecting the climate. He referred to these as the "principal oscillation patterns," or POPs. This concept addressed the issue of "detection and attribution," which refers to a previous inability to discriminate between the random internal variations and external drivers of a climate system.

This research has been invaluable in detecting climate patterns within a seemingly chaotic climate trajectory. For instance, the POP concept was used to predict the El Niño–southern oscillation. And, while Manabe correlated increased global temperature to increased atmospheric concentrations of carbon dioxide, Hasselmann's detection and attribution theory was influential in connecting this phenomenon to anthropogenic emissions of carbon dioxide. This discovery was used in the U.N. Intergovernmental Panel on Climate Change's recognition of human-induced climate change in 1995 and its potential to intensify without effective policy changes targeting carbon dioxide emissions. Klaus Hasselmann's noteworthy contributions have given life to today's accepted theory of global warming by providing a foundation of scientific fact for this discourse.

*Oxford Research Encyclopedia of Climate Science* (2022). DOI: 10.1093/acrefore/9780190228620.013.931  
*Journal of Geophysical Research Atmospheres* (1988). DOI: 10.1029/JD093iD09p11015

PHOTO VIA SHUTTERSTOCK





Fractals are everywhere in nature for the simple fact that they're both elegant and efficient. Plants, like the ferns in the Hawai'i Volcanoes National Park, try to use as little energy as possible as they grow while filling up as much space as possible to maximize the amount of sunlight their leaves absorb. Their architectural cleverness comes from following a simple repetitive rule: just keep branching.

PHOTO BY JIAJIA FU, BIOENGINEERING, 2026

# One step forward, two steps back

## A glimpse into the Fibonacci sequence

ARTICLE AND DESIGN BY ANANYA JAIN, BEHAVIORAL NEUROSCIENCE, 2025

0, 1, 1, 2, 3, 5, 8, 13, 21 ...

**T**he famed, infinite Fibonacci sequence forms its pattern using a “one step forward, two steps back” approach. It generates each subsequent nth term by adding the two preceding numbers. A mathematical concept rarely elicits excitement; however, Fibonacci’s sequence can help explain how nature creates order and how humans respond to patterns, influencing a myriad of domains. Shown in ecology, finance, music, algorithms, and poetry, this sequence is more powerful than you might have been led to believe in your fifth grade math class.

The sequence predates its publication by Leonardo of Pisa (*the Fibonacci*) and can be traced back to ancient India. It was specifically used for defining rhythm in Sanskrit poetry between long and short syllables. Leonardo of Pisa came across the same pattern upon conducting a theoretical experiment to track rabbit population growth, which spread to the West after his publishing. He postulated how many pairs there would be after mating every month. One pair mates and gives birth to another pair in the third month (creating 1, 1, 2). This growth birthed the pattern we know today.

As each number in the sequence gets logarithmically larger, a spiral can be drawn representing the proportions between Fibonacci squares.

Further deriving and taking the quotient between each successive pair lead closer to the golden ratio: 1.61. A number and sequence seemingly so obscure governs the shapes of nautilus shells, ears, galaxies, and pine cones. These concepts, Fibonacci and the golden ratio, are found in natural happenings like honeybee female to male ratios and manufactured into trader techniques and poetic rhetoric.

Seeing the utilization of this sequence in the workplace, what purpose leads plants, mollusks, and even hurricanes to integrate this rhythmic code? The appearance of these buds, shells, and weather patterns are just as organized and purposeful as the uniform cells inside, where every part is formed with function in mind. A possible explanation is summarized in Anjan Chatterjee’s literary exploration, “The Aesthetic Brain,” where he suggests “these arrangements and spirals seem to minimize energy in systems” due to sunlight and nutrient needs. Chatterjee notes that these seemingly coincidental patterns appearing countless times in nature bolsters the idea that this composition is no accident. Rather than nature being completely random, this concept suggests that it is more orchestrated chaos.

“A simple ‘one step forward and two steps back’ rhythm to numbers has had such great impact on our world, humans and nature alike.”

Much can be discerned about the ways math reveals nature’s hidden patterns to us observers. A simple “one step forward and two steps back” rhythm to numbers has had such great impact on our world, humans and nature alike. This infinite string of numbers has been harnessed from the wild as a tool for both analysts of the 21st century and poets of the second.

*The Aesthetic Brain* (2013). ISBN: 9780190262013

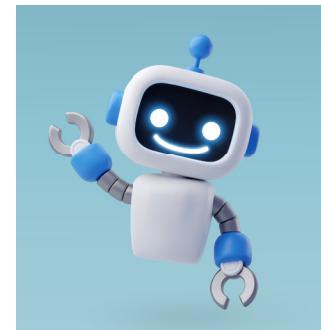
PHOTOS VIA PIXABAY

# Chatbots

## Who are you really talking to?

BY RAISA BHUIYAN, COMPUTER SCIENCE & MATHEMATICS, 2025

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING & DESIGN, 2024



**t** is likely that, at some point, you have opened a website and saw a chat box pop up at the side of the page with a message from someone asking how they could assist you.

Have you ever wondered who was on the other side of that conversation? Maybe it was a human or maybe it was a bot. How would you even tell the difference between the two? Traveling back in time to the middle of the 20th century may help answer this question.

In 1950, computer scientist Alan Turing published an article titled “Computing Machinery and Intelligence,” in which he first contemplated the question of whether machines can think. He discussed that this question was difficult to answer, and instead asked whether a computer could communicate in a manner almost identical to that of humans: Could a computer successfully make a person think they are speaking to another person?

Turing tested this by creating the “imitation game,” also known as the Turing test. This game involves three players: A, B, and C. Either player A or B is a computer, and player C must determine which is which by asking them questions and evaluating how “human” each player’s answers sound. If the computer can successfully trick player C into thinking it is human, then it passes the Turing test.

Artificial Intelligence (AI) is used in chatbots, software that communicates with either humans or other bots to simulate human interaction. Chatbots undergo the Turing test to determine if they can behave like humans. An early example of this is ELIZA, a chatbot created at MIT in the 1960s by Joseph Weizenbaum. ELIZA was supposed to act as a psychotherapist for users to talk to about their issues. It crafted responses to users’ questions by pinpointing certain keywords or by rephrasing the question. Although ELIZA was very limited in what responses it could give and was not capable of in-depth conversation, many users still had a hard time realizing they were talking to a piece of technology.

ELIZA was not supposed to pass the test since it cannot express basic emotions, yet users grew attached to ELIZA; they were confiding in the software as if it were their closest friend. People started associating ELIZA with human characteristics, leading to the coining of the term “ELIZA effect,” which describes the phenomenon where people associate AI with human characteristics. Weizenbaum warned people against letting machines make human choices, arguing that it was both wrong and dangerous to

give computers such power.

Now, some researchers think it is possible for GPT-4 to pass the Turing test since it can trick people into thinking they are speaking with a human within short conversations. In May 2023, a lab in Tel Aviv had 1.5 million players chat with either other humans or with a chatbot powered by Large Language Models — the same type of model as GPT-4 — that was built to mimic human behavior. Players identified bots around 60% of the time, which is not much better than chance.

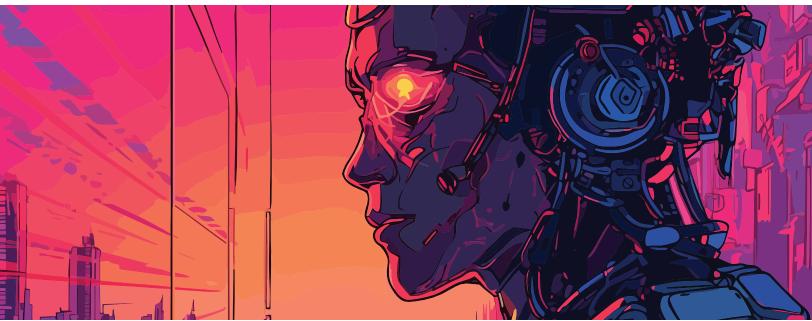
This means that the Turing test may not be the best way to test AI. In fact, Mustafa Suleyman, former head of applied AI at Google’s AI research lab DeepMind, expressed uncertainty regarding the effectiveness of the Turing test. In his book “The Coming Wave: Technology, Power, and the Twenty-first Century’s Greatest Dilemma,” he wrote, “It doesn’t tell us anything about what the system can do or understand, anything about whether it has established complex inner monologues or can engage in planning over abstract time horizons, which is key to human intelligence.”

Alternatives to the Turing test exist: OpenAI, the group that created GPT-4, has its own set of benchmarks for AI tests that include coding, reading comprehension, and mathematics tests. GPT-4 has done well in these, too — it performed at around the 90th percentile on the bar exam and it performed at around the 80th percentile on the GRE. It is unclear whether these benchmarks are useful, but this new method could be more thorough than Turing’s. Regardless, it remains clear that it is time for new puzzles to test AI.

*Nature* (2023). DOI: 10.1038/d41586-023-02361-7  
*The Coming Wave: Technology, Power, and the Twenty-first Century’s Greatest Dilemma* (2023). ISBN: 978-0593593950  
*DEStech Transactions on Computer Science and Engineering* (2019).  
DOI: 10.12783/dtcse/aicae2019/31439

PHOTOS VIA SHUTTERSTOCK





**A**t the crossroads of order and chaos, humanity has consistently sought paths leading to discovery and invention, creating equilibrium amidst perpetual disorder. Calm, in this context, embodies the rules governing human civilization — a structured order that harmonizes existence and guides our collective journey toward desired outcomes. Take Mesopotamia for instance, the earliest urban and literate civilization globally. Mesopotamia pioneered the establishment of societal structures, laying down foundational rules for governance and culture.

However, within this structured calm, a term known as singularity emerges as a conceptual veil poised between our world of calm and the uncharted territories of chaos and uncertainty. This enigma emerges when the foundations of our knowledge, rules, and theories crumble, challenging the essence of our understanding. It presents a dichotomy: facing the dark fear of the unknown or embracing the exhilarating excitement of unexplored possibilities on the horizon.

In today's world, technology stands at a precipice, steadily advancing toward the elusive veil of singularity — a point where the familiar norms of our digital realm dissolve, prompting us to ponder the mysterious spaces that lie beyond. In essence, technological singularity is a hypothetical point where progress knows no bounds, transcending exponential growth to become hyper-exponential, potentially reaching infinity within decades.

Achieving this point likely involves artificial intelligence (AI), which can be classified into three types. Artificial narrow intelligence (ANI) is designed for specific tasks, exemplified by technologies such as virtual personal assistants, facial recognition software, chess-playing programs, and self-driving cars. On the other hand, artificial general intelligence (AGI) represents a level of intelligence in machines that mirrors human cognitive abilities. AGI machines have the capacity to understand, learn, and apply knowledge across a broad spectrum of domains. Finally, artificial superintelligence (ASI) is a theoretical concept that envisions machine intelligence surpassing human intelligence comprehensively across all domains.

The rapid progress of science and technology facilitated by ASI holds transformative potential across various domains. In the realm of scientific discovery, ASI's ability to process vast datasets and comprehend complex simulations could unlock breakthroughs in physics, biology, and other scientific fields.

BY SAAKSHI SHAH, BIOTECHNOLOGY, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

## CALM, CHAOS, AND THE TECHNOLOGICAL SINGULARITY

Moreover, in material science and engineering, ASI's design capabilities could lead to the creation of unprecedented materials, impacting industries such as construction and aerospace. ASI's influence extends to addressing energy challenges by developing innovative solutions, including efficient fusion power and alternative energy sources.

In the domain of problem-solving and optimization, ASI has the capacity to tackle global issues like climate change and poverty through comprehensive and interconnected solutions. Economically, ASI's analysis of data and trends could predict market shifts and optimize resource allocation for global prosperity. In the healthcare sector, ASI's analytical prowess could revolutionize personalized medicine, predicting diseases and crafting individualized treatment plans for substantial improvements in healthcare.

As ASI looms as the ultimate AI, promising unparalleled problem-solving, creativity, and efficiency through recursive self-improvement, ethical and existential questions arise. Can we control and ensure the safety of ASI, navigating its implications for humanity? Balancing innovation and responsibility is crucial, necessitating collaboration, ethical frameworks, and legal regulations in navigating machine learning, neural networks, and quantum computing to maximize ASI's benefits while minimizing risks. This transformative journey requires a thoughtful approach, recognizing the promises and perils of ASI, as today's decisions will shape the future of human-AI coexistence.

Intelligence doesn't always lead to complexity. ASI, despite its perceived complexity and superior intelligence, might actually end up choosing straightforward or simple solutions to address problems.

Furthermore, while popular sci-fi narratives depict ASI potentially taking over the world, what if ASI, much like humans, shares a fundamental characteristic — the inclination to question its purpose? This introduces a philosophical dimension to the discourse, prompting contemplation on whether ASI, akin to humans, could grapple with existential inquiries regarding its own existence and objectives.

The realm of singularity is laden with speculative "what if" questions, each prediction carrying heavy weight. Amidst this uncertainty, our current power lies in following computer scientist Ray Kurzweil's insight: "What we spend our time on is probably the most important decision we make."

*Information* (2018). DOI: 10.3390/info9040082

*AI - The new intelligence in sales* (2022). DOI: 10.1007/978-3-658-38251-3\_1

PHOTOS VIA SHUTTERSTOCK



# Connecting the dots

## A look into applications of Graph Theory

BY HOAN LA, MATHEMATICS, 2025  
DESIGN BY KATHRYN FURMAN, COMPUTER SCIENCE & MATH, 2025

- At first glance, graphs are collections of nodes, or vertices, connected by lines, or edges. Although visually simplistic, they are surprisingly useful as tools, especially in machine learning. As Frank Harary, a founder of *The Journal of Graph Theory*, once wrote, "It has become fashionable to mention that there are applications of graph theory to some areas of physics, chemistry, communication science, computer technology, electrical and civil engineering, architecture, operational research, genetics, psychology, sociology, economics, anthropology, and linguistics." Fundamentally, graphs can model any relation between objects, from websites to animal species to molecules.

### Google's PageRank algorithm

The Google search engine has dominated humans' lives for decades. The key to its effectiveness is a powerful algorithm. But how does it work? And what makes it so powerful? The short answer is PageRank.

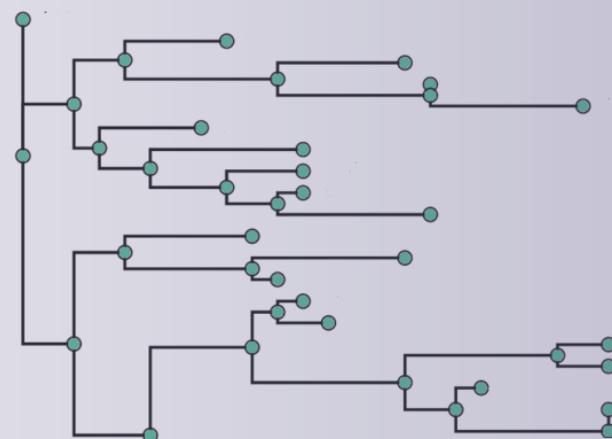
Mathematically speaking, the algorithm is the application of Markov Chains. These are directed graphs in which two nodes are connected by arrows with values assigned to them rather than simply by lines. Each arrow's values represent the probability of going from one node to another, and, according to the rules of probability, the sum of the values going out of each node must be 1. So, if a node has only one arrow pointed out of it, the value of its arrow must be 1. Consider a graph with nodes A, B, and C where the starting node is A. If A has arrows pointing to nodes B and C, both arrows may have probabilities of 0.5 (as  $0.5 + 0.5 = 1$ ). So, half the time, if a person is standing at node A, they will travel to node B. Similarly, half the time, they will

travel from node A to C. This process of traveling between nodes can be repeated and is called a "random walk."

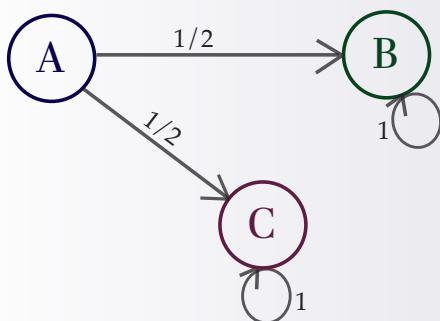
PageRank is a random walk on the World Wide Web graph, where the nodes are webpages and the arrows are hyperlinks. Before PageRank starts, it assigns each hyperlink

with the same probability. Given n pages, each probability is  $1/n$ . The total probability of ending on a particular page is then the number of its hyperlinks times  $1/n$ . If a page has 6 hyperlinks, for example, the total probability is  $6/n$ . At each step, PageRank reevaluates each probability. Thus, given a page with the most hyperlinks, the probability of ending on such a page is higher than any other page. This process is how the ranking of a page after a Google search is determined, hence the name PageRank. Explicitly, the page with the highest probability has rank 1, the second highest has rank 2, and each subsequent page is ranked according to this ordering of probabilities from highest to lowest.

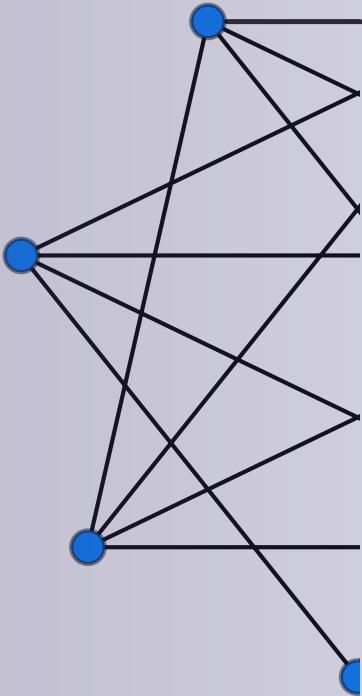
### Phylogenetic tree reconstruction



From the evolutionary trees in secondary school to mapping families of organisms, phylogenetic trees help explain the process of species grouping. It may be assumed that graphs can simply be used in the following way: take a group of any animal, say birds. Each bird is a node, and two birds are connected via a line if they are related. However, this representation only shows whether two birds are related and not how related they are.



As with PageRank, each line on the graph can be assigned a value. However, the graph representing phylogenetic trees is different than a Markov Chain. In this graph, the values of each line take distance, or relatedness, into



account: Small values between nodes mean they are closely related, while larger values indicate they are loosely related. With the graph of the phylogenetic tree, it is then possible to construct a phylogenetic tree explicitly by finding the common ancestor of all species first and then its descendants, using normalized graph cuts.

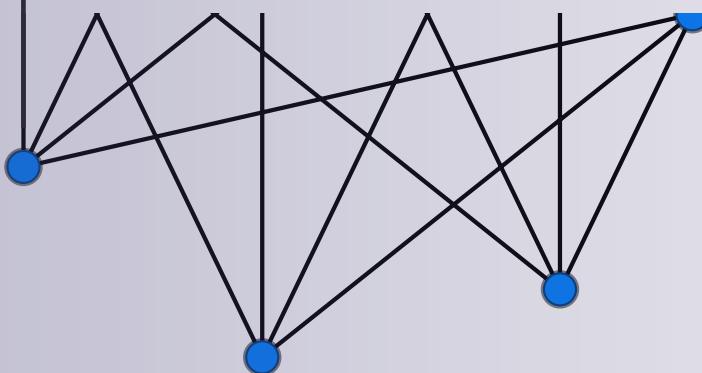
A graph cut, as the name suggests, is the removal of a node from the graph. To determine which node to cut, each node is given a value, which is the sum of all values of lines connected to such node. The nodes are cut according to an ordering of these values from smallest to largest. The smallest value is cut first, then the second smallest, and so on. A “normalized” graph

cut is different only in how the value of each node is computed. Instead of just taking the sum, the value is then divided by the total number of lines in the graph. If there are two or more nodes with the same value, then all of them are cut simultaneously. In the context of phylogenetic tree reconstruction, the first cut node is the common ancestor, the second cut node is its direct descendant, and each subsequent cut node is the direct descendant of the previous.

### Protein-protein interactions networks

Proteins interact with other proteins. By studying protein-protein interactions (PPIs), scientists seek to better understand their behavior and their roles collectively. Graphs can be used to model the disassortative or assortative nature of the PPI networks, which is to say how the PPI networks are organized. Disassortative PPI implies that the proteins involved are genetically dissimilar, while assortative PPI implies that they are genetically similar.

The “assortativity” of a graph refers to how nodes connect to one another based on their properties. Assortative graphs have nodes that connect to each other if they have similar properties. Conversely, disassortative graphs have nodes that connect to each other if they have dissimilar properties.



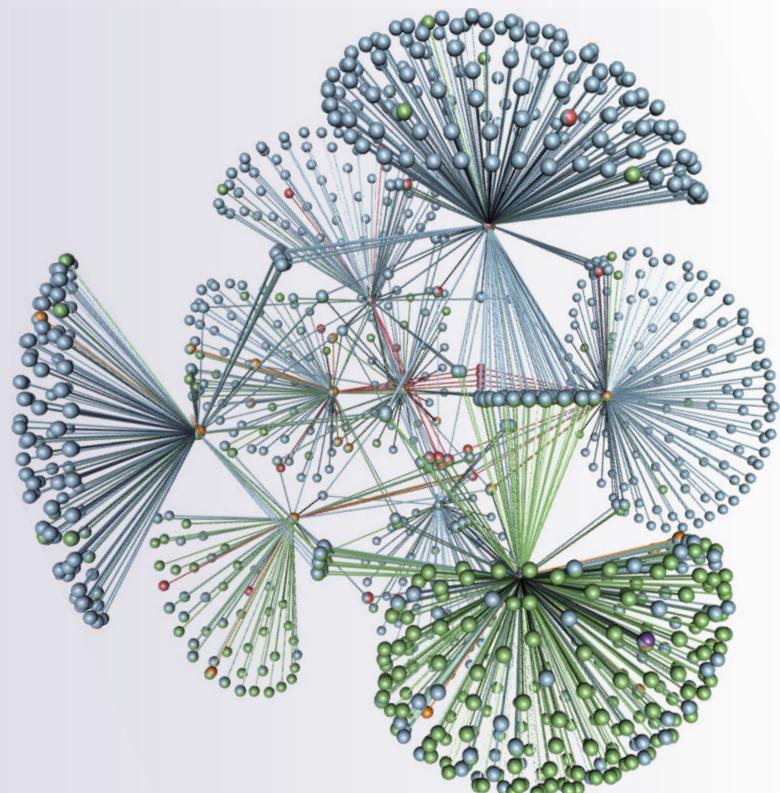
In this setting, each node is a protein. If they interact, then they are connected via lines. For assortative graphs, nodes tend to form one collective hub. For disassortative graphs, nodes are found in different groupings or clusters. As PPI networks are thought to be more disassortative than assortative, graphs may help study the complexity of these proteins.

\* \* \*

These applications are among a few in a myriad of uses for graphs. Yet they can model any relationship between objects. Moreover, they are very visual, providing insights into how they work. As a field of study, graph theory speaks to the omnipresent aspect of mathematics; the fact that it is universal in its power to describe and study the world.

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*Graph Theory* (1972). ISBN: 978-0201027877  
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PHOTOS VIA RESEARCHGATE & WIKIMEDIA COMMONS



# Journeying through healthcare inequality in South Africa



BY AIZAAZ FAIZ, BIOCHEMISTRY, 2026

PHOTO BY JIAJIA FU, BIOENGINEERING, 2026

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

**W**alk through an average South African hospital, and you'll see crowded waiting rooms full of unstable patients. Meet the diverse patients hailing from the largest cities and the smallest villages. Admire the nurses who work tirelessly to provide care despite staffing shortages and crumbling hospital infrastructure.

Drive ten minutes through the city and arrive at a state-of-the-art hospital. Now, you'll observe the overwhelmingly white patients who fly from around the world to reap the benefits of their privilege. The benefits include accomplished staff, brand-new machines, and immediate care. Such is the state of inequality that continues to plague South Africa post-apartheid.

This summer, I explored healthcare in South Africa on a Northeastern University Dialogue of Civilizations. I traveled alongside a group of 20 students, primarily health science majors, and we were given unrestricted access to many public and private hospitals in South Africa. South Africa provides universal healthcare to its citizens, but the difference in care between public hospitals and the private hospitals used by the wealthy is stark. In comparison, America is primarily driven through a private healthcare system, with some governmental health coverage provided through Medicare and Medicaid. It provides a consistent standard of care — but only to those who are insured. Both health systems have their own positive features, alongside their weaknesses.

## PUBLIC HOSPITALS: STAFFING SHORTAGES AND WAIT TIMES

The South African universal healthcare system is divided into three major levels: national, provincial, and local. Sue Armstrong, a professor at the University of the Witwatersrand, explained to our class that the national level creates healthcare policies but can do little to enforce them upon provinces. Each province manages its hospitals and its healthcare budget depending on the needs of its people. Local clinics function as ground-level providers that make healthcare accessible to all in South Africa. They exist in the highest number of all the three levels of healthcare.

The local clinics are spread throughout the many rural areas and developing townships of South Africa in order to provide medical care to those who aren't fortunate

enough to live close to a major hospital. Our class was given a tour of one of these clinics at Chiawelo Community Health Center. What immediately stood out was the lack of doctors. The clinic focused on primary care and was primarily nurse-run alongside a few physician assistants. During our tour, a physician assistant explained to us that — unlike in America — in South Africa, many nurses are certified to prescribe medicine. This was one of many healthcare policies the South African government has put in place to subdue the shortage of doctors.

On a visit to the Charlotte Maxeke Johannesburg Academic Hospital a few days later, our class was able to observe the emergency department, operating rooms, and even medical imaging rooms. A group of students and I even got the opportunity to put on scrubs, observe two operating rooms, and interview surgeons. When asked about any problems they've directly noticed in the healthcare system, the surgeons emphasized a problem with waiting times. They explained that non-life-threatening surgeries have extreme wait times and are difficult to obtain without seeking private hospitals.

This issue of waiting times was evident among the other parts of the hospital we visited, perhaps as a result of staffing shortages. The emergency room was very crowded and it was clear that patients with severe, debilitating injuries were not being seen at a rate comparable to the U.S. Apart from the problems, the surgeons emphasized that the beauty of their healthcare system is that everyone receives some form of value and care at little to no cost.

## PRIVATE HOSPITALS: SAME COUNTRY, A DIFFERENT WORLD

One week passed after our visit to the Charlotte Maxeke Johannesburg Academic Hospital. We traveled from Johannesburg to the beautiful city of Cape Town. Surrounded by the sea and coastal beaches, the vacation town had a calmer atmosphere than the bustling and industrialized Johannesburg. Instead of visiting a public hospital, our class explored the Life Vincent Pallotti Private Hospital and had a very different experience.

This hospital was fully staffed, clean, and according to the employees, the oncology center contained some of the



"best radiation equipment in Africa." I was taken into a chemotherapy center, and the nurses explained to me that wealthy people from around the world would travel to access the excellent facilities at the hospital. Furthermore, I noticed that it was much less busy than the public hospitals we had visited, and the wait times seemed insignificant.

Our group noticed that the majority of the patients in the hospital were white, which stood out considering that only 8% of South Africa's population is white. Unsurprisingly, when we asked our hospital guide about this, they dismissed it immediately without a thoughtful response.

Exploring this hospital helped us to better understand the idea of disparity. According to the CDC, health disparities "are preventable differences in the burden of disease, injury, violence, or opportunities to achieve optimal health that are experienced by socially disadvantaged populations."

Our class visited the Apartheid Museum, alongside the Mandela House, and these experiences gave us a glimpse of some of the ugly injustices that took place in such a beautiful nation. South Africa's massive health disparity can be better understood through its history of Apartheid. Apartheid was the policy of racial apartness, which segregated South Africa through its schools, housing, and hospitals until 1994. Although the physical policy of Apartheid has been done away with, South Africa was wounded, leaving scars of financial inequality that bleed the health disparities we view today.

#### HOW DOES THE US COMPARE?

Extreme healthcare inequality is not isolated to South Africa. Although America is home to some of the greatest research and medical facilities in the world, 27.5 million Americans are uninsured and cannot afford to access them. Both South Africa and the U.S.'s healthcare systems have successful aspects alongside their flaws. As an American public health student, I have seen many interesting South African innovations that I wish America would adopt and vice versa.

The beauty of the American system is that people with private and governmental insurance are able to walk into the same hospital and receive a similar standard of care. South Africa's system creates two different worlds. By having separate standards and hospitals for the public and private systems, South Africa creates financial segregation and causes the poor to receive a lower level of care than the rich. But South Africa's ability to make healthcare accessible to all is admirable. The country does what America fails to and ensures that all of its citizens receive some form of healthcare.

To achieve universal healthcare is very difficult, however, and something more feasible that America can adopt from South Africa is their larger presence of nurses in healthcare. Professional nurses can prescribe medicine in South Africa, which allows far more people who cannot reach doctors to access healthcare. This concept could be applied in America to lower the costs of healthcare as individuals could see nurses instead of doctors for certain medications and potentially pay less for the same appointments.



PHOTOS BY ANNA DENG VIA NORTHEASTERN UNIVERSITY

South Africa has also begun using community-oriented healthcare models that utilize community health workers who physically enter communities and perform checkups in people's homes, providing high population access and satisfaction. If these models are carried out at the same standard of care as our private system, they can be applied to lower-income communities in the U.S. to provide low-cost healthcare to a large scale of people.

Healthcare access is an extremely complex and expensive issue that does not have a clear solution in America or South Africa. However, both nations have certain aspects that work within their healthcare systems, and both are able to learn from each other. Visiting South Africa allowed me to better understand global health systems and how they can play a part in improving American health policies. I dream that a day will come when the governments of South Africa and America will be able to provide quality healthcare to their citizens as a basic human right. I imagine that one day I will visit South Africa again to see a high-quality universal healthcare system, and return to America to find a healthcare system that doesn't exclude those with less.

*BMC Health Services Research* (2011). DOI: 10.1186/1472-6963-11-330

*African Journal of Primary Health Care & Family Medicine* (2022). PMCID: PMC8905368



# Baby-Blue Blood: Nature's Antidote

BY ASHNA SHAH, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

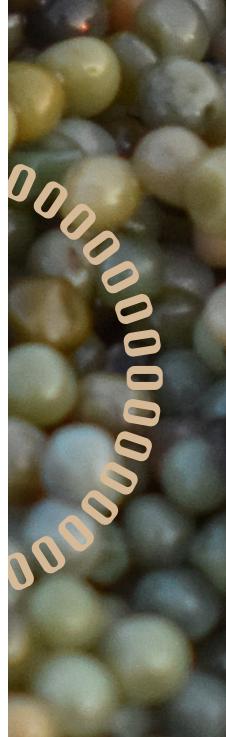
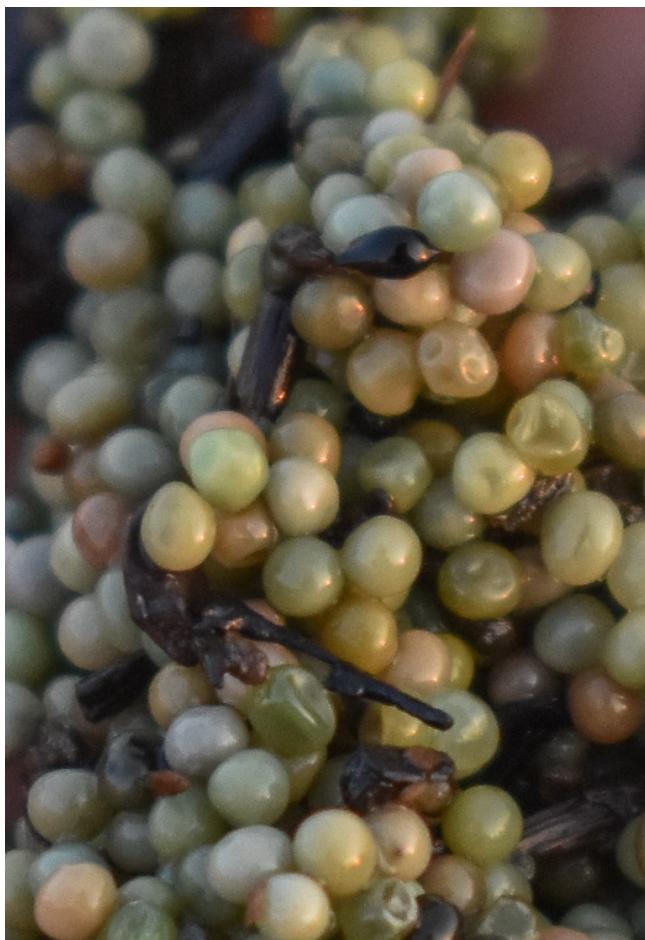
**A** creature more ancient than dinosaurs by over 200 million years, the Atlantic horseshoe crab is an organism treasured by conservationists, biomedical researchers, and even Northeastern's very own "Dang, I love fossils" club. With five pairs of claws and able to grow up to two feet long, the horseshoe crab is an incredibly useful animal in many areas. These horseshoe crabs serve as a huge factor in maintaining the ecosystems of the Atlantic coast. Their eggs are used to nourish the red knot bird, a threatened species. The Atlantic horseshoe crab is also a common form of fishing bait used to attract eels and conchs. Additionally, and perhaps most importantly, it was discovered in the 1960s that this prehistoric creature contains a powerful substance for scientific research — its baby-blue blood.

The Atlantic horseshoe crab's blood is used as a reliable determinant of toxin

levels in scientific technologies such as vaccines, antibodies, gene editing drugs, and implanted medical tools. These crabs are the sole source of a substance called limulus amebocyte lysate (LAL), a toxin-sensitive tool used in biomedical research. In the presence of endotoxins, a specific type of harmful substance, the blood will start to clot in a mechanism of self-defense. Much controversy exists surrounding the use of these crabs, primarily for biotechnology companies and the often lethal "bleeding process" the crabs undergo before being returned back to the wild or fisheries. Now, scientists are looking for alternatives.

These crabs populate the eastern coastlines of the U.S. and the Gulf of Mexico. In 2021, over 700,000 crabs were drained of their blood — the highest count since the early 2000s. With the increasing need for both the crabs themselves and their blood,





safer methods of extracting the blood have been developed to ensure the crabs' survival. However, according to the Atlantic States Marine Fisheries Commission, the bleeding process is still lethal for about 112,000 crabs, amounting to 15%.

The crabs are shipped off to various biomedical facilities for the process. A needle is inserted into the crab's chest cavity and an absolute maximum of 400 milliliters of blood can be drawn at once. The mixture is handled in temperate environments to avoid unwanted clotting. Unfortunately, it takes dozens of crabs to generate one vial of blood. A gallon of blood is worth a whopping \$60,000. Depending on the state, the crabs are then transported back to their native habitats in South Carolina or New Jersey, or sold as bait in Massachusetts.

Once harvested and maintained, the blood is incorporated into the LAL test, which is a research procedure that allows scientists to determine the toxin concentration of a drug to determine whether it is safe for human use. The LAL test specifically detects levels of endotoxin, a component of bacterial membranes that humans are highly sensitive to. Upon endotoxin detection, the blue blood will clot corresponding to the endotoxin concentration, with more clotting representing higher levels and thus indicating that a drug is unsafe for human use.

Since endotoxin elimination remains critical for drug development and discovery as the numbers of healthy Atlantic horseshoe crabs diminish, alternatives to the LAL test are needed. Two such potential options are the Recombinant Factor C(rFC) test and the monocyte activation test (MAT). One of the benefits of rFC is that it utilizes a non-animal substance to detect endotoxins. The substance is a synthetically generated clone of Singaporean horseshoe crab blood and has the same mechanism of action as the blue blood in the LAL test. Considered an untraditional method, the rFC method is not popular, but according to an article published in *Frontiers in Marine Science*, it is more sensitive and specific. MAT, on the other hand, uses human white blood cells extracted from blood samples and is typically used secondary to LAL. MAT is limited because it is unable to detect certain cytotoxic substances, so further development is needed on this technique.

At present, LAL tests dominate the industry in terms of endotoxin detection, so a major driving force is needed to inspire tests like rFC to become more popular. A decline in flourishing horseshoe crab populations and disruptions to coastline ecosystems are major drawbacks in the use of these crabs as the sole source of toxin testing. Both MAT and especially rFC serve as promising options for LAL alternatives. The increased use of one of these alternate methods could greatly improve the quality of life of the Atlantic horseshoe crab and increase population numbers along the entire East Coast. It would also hopefully revitalize the threatened red knot bird population, which depends on the crabs.

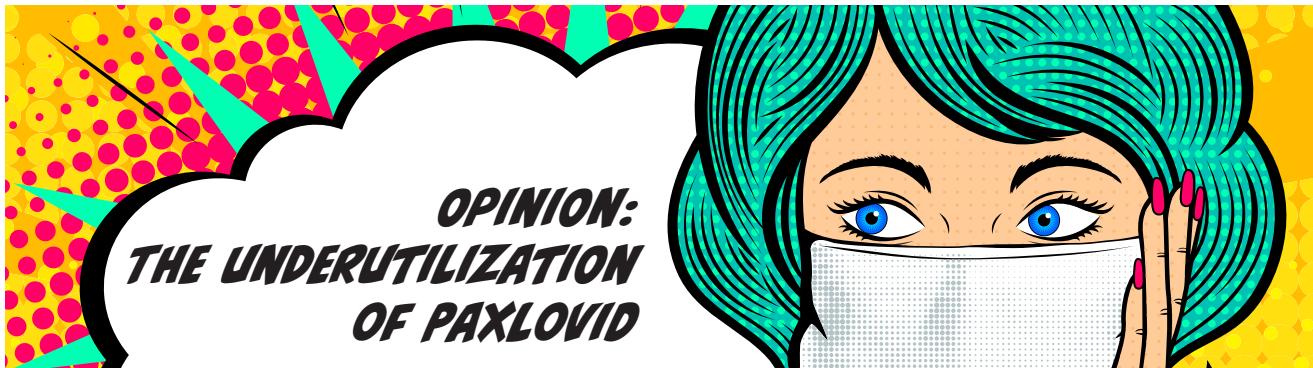
*Agriculture and Natural Resources* (2018). DOI: 10.1016/j.anres.2018.08.002

*Frontiers in Marine Science* (2018). DOI: 10.3389/fmars.2018.00185

*PDA Journal of Pharmaceutical Science and Technology* (2017).

DOI: 10.5731/pdajpst.2017.007849

PHOTOS BY JIAJIA FU, BIOENGINEERING, 2026



BY SANDEEP SOOD, BEHAVIORAL NEUROSCIENCE, 2027

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

**P**icture this: You have gotten sick from COVID-19 before. So much so, your family is worried you will be hospitalized the next time you catch the virus. After consulting your doctor, you find out about a new drug recently approved by the FDA that can mitigate the severe effects of a COVID infection, allowing you to continue life as normal — a wonder drug called Paxlovid.

The catch: It is not available for you.

Paxlovid is a drug developed by American pharmaceutical giant Pfizer to combat the severe effects of COVID-19 infection in high-risk patients. It works by disabling protease, an enzyme that cuts and frees viral proteins from longer protein sequences, allowing the virus to replicate itself. Each dose of Paxlovid contains two pills, called nirmatrelvir, that block proteases, as well as the booster pill, ritonavir, that prolongs nirmatrelvir's effects. Taking two doses a day, a severely-affected patient can expect to make a recovery within five days, instead of spending the usual two weeks cooped up in an ICU.

Despite the immense benefits of the drug, prescriptions have remained shockingly low. Paxlovid's rushed launch in the middle of the pandemic caused it to be in limited supply and only prioritized for high-risk COVID patients. Pfizer's refusal to allow research on the bioequivalence of other drugs with Paxlovid and its interactions with other medications have further contributed to its short supply.

"Companies like Pfizer often object to follow-on studies by others, including combinations, because they fear discoveries of previously undisclosed side effects," said Brook Baker, senior policy analyst at Health GAP and professor of law at Northeastern University.

These restrictions on the supply and research surrounding Paxlovid have unfortunately impacted its marketability. Physicians often do not trust the compatibility of Paxlovid for their patients because of the limited clinical research. Furthermore, research that has been conducted on Paxlovid's effectiveness often disagree on whether it actually improves

COVID-19 symptoms and recovery rates or not in a safe manner, adding to the mistrust towards the drug.

Physicians' fears, combined with little to no industry or financial incentive, has led to the refusal of insurance companies to extend coverage for Paxlovid. "Despite the government paying for Paxlovid and despite the widespread availability of federally procured self-tests," Baker said. "Insurers may have incurred costs for either initial or confirmatory COVID tests, for in person or online consultations, and for prescribing." This lack of adequate coverage places the burden of paying for treatment on COVID patients and their loved ones, denying many access to proper treatment. Patients who are covered for Paxlovid or can pay out-of-pocket may still be out of luck. The irregular supply of the medication means that many pharmacies either do not carry the medication at all or do not communicate to physicians when they have it in stock, leading to fewer prescriptions.

These conflicting factors around the availability of Paxlovid have led to Pfizer constructing a near monopoly over COVID-19 treatments. "When Paxlovid began private sector sales," Baker said. "It increased the price to \$1,390 per course of treatment, 100 times the estimated costs of production." To mitigate this, the Biden administration launched its "Test to Treat" initiative in March 2022 to provide Paxlovid treatments at a reduced or free cost to patients who qualify. However, these programs are only available at select pharmacy locations that are often located far from communities who would benefit from them most, such as older and minority populations.

Opposing monopolistic practices in the healthcare industry, as seen with Pfizer, is the best method we have to combat the discriminatory use of treatments such as Paxlovid. "We simply have to do more to overcome patent and trade secret barriers, to expand production, to lower prices, and to distribute global public goods equitably to all in need," Baker said.

PHOTO VIA SHUTTERSTOCK

# THE NATURE OF PSEUDOSCIENCE

BY ASMITA ADYA, BEHAVIORAL NEUROSCIENCE, 2026

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025



**A**rticles, blog posts, and Instagram accounts sometimes tell us that the world will end on a particular date, evoking a strong sense of panic. Some people frantically change their behavior altogether due to sudden news that the world will be ending. Concerned individuals may prepare for this time period by nestling in their basements with their closest loved ones, mentally unready for their sealed fate.

Doomsday predictions like the 2012 Maya Apocalypse, the Taiwanese True Way Prediction of 1988, and several others impacted respective communities as news spread. Dire warnings such as these trace back centuries, including Johannes Stöffler's Great Flood Doomsday Prediction of Feb. 25, 1524. Due to Stöffler's status as a noteworthy and influential mathematician and astronomer at the time, individuals fully believed a vast flood would submerge the world. In preparation for calamity, German nobleman Count Von Iggleheim even built a three-story ark. Despite these prophecies of catastrophe, the world has, in fact, survived. Yet, conspiracy theorists still insist that you are likely to encounter extraterrestrial species and go missing, rendered forever isolated, if you dare to enter the Bermuda Triangle. The lack of proof makes you wonder, however, if these claims hold any merit.

According to Dr. Google, acupuncture and acupressure treatments are valid in providing internal healing and alleviating limb pain; these and other alternative medicines are claimed to holistically treat cancer, but why do patients not see any signs of remission?

The Earth, which some Internet users note is flat and hollow, is in fact not experiencing any climate change according to

other online "experts," so human activities apparently have no impact on the environment. Fantastic—these claims seem to prove everything we input and emit lacks consequence!

Often, the pseudoscience we encounter in the media and through research is nearly indistinguishable from fact by the naked eye. It is presented in a convincing, authoritative manner with supposed "scientific fact" to support claims and pose a robust argument.

To effectively detect pseudo-intelligence from actuality, we must analyze the nature of pseudoscience. Pseudoscience is often convincingly presented with the support of a prominent social figure or a media source that is deemed reputable. Facts are often fabricated or entirely theoretical, and this is where readers must carefully investigate research methods, quantitative and qualitative data, and primary sources of data. Ask questions as you engage with research, and be sure to think critically about all components: hypotheses, claims, statistics, and conclusions.

Many pseudoscientific arguments share common elements. They are often unfalsifiable, utilize anecdotes and personal story testimony, and exclude alternative evidence. They also tend to neglect the totality of data, lack effective scientific language, exaggerate claims and evidence, and are anti-progressive. Awareness of these characteristics can allow one to spot pseudoscience upon internal reflection of the content they are consuming. Professor David Richters, a psychologist and vision scientist at Northeastern University, explains that it is crucial to realize that science is never quick to close the door on a theory. Thus, it is a red flag if any claim entirely dismisses a subject.

In order to engage our critical thinking skills when consuming science, research recommends a stronger science education starting from youth, as it is currently poor and rapidly deteriorating. This will equip our society with the mindset to discern science from a lack thereof. Adults can exercise critical thinking skills by investigating research methods in literature, gauging where statistics have originated, and assessing the pioneers behind strong scientific claims.

Pseudoscience can be incredibly damaging to our wellbeing and state of affairs. It presents plausibly fabricated or exaggerated theories and data as indisputable, wreaking unnecessary havoc and capitalizing on diminishing critical thinking skills due to differences in quality of science education. Question everything, as naivete is the culprit of susceptibility to the deceptive persuasion of pseudoscience.

*The American Biology Teacher* (1990). DOI: 10.2307/4449128

PHOTOS VIA SHUTTERSTOCK

# Researchers and journalists debate over pseudoscience allegations in consciousness theory

124 scientists signed a letter criticizing the media's coverage of a consciousness theory. A Northeastern professor who signed the letter and the journalist who wrote The New York Times's coverage weigh in.

BY NOAH HAGGERTY, APPLIED PHYSICS, 2024

BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

**C**arl Zimmer, a journalist for *The New York Times*, walked into a Ballroom in Greenwich Village, where a New York University professor's band was jamming out. The evening seemed a bit too exciting for a scientific conference. Consciousness science's biggest names were all there, including Christof Koch, who had personally invited Zimmer. The evening culminated in researchers presenting results from a new study that pitted two prominent theories of consciousness head to head. It moved fast with flashy slides; Zimmer scribbled down notes and recorded everything.

"It was challenging because these theories for consciousness are all very complex, and the way that you test them experimentally itself is also very complex," Zimmer said. "And they were ramming that stuff through pretty fast." In the young field of consciousness science, there has been little consensus, but now, some researchers are claiming one theory, Integrated Information Theory, or IIT, is accumulating significant evidence and support. Others fiercely disagree. One scientist told Zimmer the results of the study presented at the conference confirmed the predictions of IIT, and another said the results were mixed. One week later, *The New York Times* published Zimmer's article with the headline "2 Leading Theories of Consciousness Square Off."

Jorge Morales, a philosophy and psychology professor at Northeastern was also attending the conference and was even more off-put by the event. "The results were presented as an entertainment event, and that's really not something that sits well with many people," said Morales. "This is real science. The details are really tricky. It's a very complex experiment."

Just a few months later, Morales would sign a letter with over 120 fellow scientists calling IIT a pseudoscience. The signers are worried the public — and other scientists — have an incorrect view of the state of the field, partly due to the media for failing to highlight issues with the theory and present nuance. For the signers, this is a serious problem: IIT — which says computers, animals, fetuses, and many other complex systems have consciousness — has serious implications for many controversial political and social issues like AI, animal rights, and abortion.

The pseudoscience letter, published on a psychology preprint platform, spends its first two paragraphs criticizing journalists' use of the words "dominant," "leading," and "well-established" to describe IIT, and for echoing exactly what IIT proponents have told them directly, absent of peer review or a critical lens.

Consciousness is an abstract, head-spinning concept; it's what we call the fact that we experience the world. Scientists and philosophers have struggled to define the word for as long as it's been around. Some have coalesced around consciousness being "something it is like *to be*" — stare at that phrase for a minute and it still hardly provides much clarity. This, unsurprisingly, has made consciousness an incredibly difficult thing to study.

The scientific study of consciousness is still in its infancy, and the number of theories attempting to explain consciousness is proliferating, as scientists in the field have generally been welcoming of out-there long-shot theories. It's a common phenomenon in science: When the obvious approaches don't yield much, throw everything and the kitchen sink at the problem and see if anything works. IIT is one of consciousness science's many kitchen sinks.

IIT was born in 2004 at the University of Wisconsin–Madison as the brainchild of sleep researcher Giulio Tononi. His strategy was to essentially reinvent the wheel to better understand it: Started by defining its properties (it rolls), then determined what the physical object would have to look like for it to have these properties (it has to be round). He started by listing common traits of consciousness — like how experiences are complex, unique, and intrinsic to each person. Then, from this list of traits, he attempted to derive what a physical object would have to look like for it to have consciousness.

He used math to define how fundamentally conscious that physical object is based on this theory. The resulting parameter is called "integrated information." Examples of systems with highly integrated information include the human brain ... and computers. The extremely consequential predictions that IIT makes, paired with the claims from leading scientists about how much evidence supports the theory, is what the letter signers say pushes the theory into the realm of pseudoscience.

There are plenty of ways to define pseudoscience — it's as complex of a term as science itself. But a useful definition is through its social function: Pseudoscience aims to mimic science to gain credibility for claims. This can be done through bogus studies (as is the case with the anti-vax and flat Earth movements) or by simply pointing to legitimate science as evidence for something it doesn't actually support (like when some tabloids reported that a NASA-funded study — in which particles traveled in the opposite direction than expected — had found evidence of a parallel universe where time flowed in reverse). This, the letter signers argue, is what happened with IIT.

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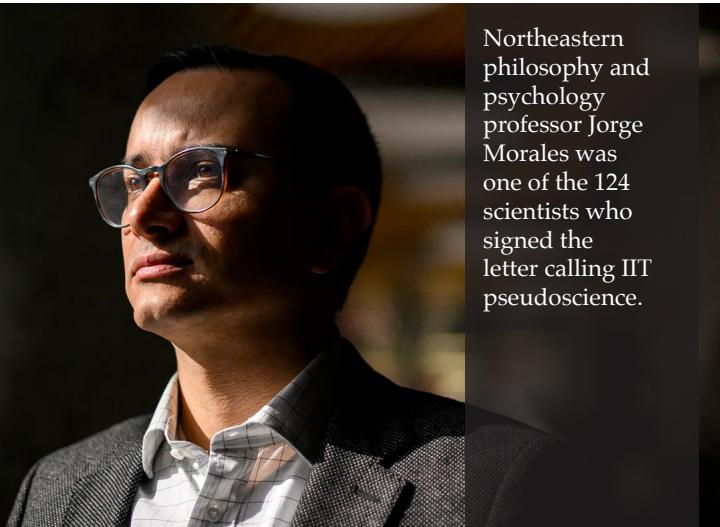
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I spoke with both Zimmer and Morales independently to understand where they agree, where they disagree, and — potentially — where things went wrong.

*The following is a condensed and edited version of their answers.*

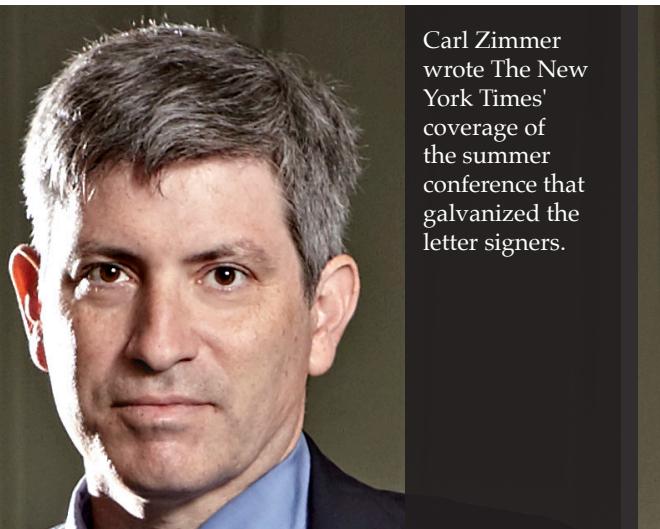
#### Do you see any clear indicators that IIT is a pseudoscience?

**Morales:** The main problem is that their hypotheses are completely trivial. For example, they predicted that if someone was conscious of a visual stimulus, the visual cortex was going to be active. And that's just the silliest of predictions — anyone can predict that.



Northeastern philosophy and psychology professor Jorge Morales was one of the 124 scientists who signed the letter calling IIT pseudoscience.

PHOTO BY MATTHEW MODOONO VIA NORTHEASTERN UNIVERSITY



Carl Zimmer wrote *The New York Times'* coverage of the summer conference that galvanized the letter signers.

PHOTO VIA CARL ZIMMER

Then you add on top of that the fact that the organizers invited *The New York Times* and the magazines for *Nature* and *Science*. There were all these newspaper or magazine articles saying, "Oh my God, great event. Two theories were tested, and one of them makes more good points." And it's not just that event. It's over a decade of hyping the theory in the media that really does not match the evidence that they have.

That's where pseudoscience comes in. It's the kind of thing that when you see it, you know it. At least for me and for many other philosophers, what makes something pseudoscience includes a psychological component. There has to be some intention of presenting something as scientific when it's not. When you look at IIT, all your experiments have nothing to do with the mathematical formalisms of the theory. The evidence

is so far and disconnected from reality that pretending that that's evidence for your very complex, rather implausible metaphysical theory, that's where the gap is.

When you sell it as a scientific theory — or even worse, the only theory that is seriously trying to tackle the consciousness problem — that intention of presenting something as science when there isn't evidence to back it up, that mismatch is what really creates a problem and should make us worry about it.

**Zimmer:** In science, there certainly are red flags that even non-scientists can recognize. For example, if a particular study has some funky statistics where it seems like they're trying to draw a remarkable conclusion from ambiguous evidence.

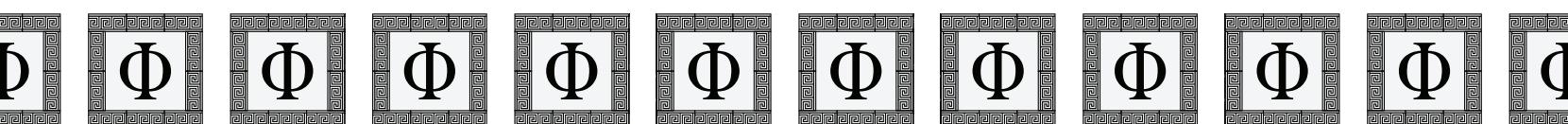
But I don't see the papers being published on IIT, or other theories of consciousness, as having clear red flags. There certainly have been scientists who have taken issue with the evidence that has been put forward for these different theories, but to argue, "You're showing me that evidence, but that doesn't really prove what you claim it proves," that's a totally legitimate part of the scientific process.

#### What do you make of the letter calling IIT a pseudoscience?

**Morales:** I think the letter emerged as an exercise for trying to balance the narrative in the public sphere and also within academia outside of the consciousness field. If you are not in consciousness and you read these newspapers, you would think, "Oh yeah, there's one theory of consciousness, and it's the winner." So, part of the idea of the letter was to say, "Hey, this media coverage is completely unhinged. It's completely disproportionate to the evidence and the scientific rigor that we hope to get from any theory."

If you have like a pet theory of something — like how sound waves travel or how water moves around — it might not matter too much. The problem with consciousness is that it's something that a lot of people care about. We're conscious. It matters. For example, abortion is one of the things mentioned in the letter, but think about end-of-life decisions, people with disorders of consciousness, people who are in a coma, children, animals. Any theory of consciousness has consequences for these — and the particular consequences aren't necessarily good or bad. It's just a way of saying this matters. Policy decisions might be made under the assumption that IIT is the leading theory of consciousness in the field, which is a distortion of how researchers within consciousness actually perceive things.

**Zimmer:** As a journalist, I have not reported on that letter. I'm certainly aware of it, but I have not interviewed the authors of that letter to get a deeper understanding of what their thinking is. I found the letter confusing because, on the one hand, it's arguing that IIT is pseudoscience. But then it seems to be presenting the fact that it's been covered in the news as evidence of it being pseudoscience. I don't really see



the evidence for their claims, and the letter itself just doesn't hold together logically for me.

I'm really quite mystified. It's not as if journalists are all part of the IIT club. In the article, I wrote that in this presentation at the conference, there were, in fact, two theories being presented, and I presented the other one hopefully just as clearly as IIT. I've written about other theories of consciousness in the past, and lots of journalists have written about other theories of consciousness in the past.

So, have there been published papers in which some scientists have challenged it? Yes, absolutely. And honestly, if you show me any prominent theory of consciousness, I can point you to some papers where people say that theory is wrong. I don't recall ever seeing a published paper in a scientific journal laying out that it is pseudoscience. So I'm puzzled why — if this theory has been around for 15 years — this is the first time in just a pre-print posted online that a group of scientists started to argue that it's pseudoscience. It seems strange to me why, if this is true, that claim has not made it into the same peer-reviewed scientific literature that IIT and many other theories of consciousness have.

#### **What role can scientists play in creating a pseudoscience? What are their responsibilities to ensure a science doesn't become a pseudoscience?**

**Morales:** I think in general, scientists are heavily responsible for some of the misconceptions in the public medium. And there is research about this — the main originators of exaggerated claims are scientists themselves, often through their universities' press offices. When researchers talk to their press offices or journalists, they want to say, "Hey, we just discovered this amazing thing, and it's the best thing ever," and that's never true. There are always caveats.

In the case of IIT, the researchers actually bypassed press releases. They are, themselves, doing the PR campaign. If you go to *Scientific American*, you see Christof Koch writing about IIT being the best thing since the dawn of time. For some reason, he has access to these publications. He can publish these things.

I do think that there is a fine line between creating a narrative about the importance of a finding and outright just exaggerating it. We're guilty of this not even just in the media, but in our scientific journals, too. People like to hype their findings because, I don't know, they sound more interesting not just to journalists, but to other scientists.

I think narratives are important — for the general public and for scientists. We're not so good at just processing raw data. But it's very important to make sure that you keep yourself at bay and try to keep things interesting but truthful and proportional to the evidence. And it is often the case that we

scientists don't do that, in part because maybe if it sounds better, it will get into a better journal. If you get into a better journal, you might get more funding, more grants, more jobs. So the incentives are not great for keeping us humble. But I think that we can say, "Hey, this is great, but we didn't control for these things," or "This is great, but it's limited to these species." You need to be humble and accept that your research has limitations that have to be addressed in different studies or by different people.

#### **What role can journalists play in creating a pseudoscience? What are their responsibilities to ensure a science doesn't become a pseudoscience?**

**Zimmer:** In journalism, we are not publishing scientific reviews. We are not publishing 10,000-word monographs on consciousness. I'm lucky if I can write 100 words about consciousness — and for an audience where I cannot take for granted that they all have PhDs in neuroscience. So, I think sometimes when scientists complain that some crucial nuance is lacking from reporting, sometimes that is confusing the role of journalism with the role of scientific papers.

We certainly have an obligation to vet the people that we're writing about, and you do that by talking to other scientists and by trying to read widely. And I think that when you do that as a journalist, writing about IIT is a perfectly valid thing to do.

There are certainly cases of scientists who did great work, got tenure, and then their work went downhill. Look at history; that's not a rare thing. It doesn't matter if someone has a lot of accolades — there are tenured professors who would deny that HIV causes AIDS. That doesn't make it true. Certainly, journalists have to be ready to recognize that they've made mistakes if they have highlighted science that turns out to be poorly done or wrong. I see it more as an ongoing process. There's no quick easy "science legitimacy machine" that you can use. You have to be working on it all the time.

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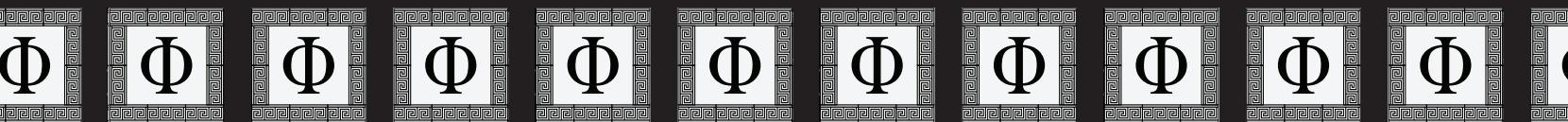


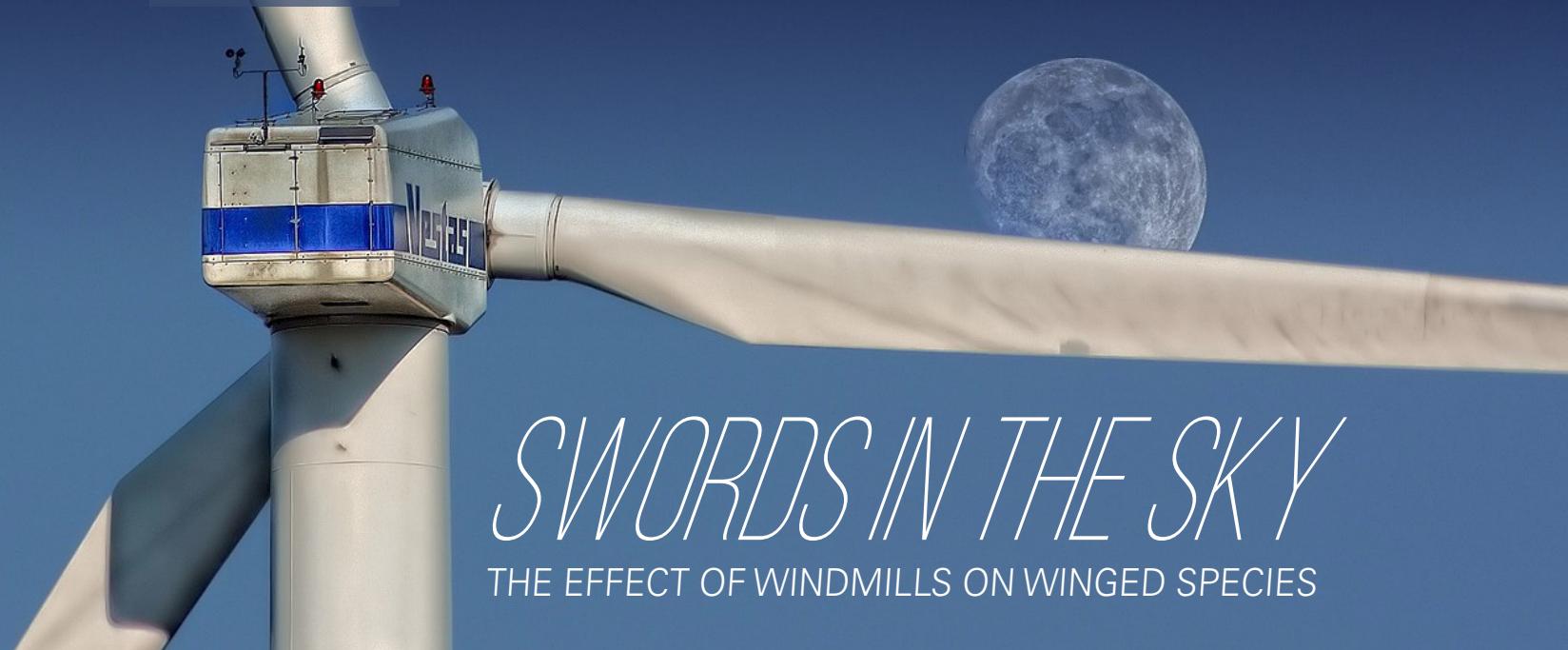
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The letter, like the label "pseudoscience" itself, is a tool. It raises the alarm, hoping to teach scientists, journalists, and the public alike to tread with caution — to think more critically about IIT. The letter likely won't kill IIT, but it might force the theory to better ground itself in disciplined scientific practice and send a signal to journalists that they should pay attention to the large number of scientists concerned about IIT.

Sometimes scientists push theories too far, and it requires a balancing force like the letter signed by Morales to keep science in check: The letter itself could just be an example of the checks and balances built into science working.

PHOTO VIA SHUTTERSTOCK





# SWORDS IN THE SKY

## THE EFFECT OF WINDMILLS ON WINGED SPECIES

BY MICHAEL OZGAR, ENVIRONMENTAL & SUSTAINABILITY SCIENCES, 2027  
DESIGNED BY GIULIA WALKER, DESIGN, 2027

For centuries, humanity has built structures capable of converting the kinetic energy of the wind into usable electricity — we call these structures windmills. As the modern world faces an unprecedented climate crisis, scientists and engineers have endeavored to make windmills more efficient. As a result of this, most modern windmills are incredibly tall structures with massive spinning blades. Although this design structure allows for an abundance of sustainably produced energy, it also has unintended negative effects on winged animal populations.

For the last decade, scientists have generally agreed that the existence of windmills directly causes both bird and bat fatalities as they consistently fly into the spinning blades, but they still debate the severity of the situation. Many point to the fact that windmills are responsible for significantly fewer winged animal deaths as compared to collisions with windows and predation by house cats, but

others argue that windmills also indirectly induce death by severely obstructing winged species' migratory paths. In recent years, scientists and engineers have been researching various ways to mitigate the harm caused by windmills through both better planning and adjusted windmill designs.

The two major winged species that are most negatively affected by windmills are birds and bats. As birds of prey navigate their ecosystem for prey, they typically look down at the ground instead of where they are flying. The blades on windmills can reach speeds of up to 179 mph, easily slicing into these unaware fliers, many of which may belong to endangered species. Other birds cannot discern the location of the blades, which are nearly invisible while in motion due to the motion smear effect created by their high speeds. This effect is made worse by the fact that the blades, often painted grey or white, blend into the skyline. Migratory tree bats are also disproportionately affected by windmills, as they collide with turbines during their migration season.

**“** Scientists have been researching various ways to mitigate the harm caused by windmills through both better planning and adjusted windmill designs.”

When these species eventually become aware of windmills, they learn to avoid the areas where windmills exist. This avoidance behavior leads to both reduced reproduction rates and increased offspring mortality rates. Since it requires more energy to arrive at reproduction locations, these species will have less energy left over to reproduce and raise their young. Over an extended period, individuals who produce a smaller number of offspring will be more reproductively successful as they will have the energy to care for their young, and the overall population will develop the trait of producing fewer offspring. In addition to this, extensive energy expended during the avoidance process may lead to exhaustion-induced death for the animals

before they even have the chance to reproduce. For all these reasons, winged species experience both individual death and general population decline as a result of windmills.

Some scientists believe a change in design might help mitigate these effects. The most ubiquitous design for windmills contains three blades spinning across a horizontal axis. This allows for maximum efficiency, relative affordability compared to other designs, and overall superiority in terms of energy production. However, there is another design that scientists believe may provide a more sustainable alternative to horizontal-axis windmills – the vertical-axis windmill. The vertical-axis windmill is not only shorter than the horizontal-axis windmill, but the fact that its blades rotate around a vertical axis means that collisions with birds are less likely. Although more research is needed to determine how efficient this design can become at producing energy before there are any talks of a full transition, a design change seems to be a promising strategy in both committing to wind energy and preserving our winged species populations.

Other research analyzes the changes that can be made to existing windmill structures to improve the survivability of the surrounding winged species. Scientists in Norway discovered that painting one blade black eliminates the

motion smear effect and reduces avian fatalities by roughly 70%. Recent advancements in Artificial Intelligence (AI) have made it possible for AI to detect approaching birds and shut down windmills until the birds have safely passed. Although still too unreliable and expensive to use everywhere, this technology could develop to become a critical solution to this problem.

Despite the tangible threat that windmills pose to winged species, the other forms of energy production that windmills replace, such as fossil fuels, are undeniably more damaging to winged species populations. The existing repercussions of human-induced climate change, which will only grow worse in the future if sustainable energy is not adopted, have already interfered with both bird and bat migration patterns greater than windmill disruptions. All of that being acknowledged, many of the detrimental effects that winged species face as a result of the continued adoption of wind energy are demonstrated to be preventable while not compromising the shift from unsustainable energy.

The continued development of these technologies and designs will lead to new, successful ways to benefit both the fight against climate change and the sustainability of winged species populations, hopefully in the near future.

*Ecology and Evolution* (2020). DOI: 10.1002/ece3.6592

“The tangible detrimental effects that winged species face as a result of the continued adoption of wind energy are demonstrated to be preventable while not compromising the shift from unsustainable energy.”



PHOTOS VIA PIXABAY

# A garden in the dark

BY DIVYA RAVIKUMAR, BIOENGINEERING & BIOCHEMISTRY, 2025

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

**A**s the possibility of deep space missions to Mars looms closer, scientists are actively addressing one of the biggest concerns: food.

For previous space missions, scientists prioritized providing astronauts with necessary nutrition over food quality. However, this mindset is not sustainable when considering a long-term space mission. With factors like the weight of the food supply, the potential degradation of micronutrients, and the physical and mental well-being of the crew, scientists agree that the revision of the current food preservation system is a necessity.

The predicted duration of a Mars mission is almost three years, but to adequately support the crew, at least five years' worth of food is needed. However, not only would this food supply weigh a lot, but as of now, the astronaut food supply has only lasted up to a year. Due to these challenges, an ideal solution would be for astronauts to grow their own gardens, thus saving resources and promoting a healthy diet. However, they would need to cultivate this "space garden" in the dark with artificial nutrients rather than sunlight, which bypasses plants' natural process of photosynthesis. Robert Jinkerson, a chemical engineer at the University of California, Riverside, believes the key to growing plants in the dark is reactivating metabolic pathways that plants use to germinate as seedlings underground.

Previously, researchers had already found that plants cannot grow in dimmer or dark conditions once exposed to light. Therefore, Jinkerson reasoned that people can only grow in space by replacing plants' dependence on light with hydrocarbons derived from exhaled carbon dioxide and water. In his previous research, Jinkerson found that certain types of algae could grow in the dark when fed acetate, a liquid hydrocarbon. He partnered with Feng Jiao, a chemist from the University of Delaware who was working on an electrolyzer that converted carbon dioxide and water to acetate and ethylene using electricity. Jiao and his students revamped the electrolyzer to alter the output from 30% to 99% acetate, high enough to directly feed plants. To confirm the effects of acetate on plant development, Jinkerson, Jiao,

and their team fed acetate to pearl oyster mushrooms, yeast, and algae grown in the dark. The team found that these organisms converted chemical energy into new growth nearly 18 times more efficiently than if they had fed plants grown through photosynthesis.

Any diet, however, needs variety. The three organisms they tested are naturally grown in the dark, but plants require sunlight. In the same study, the team fed acetate to various crops grown in the dark, like lettuce and tomatoes. Although the vegetables fully developed, they did not grow to their full size, remaining in a miniature form. To optimize a plant's growth on acetate, Jinkerson and his colleagues are using CRISPR technology to reactivate the genes that are used during germination. The most promising avenue is the glyoxylate cycle, a metabolic pathway that conserves more carbon to use later for growth, which involves a prominent enzyme in the process that breaks down acetate. To test the viability of the cycle, they engineered mustard plants to produce more of this enzyme, resulting in the plants growing to their full size instead of being stunted. This success is propelling researchers forward to further reroute the metabolism of acetate to the glyoxylate cycle instead of the typical metabolic pathways.

Even with these advances, it will be difficult to raise plants in complete darkness since they rely on light for a multitude of other aspects, such as flowering. Jinkerson and his team are currently working on adjusting the amount and timing of light exposure so that plants are only exposed for crucial development. Overall, this research is taking promising steps toward a new source of space food and is bringing science closer to its goal of further space exploration. Sooner or later, food could be grown anywhere in any condition, especially on Mars.

*Nature Food* (2022). DOI: 10.1038/s43016-022-00530-x  
*The Journal of Nutrition* (2020). DOI: 10.1093/jn/nxaa188  
*Frontiers* (2021). DOI: 10.3389/fpls.2021.688053

# The truth behind the end of a solar panel's life

BY JULIA LAQUERRE, JOURNALISM AND ECOLOGY & EVOLUTIONARY BIOLOGY, 2025

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025



PHOTO BY VATSAL MEHTA, COMPUTER SCIENCE, 2025



PHOTO VIA RAWPIXEL

**W**hen picturing the future of sustainability, renewable energy often comes to mind. However, solar panels may not be all that sustainable — especially when they eventually die.

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As the interest in  
renewable energy rises,  
so does its waste.”

Solar panels are the face of the green energy movement. They accounted for 54% of new electricity added to the United States electrical grid in 2023. But what happens when they hit the end of their efficient life and fade out?

As interest in renewable energy rises, so does its waste. In Massachusetts, “based on an average 25-year panel lifespan, the amount of solar panels retired will reach about 6,500 tons annually by 2030, with a maximum annual tonnage

of approximately 40,000 tons by 2050,” according to the Massachusetts Department of Environmental Protection.

All this waste has to go somewhere; the question is, are solar panels recyclable? The simple answer is yes, but the responsibility of properly recycling them lies with the owner of the solar panels. When they are properly recycled, a company takes them apart, removes the hazardous waste, sells any profitable materials, and recycles what’s left.

However, sending them to the dump is cheaper than hiring a company, so solar panels often end up oozing hazardous waste in landfills, ultimately reversing some of their positive environmental impacts.

# Sea otters

## Guardians of the kelp forest

BY MAGGIE EID, ENVIRONMENTAL &amp; SUSTAINABILITY SCIENCES, 2025

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

**S**ea otters, adored for their expressive faces and fluffy fur, are some of the most well-known and charismatic aquatic animals. Beyond their cuteness, these marine mammals are keystone species that play an integral role in their environment. As top predators, sea otters are crucial to balancing coastal ecosystems such as kelp forests, enhancing ecological resilience to climate change. Recent research showcasing the sea otters' environmental benefits may provide direction in the work to preserve these crucial ecosystems.

Found along rocky coastlines throughout the world, kelp forests are vast submarine habitats that support an extensive diversity of plants and animals. Kelp is a large, brown algae that thrives in cool, nutrient-rich, turbulent waters, forming dense stands similar to terrestrial forests. The kelp forest canopy offers abundant food and shelter for hundreds of species of fish, invertebrates, and marine mammals. Growing up to two feet per day under ideal conditions, this giant seaweed can extend to depths of 175 feet. Due to their quick growth rate, kelp forests are some of the world's most productive ecosystems, rivaling tropical rainforests. Despite inhabiting a small percentage of the Earth's total surface, kelp forests are estimated to capture 4.91 million tons of atmospheric carbon per year globally. Alongside carbon sequestration, kelp forests provide other valuable ecosystem services, such as reducing coastal erosion, promoting nutrient cycling, and supporting commercial fisheries, collectively generating an average of \$500 billion annually.

Yet, kelp forests are declining across the globe due to several threats, including climate change, commercial overharvesting, and pollution. In addition to these anthropogenic stressors, overgrazing by predators contributes to the forests' collapse. One such destructive grazer is the sea urchin; this spiky, spherical echinoderm has a voracious appetite for kelp. When its population grows without constraints, sea urchins can destroy entire stands of kelp, creating zones called urchin barrens. In these areas, sea urchins carpet the seafloor, turning the once vital and diverse kelp forest into a desolate region. The creation of urchin barrens marks a tipping point for the ecosystem in which essential functions are lost. Preventing this collapse is essential, which is why sea otters are integral components of kelp forests. Eating 25% of their body weight each day, sea otters keep sea urchin populations in check, guarding against overgrazing to maintain healthy kelp canopies rich in species. As a result, sea otters can nearly double the amount of carbon stored in a kelp forest.

In a recent study by Monterey Bay Aquarium, researchers found that California's growing southern sea otter population increased kelp forest resiliency to environmental stressors and mitigated statewide decline over the last century. Using historical survey estimates and contemporary datasets of kelp forests, the researchers analyzed canopy coverage, biomass, and carbon storage from 1910 to 2016. Machine learning models indicated sea otter population density as the leading predictor of kelp canopy change during this period. Along California's central coast — the only area where southern sea otters have recovered since being hunted to near extinction during the fur trade of the 1800s — the kelp canopy increased by 57%. This growth offsets the losses in regions where sea otters are absent. Although the canopy decreased along the northern and southern coasts by 63% and 52%, respectively, the overall decline across the entire state was only 6.9%.

While sea otters were the dominant driver of positive change in kelp forests, the study revealed other significant factors predicting decreases in the kelp canopy, including extreme marine heat. As climate change progresses, marine heat waves will increase in intensity and frequency, placing substantial stress on the sensitive kelp forest ecosystem. As sea otters buffer against heat-induced losses by maintaining ecosystem integrity, conserving this keystone species is essential to protecting kelp forests, including their rich biodiversity and instrumental ecological functions. Reintroducing southern sea otters to their historical ranges along the California coast offers a promising nature-based solution to promote kelp forest climate resiliency.

PHOTO VIA SHUTTERSTOCK

*Frontiers in Ecology and the Environment* (2012). DOI: 10.1890/110176*Nature* (2023). DOI: 10.1038/s41467-023-37385-0*PLOS Climate* (2024). DOI: 10.1371/journal.pclm.0000290*World Seas: An Environmental Evaluation* (2019). DOI: 10.1016/B978-0-12-805052-1.00003-6

# Seaweed and cow burps

## A potential solution to climate change?

BY SOPHIE DONNER, ENVIRONMENTAL &amp; SUSTAINABILITY SCIENCES, 2025

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

**T**he slimy and smelly seaweed known to repulse many swimmers and beachgoers may serve as a key mitigation strategy for climate change in the near future. A species of red macroalgae known as *Asparagopsis taxiformis* has been shown to reduce methane emissions in livestock. Methane is 28 times more potent as a greenhouse gas than carbon dioxide, and livestock production is the largest anthropogenic methane source. Ruminant livestock, such as cattle, sheep, and goats, ferment plant-based food in a separate stomach known as the rumen prior to digestion. During this fermentation, a group of microbes produce methane in a process called methanogenesis. The methane is then released into the atmosphere, mainly through belching or flatulence.

Since methane has such a strong warming potential and is short lived in the atmosphere, targeting emissions may translate to noticeable reductions in warming within the next few decades. In areas of Northwestern Europe, seaweed has historically been fed to cows, but the potential benefit of seaweeds under the *Asparagopsis* genus has only recently been discovered.

A team of researchers at James Cook University in Queensland, Australia have revealed how effective *A. taxiformis* can be at reducing methane emissions from cattle. Over the course of 90 days, the team fed cattle high grain diets with various concentrations of *A. taxiformis*. Throughout the study, cattle were placed in respiration chambers to monitor total methane production. Generally, as seaweed inclusion in the livestock feed increased, methane production decreased. Methane reductions reached 98% in cattle fed the highest amounts of seaweed.

The main bioactive compound in *A. taxiformis* that is responsible for reducing methanogenesis, known as bromoform, is thought to be carcinogenic to humans. However, in samples of meat, kidney, and fat taken from the cattle, no

bromoform residues were detected. Additionally, as determined by consumer sensory evaluations, the seaweed did not impact the cattle meat tenderness, flavor, or quality.

While implementing *A. taxiformis* as a feed additive could drastically reduce livestock methane emissions, there are many uncertainties regarding economic feasibility. Wild harvesting of *A. taxiformis* likely would not meet the demand of the growing agricultural industry, creating a need for upscaled cultivation methods. In order for *A. taxiformis* to be effective at inhibiting methanogenesis, high bromoform concentrations are crucial. Jennifer Smith and her lab at the Scripps Institute of Oceanography in San Diego are working to identify ideal conditions to maximize seaweed bromoform concentrations and are further developing aquaculture approaches for onshore cultivation of *A. taxiformis*. The seaweed is native to

Australia and New Zealand but has spread globally and is considered an invasive species. To avoid damaging native ecosystems through open ocean aquaculture, Blue Ocean Barns, a Hawaii-based aquaculture farm, cultivates *A. taxiformis* in land-based tanks. However, expanding land-based cultivation of seaweeds to a larger scale may introduce land use conflicts and challenges with resource management.

Although *A. taxiformis* would greatly reduce livestock methane emissions, the agricultural industry inflicts a plethora of other environmental issues, from degraded water resources to loss of biodiversity. When used in combination with improved agricultural practices, seaweed in livestock feed could be a promising solution for methane emissions but does not address the other damages caused by growing agricultural production.

*Journal of Archaeological Science* (2020). DOI: 10.1016/j.jas.2020.105140  
*Journal of Cleaner Production* (2020). DOI: 10.1016/j.jclepro.2020.120836  
*Nature Sustainability* (2019). DOI: 10.1038/s41893-019-0299-x

# The rapid extinction of the world's slowest creatures

BY JAIME ADAMS, ENVIRONMENTAL &amp; SUSTAINABILITY SCIENCES &amp; CHEMISTRY, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025



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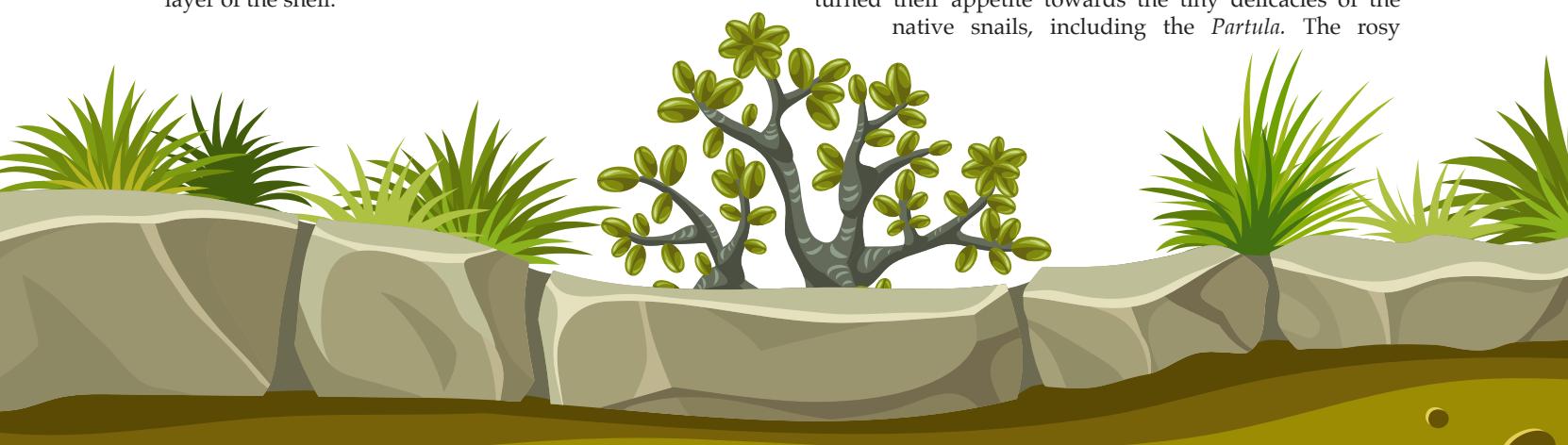
**I**t was 2007 — the year of *Spider-Man 3* starring Toby McGuire, Obama's first election campaign, and the launch of the first iPhone. On a small island in French Polynesia, the last tree snail of the species *Partula cytherea* quietly, and most likely violently, met its demise. Reports from the International Union for Conservation of Nature and Natural Resources (IUCN) Red List state that the *P. cytherea* is not the only tree snail species across the Pacific Islands that faced extinction in the past few decades; the native snails of the islands are disappearing at an astonishing rate, resulting in unforeseeable consequences on the ecosystem.

The fascinating features of the *P. cytherea*, particularly their shells, deserve to be explored before revealing the series of events that led to these creatures' demise. *Partula* snails are a genus of tree snails endemic to the French Polynesian islands. They are detritivores, meaning that they consume dead organic matter. Through this food source, they receive calcium and bicarbonate, the primary nutrients needed to form the outer layers of their shells. The ions are transported via the hemolymph, the snail equivalent of blood, to the mineralizing site located where the shell and the body meet. Transmembrane pumps then increase the concentrations of both ions in the extrapallial space, which is the space between the flesh and the shell. Here, the shell is eventually formed. The calcium ions bind to the carbonate ions, creating calcium carbonate, which, along with proteins that are pumped out by surrounding epithelial cells, constitutes the outer calcified layer of the shell.

Within the basic building process for the outer shell, there are also thousands of unique variations in pattern, color, texture, size, and other traits, which are controlled by a combination of specific gene sequences and environmental factors. Snails can even show a form of handedness, preferring a clockwise-spiraling shell, much like how humans often prefer right-handedness. This trait also manifests in early development.

These shells are the product of complex mechanisms and thousands of years of evolution. Additionally, snails play a crucial role in the ecosystem, recycling dead organic matter and functioning as a valuable part of the food chain. Aside from that, snails have been intertwined with humanity throughout history: Romans created the dye Tyrian Purple from sea snails, medieval monks drew snails into their marginalia, indigenous Hawaiian culture admires singing snails, and nowadays, people use skincare products containing snail mucin. The loss of distinct snail species is not just a loss to the ecosystem but the loss of years of evolution and human culture.

The driving force of the *Partula* snail's decline is not due to habitat loss or disease but rather an invasive species. Specifically, it is the *Euglandina rosea* snail species, commonly known as the rosy wolfsnail. Despite its charming name, these creatures are bloodthirsty cannibals. Initially introduced as ecological control for giant African snails that were damaging farmland crops, they quickly turned their appetite towards the tiny delicacies of the native snails, including the *Partula*. The rosy





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The loss of distinct snail species is not just a loss to the ecosystem, but the loss of years of evolution and human culture.”

wolfsnails track down their prey by following trails of slime and due to their speed, they can quickly (well, relatively) catch up and devour them. While the rosy wolfsnail has become the most devastating perpetrator of the native snail downfall, they are not the only cannibalistic invasive snail species; *Oxychilus alliarius*, among other predatory snails, is also widespread across the Hawaiian Islands.

Once conservationists in the 1980s and 1990s recognized the extensive damage, efforts were made to preserve the remaining species. Remaining snails were captured and bred to have their offspring rereleased, and protective enclosures were set up across the islands. Sadly, anywhere from 50%–90% of species were estimated to be lost. In 1990, Malacologist Alan Solem suggested four actions to further conservation efforts: establishing a baseline of the diversity and abundance of the species from museum collections, conducting field surveys on the remaining taxa, identifying immediate threats and creating a habitat that addresses them, and continuing research on the taxa for further future conservation efforts. In a 2018 article, scientists Norine Yeung and Kenneth Hayes from the Pacific Biosciences Research Center suggested an additional action — changing the public perception of the little creatures.

It is important to acknowledge that, while the rosy wolfsnail may be the primary cause of the snails' deaths, humans are ultimately behind the extinction. It was humans who first

introduced the species in the act of misinformed pest control and who introduced the giant African snails to begin with. Not all hope is lost, though; in 2023, the Partulid Global Species Management Programme released 5,694 snails from seven species in Tahiti and Moorea, allowing them to reestablish themselves in the area. Avid monitoring has shown a continuous presence of the species, and some have even reproduced further.

2007 was a big year, and although not great for the snails, it saw the innovation of the iPhone and the history-making election campaign of President Obama. Hopefully, decades later, humans can add the restoration of the tree snails to their legacies.

*Evolutionary Applications* (2019). DOI: 10.1111/eva.12778  
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*Oryx* (2023). DOI: 10.1017/S003060532300114X

PHOTOS VIA SHUTTERSTOCK



# Poison dart frogs: What doesn't kill you makes you stronger

BY DESSY DUSICKA, COMPUTER SCIENCE &amp; BIOLOGY, 2025

DESIGN BY ANJANA BALAKRISHNAN, STUDIO ART, 2027

**W**hile some dangerous creatures opt for a more subtle approach, the poison dart frog is remarkably considerate for letting predators know ahead of time that it is not to be messed with. Its vibrant color is meant to signify its high toxicity, an example of aposematism, or an animal advertising to its predators that it is not worth pursuing. By boldly showcasing its red flags upfront, this creature conveys a powerful message to potential predators who learn to associate the bright color with danger.

The frogs' poison is so powerful that it even has indirect victims. The "dart" in "poison dart frog" comes from an old hunting strategy where indigenous communities in South American rainforests would rub their blow darts and arrow tips on the backs of these frogs before going hunting. The poison from one golden poison dart frog has been found to kill 20,000 mice, which is roughly equivalent to 10 humans.

The frogs are poisonous because of alkaloids, small molecules found in their diet of insects, specifically ants, mites, and termites. Other organisms contain alkaloids for similar reasons, including the blue-ringed octopus, pufferfish, and certain butterfly species. Rather than breaking down these toxic alkaloids, the frogs absorb and accumulate them into their skin to serve as a defense mechanism. Researchers have long wondered how poison dart frogs can contain so much poison without harming themselves.

The mechanism for this is still not fully understood, but a recent study by Stanford researchers has shed some light on the molecular carrier, a liver-derived protein called alkaloid binding globulin. To learn more about toxin transport in the frogs, the researchers used a bioengineered compound resembling an alkaloid as a "molecular fishing hook" to bind to proteins in frog blood samples. This compound was made to glow in fluorescent light, allowing the scientists to see which proteins bound to this planted molecule.

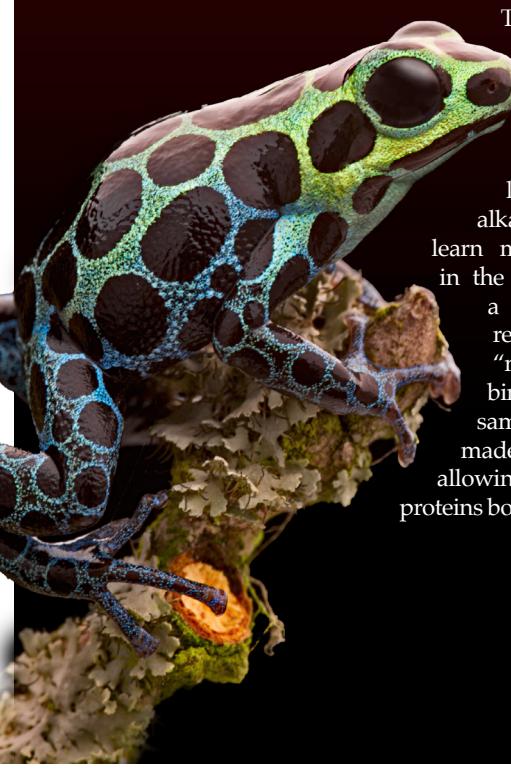
After analyzing the various proteins that were reeled in by the mock alkaloid, the researchers found that alkaloid-binding globulin (ABG) acted like a "toxin sponge" that collected the poisonous compounds. They were surprised to find that ABG was responsible, rather than albumin, a molecule widely known for its role in the transport of small molecules like hormones.

The researchers then pinpointed which parts of the protein bound to the alkaloids. They found similarities between ABG and proteins that transport hormones in humans, suggesting a pattern of evolution that may have important human health implications. Most notably, studying and harnessing the power of binding proteins like alkaloid-binding globulin can potentially be used to treat humans poisoned with similar molecules. For example, there is an opportunity to reverse overdoses by binding to toxic chemicals in drugs.

When it comes to solving complex biological problems, it's often best to look to the expert: nature. From the waves of the ocean to the smallest of amphibians, the answers to some of the most pressing scientific questions can be found right outside our homes.

*eLife* (2023). DOI: 10.7554 eLife.85096

PHOTOS VIA SHUTTERSTOCK



# Mirror of the sun: The Hawaiian silversword

ARTICLE AND PHOTOS BY JIAJIA FU, BIOENGINEERING, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

**S**tars flicker faintly as the dark horizon reddens. Howling, freezing winds and desolate craters starkly contrast the lush tropical rainforests and coral gardens 10,000 feet below. As the blinding light finally emerges over a sea of swirling clouds, a bright reflection appears from the sparse, reddish slopes. It is a silver plant, radiating under the climbing sun.

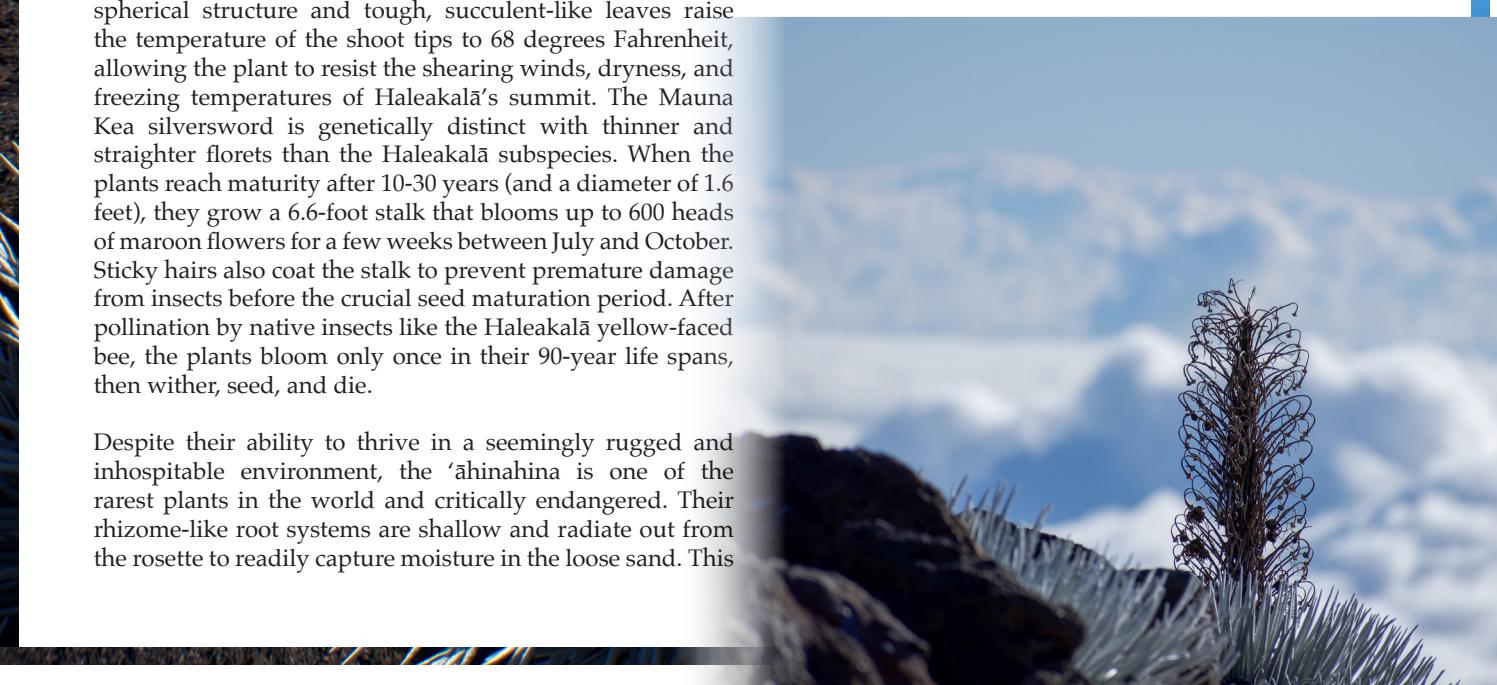
Born from volcanoes and spanning seven distinct climate zones, the Hawaiian Archipelago is home to some of the most biodiverse landscapes on Earth. Due to geographic isolation, Hawai'i also has one of the highest densities of endemic species in the world, which means they are found nowhere else. A prime example is the Hawai'i silversword, or 'āhinahina (literally meaning "very gray"). The two subspecies of this resilient plant only grow in alpine cinder deserts atop Hawai'i's tallest volcanoes — Maui's dormant Haleakalā and Mauna Kea and Mauna Loa on the island of Hawai'i.

The 'āhinahina biology and life cycle are specialized to the extremes of a high-altitude, volcanic climate. Its spiral shards coated in reflective, silvery hairs act as mirrors, refracting sunlight to the center of the plant's rosette. This spherical structure and tough, succulent-like leaves raise the temperature of the shoot tips to 68 degrees Fahrenheit, allowing the plant to resist the shearing winds, dryness, and freezing temperatures of Haleakalā's summit. The Mauna Kea silversword is genetically distinct with thinner and straighter florets than the Haleakalā subspecies. When the plants reach maturity after 10-30 years (and a diameter of 1.6 feet), they grow a 6.6-foot stalk that blooms up to 600 heads of maroon flowers for a few weeks between July and October. Sticky hairs also coat the stalk to prevent premature damage from insects before the crucial seed maturation period. After pollination by native insects like the Haleakalā yellow-faced bee, the plants bloom only once in their 90-year life spans, then wither, seed, and die.

Despite their ability to thrive in a seemingly rugged and inhospitable environment, the 'āhinahina is one of the rarest plants in the world and critically endangered. Their rhizome-like root systems are shallow and radiate out from the rosette to readily capture moisture in the loose sand. This

makes the structures extremely delicate — stepping within 5 feet of the plant can crush and kill them. Ungulates like cattle and sheep introduced by European colonizers heavily grazed and trampled the 'āhinahina, while tourists ripped out the plants as souvenirs, dried them as decoration, and even used them as kindling. Now that the 'āhinahina's habitat is controlled by Haleakalā and Hawai'i Volcanoes National Parks, the plants are federally protected and fenced off to prevent grazing animals, invasive plants, and visitors from stepping on seedlings. Researchers have also collected and reintroduced more than 32,000 Mauna Loa silversword seedlings with a survival rate of over 70% since 2007.

The existential threat of introduced invasive species alleviated by successful conservation efforts to restore the 'āhinahina mirrors that of countless species throughout Hawai'i. From the state bird nene to the 'ōhi'a lehua, a colonizer plant of lava, Hawai'i's wildlife is returning from the brink of man-made extinction. However, climate change now poses a new threat, creating droughts and a hotter climate that threaten the highly specialized 'āhinahina. Only by fostering research, awareness, and legislation can we protect this precious 'āina ("land" in Hawaiian) for millennia to come.



# 'I can quit whenever I want'

## How the e-cigarette industry retains customers for life

BY EMILY XU, BEHAVIORAL NEUROSCIENCE, 2026

DESIGN BY KRISHNA VASIRAJU, BEHAVIORAL NEUROSCIENCE, 2027

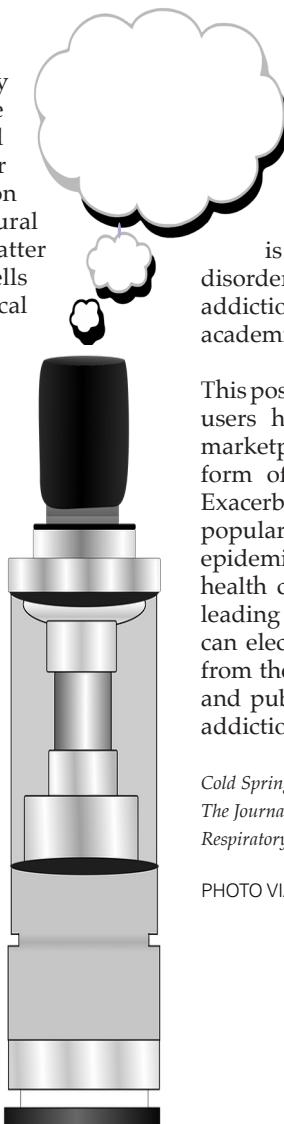
**I**nitially, electronic nicotine delivery systems were not marketed to target teenagers. However, their sleek design and soothing fruity flavors had a consequential appeal to youth. For example, the first highly popularized e-cigarette by JUUL gained traction in 2015. Shaped like a USB drive and mango flavored, JUUL and similar e-cigarette brands quickly became the cool new gadget that proliferated on social media to a substantial network of teenagers.

Unfortunately, the brain does not fully develop until 25 years old, and adolescence is matched with exclusive behavioral changes — including risk-taking and peer associations — to understand the transition to independence. During maturation, structural and functional reorganization of gray matter and white matter, which make up the cells of the nervous system and neurochemical systems, renders the brain acutely sensitive to new experiences. Plasticity, an experience-dependent ability by the brain to reorganize itself through external stimuli, occurs in the developing prefrontal cortex — the part of the brain responsible for executive performance and decision-making.

The unique neuroplasticity of the adolescent brain explains its vulnerability to nicotine addiction. Specifically, nicotine consumption rewires the brain by altering the functioning of synapses in the prefrontal cortex that underlie cognitive function: When nicotine enters the blood system through the lungs, it reaches the brain in just 10–20 seconds where it binds to the target nicotinic acetylcholine receptors. It then participates in cholinergic signaling, an essential process to cognitive function. As a result, the adolescent brain becomes more sensitive to long-lasting changes in nicotine binding and brain

function, leading to impaired cognitive processing. While marketed as an aid to cease smoking cigarettes as a "safer" alternative, e-cigarettes are not subject to FDA regulation and foreshadow serious subsequent addictions. Research indicates that among youth who have never smoked a cigarette, recent vapers are more likely to smoke cigarettes in the future. These results contribute to the evidence supporting that vaping is the strongest link to cigarette smoking among youth. So, how much "safer" *really* is vaping compared to cigarettes?

Exacerbated by the increase in electronic cigarette popularity and its rapidly evolving market, the nicotine epidemic has developed into one of the largest global health crises with millions of users."



Nicotine creates adverse effects on cardiovascular and lung systems, and a continued history of smoking during teenage years predicts cognitive impairment later in life. Several studies also show that nicotine consumption during adolescence also has long-lasting effects on emotional behavior and is associated with a later risk of developing mental disorders including depressive disorder, panic disorder, addiction to other substances, personality disorders, and academic problems.

This poses a significant issue as the demographic of e-cigarette users has been dominated by adolescents. Entering the marketplace in 2007, vaping has been the most common form of nicotine consumption among youth since 2014. Exacerbated by the recent increase in electronic cigarette popularity and its rapidly evolving market, the nicotine epidemic has developed into one of the largest global public health crises with millions of users. As tobacco claims the leading cause of preventable death again this past year, how can electronic nicotine delivery systems be marketed away from the youth population? How will government agencies and public health services address the widespread teenage addiction to vaping?

*Cold Spring Harbor Laboratory Press* (2012). DOI: 10.1101/cshperspect.a012120  
*The Journal of Physiology* (2015). DOI: 10.1113/JP270492  
*Respiratory Care* (2019). DOI: 10.4187/respcare.06300

PHOTO VIA PIXABAY

# Shades of green

## THC and the teenage brain

BY SAI TUMMALA, CELL &amp; MOLECULAR BIOLOGY, 2026

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING &amp; DESIGN, 2024



**B**ud, dope, reefer, Mary Jane, cannabis — our country's history with this leafy green plant is as diverse and plentiful as its names. The 1936 film "Reefer Madness" follows a group of high schoolers who are pressured into smoking marijuana, subsequently falling into lives of crime, self-harm, and madness. President Reagan's "War on Drugs" of the 1980s spiraled into the criminalization of marijuana, resulting in the incarceration of millions of young, primarily African-American, men for minor cannabis use. Today, weed is less controversial yet ubiquitous among youth — try taking a deep breath in the Boston Common on the days succeeding April 20th.

Despite 20th century efforts to rid the nation of cannabis, 24 states have legalized adult recreational use of the drug as of November 2023. Regulation of tetrahydrocannabinol (THC), the main psychoactive compound in cannabis products, has softened. There has also been a consistent interest in scientific research into cannabis's purported therapeutic effects. Popular studies have associated THC with pain relief, anti-nausea, and anti-anxiety. At the same time, many people have certain beliefs about cannabis that have been proven as myths — "You can't get addicted to weed," "It's good for you," or "It's not as bad as alcohol." Aligning with these myths, the CDC reports that 37% of U.S. high school students regularly use marijuana as of 2019. But the weed that young people are smoking today is not your grandmother's reefer. Today's cannabis is a different beast.

**“**The way weed is advertised today recalls a time from the past when cigarettes were 'physician-tested' and opiates were prescribed for the common cold."

It wasn't until the 1960s that scientists discovered what people actually liked about marijuana: the THC. THC's structure mimics that of anandamides, endogenous molecules that fit perfectly with cannabinoid receptors on certain neurons. When THC molecules attach to these receptors, the brain releases a surge of dopamine. In short, like any addictive drug, THC activates the brain's reward system.



Cannabis manufacturers and retailers quickly realized that highly concentrated THC products were in demand. Prior to the 1980s, the THC content in most strains of cannabis was less than 2%. Compare that to the concentrated products of today — edibles, oils, dab pens — where the THC content can reach 95%. According to Dr. Elizabeth Stuyt, an addiction psychiatrist and professor at the University of Colorado's Health Science program, there are "significant consequences of long-term or heavy marijuana use beginning in adolescence." In teenagers who regularly use cannabis products, THC has been found to impair development of the prefrontal cortex, the portion of the brain that controls judgment, learning, and emotions. Studies also associate adolescent THC use with reduced hippocampus size, leading to "disturbances in hippocampal-dependent learning and memory."

Many young people have begun to notice THC's detrimental effects on cognition. On TikTok, many high school and college students talk about the "cartdemic," an era from 2020-2021, when the sale of THC vape pen cartridges was extremely unregulated among teens. Self-proclaimed victims of this "cartdemic" note that overusing their dab pen led to long-term verbal and cognitive deficiencies such as slow thinking, slurred speech, stuttering, and memory loss. In a similar vein, a 2017 study by researchers at Yale found that students who used cannabis had a significantly lower GPA than students who did not. Students' GPA dropped further if they used cannabis and consumed alcohol, as many college students do.

When it comes to cannabis, it is difficult to separate fact from fiction. It is even harder to determine if knowing the consequences of excessive THC consumption will deter teens and young adults from using the drug. What is known is this: society does not talk about cannabis the way it talks about other addictive drugs. The way weed is advertised today recalls a time from the past when cigarettes were "physician-tested" and opiates were prescribed for the common cold. Only deeper, long-term research can uncover the truth about THC.

Issues like this are rarely black and white. Sometimes, they are several shades of green.

*Drug Alcohol Depend* (2013). DOI: 10.1016/j.drugalcdep.2012.12.005

*PLoS One* (2017). DOI: 10.1371/journal.pone.0172213

PHOTOS VIA SHUTTERSTOCK

# Our brains on psychedelics

## Getting creative in the treatment of mental illnesses

BY ISABELLE BRANDICOURT, ELECTRICAL ENGINEERING & MARINE BIOLOGY, 2023

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING & DESIGN, 2024

**B**ill Wilson co-founded Alcoholics Anonymous in the 1930s. He had struggled with alcoholism since his early twenties and depression even longer. While AA helped Wilson recover from alcoholism, he remained frustrated with available mental health treatments. Entering the '50s, he began collaborating with psychologist Betty Eisner and discovered the power of LSD. In a letter to science writer and philosopher Gerald Heard, he wrote, "I am certain that the LSD experience has helped me very much. I find myself with a heightened color perception and an appreciation of beauty almost destroyed by my years of depression ... The sensation that the partition between 'here' and 'there' has become very thin is constantly with me."

That era marked the beginning of the complicated modern history of psychedelics, mental health treatment in the U.S., and the science behind these substances. On Nov. 15, NU Sci and the Northeastern Psychedelics Club — NEU Psyches — hosted a meeting to explore this history. NEU Psyches e-board members, Camille Tosques and Indigo Zenobia, walked through an overview of psychedelics and their place in our healthcare system. NEU Psyches supports the spread of information, education, and research surrounding the history and practice of psychedelic substances, but does not suggest the use of drugs.

Popular psychedelics include psilocybin (magic mushrooms), LSD (acid), Ketamine, DMT, and MDMA (molly). Most psychedelic research is based on structure-activity relationship studies, which look at the chemical structure of the psychedelic and the biological response of compounds in the brain. While there is still a lot of research to be done, existing structure-activity studies have shown that psychedelics are agonists; they activate serotonin receptors in our brains. Serotonin is a neurotransmitter, a chemical that carries signals throughout the brain and body and encourages long-lasting happiness and well-being. By increasing serotonin reception, psychedelics promote neuroplasticity, a phenomenon that builds new connections between neurons.

Human beings tend to fall into patterns of behavior as a result of feedback loops. We form these loops throughout time as we react repeatedly to given stimuli. While some feedback loops can be incredibly beneficial to our health and wellness, such as the endorphin boost from exercising, others can become increasingly detrimental. For example, alcoholism is built from the feedback loop of drinking to

alleviate the discomfort of a comedown or hangover from drinking initially. Many addictions are built off of these feedback loops, leading to habits that are overwhelming to our daily lives and challenging to break.

The use of psychedelics has had significant breakthroughs in the treatment of addiction via this ability to crack feedback loops. The boost of serotonin receptors directly targets the decreased serotonin levels typical of patients with substance use disorder, and therefore decreases the desire or need for the previously depended-upon substance. Studies have shown significant positive results for the use of psychedelics in the treatment of tramadol addiction in Central and South Africa, alcoholism, nicotine and tobacco addictions, and even gambling and sexual addictions. Instead of targeting symptoms and after-effects of substance abuse disorder, psychedelic treatments target the root cause, meaning that the results could be much more consistent and long-lasting.



Psychedelics 'enable you to look at yourself with compassion,' Tosques said, which is a skill that many people, particularly young people in today's world, really struggle with."

Beyond addiction, there are a slew of mental health disorders that plague modern society. Anxiety, depression, PTSD, eating disorders, bipolar disorder, and OCD are all increasing in prevalence and our understanding and treatment of them are struggling to keep up. Official studies and testimonies from self-guided treatments report that the "change in perception" and the "conscious-altering" effects of psychedelics are incredibly effective at alleviating many symptoms and even the roots of these mental illnesses.

The most powerful tool of psychedelic treatment is ego dissolution, or the near physical separation of consciousness from the perception of a "self." Subjects under the influence of psychedelics report the ability to objectively view their mental health struggles from the outside. Since many mental health disorders are overwhelmingly self-consuming, there is often an associated distortion of reality. Removing this distortion for individuals with mental health issues to view

themselves as they truly are can have a profound impact on how they face mental health challenges. Individuals suffering from anxiety, particularly social anxiety, use ego dissolution to view themselves less critically and accept themselves as they accept those around them.

During the club discussion, Tosques and Zenobia spoke about the use of psychedelics to allow patients with depression to “realize that life is beautiful and worth living,” patients with OCD to “relinquish control” after tripping, and patients with PTSD to separate pain from traumatic emotional processing, allowing them to move forward with a better sense of closure. A slightly more niche use of psychedelics has been documented in terminal illness cases, allowing patients to remove the intense fear of death and accept the end of their lives with peace. In general, psychedelics “enable you to look at yourself with compassion,” Tosques said, which is a skill that many people, particularly young people in today’s world, really struggle with.

With so many studies and testimonies as to the effects of psychedelics, research into the physical effects is still emerging. The near-spiritual experiences of many frequent trippers (or psychonauts, as they call themselves) are often described as a heightened sense of consciousness and the ability to access new areas of their brains. We typically use the visual cortex, a section near the back of our brains, to perceive our environment. Recent scans of brains on various psychedelics revealed much more of the brain lit up, reflecting heightened and much less predictable brain activity. This explanation of increased variance in brain networking supports claims that psychedelics encourage neuroplasticity and habit-breaking.

University of Sussex professor Anil Seth describes the difference in consciousness levels as sleep states, waking states, and trip states. Brain imaging shows the absence of consciousness and brain activity during deep sleep, with almost no visible activity. Extensive imaging on sober waking states gives a solid baseline — around 30% of the brain — for how the majority of people typically operate.

Theories of consciousness indicate that human beings naturally limit our brain capacity to just below a critical level, allowing us to operate at what is known as secondary consciousness. This behavior is an evolutionary trait that limits our perception to focus on self-awareness, reality,



PHOTO BY JIAJIA FU, BIOENGINEERING, 2026

organization, and careful decision-making. In doing so, we keep ourselves safe and reduce potentially dangerous fantasies or ideologies.

Primary consciousness, achieved under the influence of psychedelics, expands activity to typically dark areas of the brain, allowing trippers to come to out-of-the-box conclusions that are not influenced by the regular evidence-based feedback loops. Unpredictable conclusions are a result of a scrambling or disorganization of typical brain linkages and network patterns. Whereas normally our brain is grouped into functional groups that communicate very well within themselves, on psychedelics, sections of our brain are much more capable of breaking out of their groups and talking to each other.

This theory supports the explanations for the psychedelic treatment of mental health disorders. Take depression for example: Cognition in patients with depression is continually altered by an unyielding sense of pessimism. By scrambling these learned network connections linking pessimism to an individual’s predicted reality, suddenly pessimism affects a variable amount of their thoughts and decisions. The brain is then able to flex its secondary consciousness to reflect the experience during primary consciousness and reduce the impact of pessimism.

Despite all of the studies, testimonies, and groundbreaking research surrounding psychedelics and their incredible impacts on our cognition and health, there is still a great deal of stigma surrounding their use, decriminalization, and legalization. Many of society’s stigmas come from an association of substances with minority groups, similar to the association of marijuana with Black people in America. In the United States, the association of psychedelics with the hippie and counterculture movement of the 1960s followed by the War on Drugs movement in the early ‘70s has resulted in the negative connotation of psychedelics. This likely results from a misrepresentation of the counterculture movement, with much of today’s youth citing drugs as a main tenet of the hippie movement — when in reality the political demonstrations were of much more importance — and those who partook in drugs often getting called “freaks.”

As with the slow decriminalization and legalization of marijuana, there is hope for the future of psychedelics in medicine and treatment plans. With continued education and research, we can come closer to reliable solutions for the countless members of society who suffer from mental health disorders. Interest groups like NEU Psyches, which is supported by Northeastern University, are making the topic less taboo and more accepted by the general public. If Bill Wilson was around to see this resurgence in psychedelic research, hopefully he would be excited and inspired by the potential for the widespread use of psychedelics in medicine.

*Behavioral Neurobiology of Psychedelic Drugs* (2017). DOI: 10.1007/7854\_2017\_475  
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*Journal of Addictive Behaviors, Therapy & Rehabilitation* (2014). DOI: 10.4172/2324-9005.1000106

PHOTOS VIA SHUTTERSTOCK

# TREATMENT OF DEPRESSION THROUGH SPINAL CORD STIMULATION

BY AARUSHI THEJASWI, COMPUTER SCIENCE & BEHVIORAL NEUROSCIENCE, 2027

DESIGN BY SAMARTH KEERTHIVASAN, CELL AND MOLECULAR BIOLOGY, 2027

**C**urrently affecting millions of people worldwide, major depressive disorder (MDD) is a serious and chronic mental health condition whose prevalence has only been exacerbated by the recent COVID-19 pandemic. Symptoms include consistently low mood, lack of energy, changes in sleep or appetite, and suicidal thoughts and feelings. A variety of biological, environmental, and psychological factors can cause MDD. Though the disorder cannot be completely cured, various methods exist to manage the condition and improve patients' quality of life. The best treatment option varies based on an individual's specific situation, but some examples are psychotherapy, medication, and electroconvulsive therapy.

Recently, researchers at the University of Cincinnati have found that electrical stimulation of the spinal cord can effectively treat the symptoms of MDD. The spinal cord is essential for connecting the brain and body and contains neural pathways involved in emotional experiences and feelings. Spinal cord stimulation focuses on depression caused by the overloading of this brain-body pathway. If the pathways are working as they should, the brain is sent information that it can consistently use for mood regulation. However, when information overwhelms these pathways, such as due to chronic stress or hypertension, the brain-body circuit will become hyperactive and burn out over time. Once the system burns out, the brain cannot adjust and regulate mood as effectively.

The process of spinal cord stimulation involves placing electrodes on a patient's back along their spinal cord and sending electrical impulses through a remote control. This method has been primarily used for pain relief and improvement in psychosocial functioning, and the applications for MDD are currently being explored. If a small electrical current is run through the spinal cord, the flow of information into the brain-body circuit will decrease, preventing potential system overloads and allowing the brain to readjust and better regulate mood levels. Over an

eight-week trial, a research team from the University of Cincinnati conducted this spinal cord stimulation technique on 20 adults aged 18–55 years who were diagnosed with MDD or had moderate MDD symptoms. The results showed that those who received the electrical stimulation had a more significant decrease in their depressive symptoms than those in the control group.

“

The results of this initial study look very promising for the future of MDD treatments, potentially saving hundreds of lives.”

While the study displayed positive impacts in treating MDD, there were mild side effects to the trial and potential safety concerns about spinal cord stimulation. Some participants experienced skin redness, brief itchiness, or burning sensations at the stimulation site, though side effects did not last very long after treatment sessions. Potential risks for the spinal cord stimulation technique include the risk of infection around the hardware, and device malfunctions. Due to advances in procedures and technology, these events have become less common, however.

However, the small sample size of 20 people limits confidence in the results. In future studies, the research team plans to run the trial on a larger group and vary the strength of the current to find an optimal level. The results of this initial study look very promising for the future of MDD treatments, potentially saving hundreds of lives.

*Molecular Psychiatry* (2023). DOI: 10.1038/s41380-023-02349-9  
*Pain Medicine* (2016). DOI: 10.1093/pmt/pnw152  
*Major Depressive Disorder* (2023). PMID: 32644504

PHOTO BY IFTIKHAR ALAM VIA VECTEEZY

# Beyond the senses

## COVID-19's influence on brain maturation and the aging process

BY CECELIA KINCAID, BEHAVIORAL NEUROSCIENCE, 2027

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

**F**or millions of people around the world, COVID-19 was not just a week-long scare; it became a chronic condition. The most familiar symptoms of COVID-19 resemble those of the common cold, but it had a much farther reach than respiratory or muscular difficulties, especially in adolescent communities.

Newer concerns are coming to light regarding how COVID-19 physically altered the brain. One group, led by Stanford University psychologist Ian Gotlib, found anatomical differences in the brains of teenagers who suffered from COVID-19 compared to adolescents who did not, which indicated early brain maturation. Gotlib's study compared 163 teenagers split into two groups with roughly equal proportions of age and sex. One group was assessed before the pandemic (pre-COVID), and the other was assessed during it (peri-COVID). They found that many of the peri-COVID adolescents had considerably thinner cerebral cortices than what was expected for their age.

The cerebral cortex is largely responsible for higher-level processes of the brain such as language, learning and memory, reasoning and decision-making, and personality. While the cerebral cortex naturally thins with age, premature thinning could possibly lead to issues with attention and memory and even increase the risk of depression due to disturbances of social stimuli. The study also revealed that the peri-COVID group had increased hippocampal and amygdala volumes. The hippocampus and amygdala are crucial to regulating memory and emotion, and issues with these parts of the brain could lead to behavioral or learning difficulties.

Gotlib's lab concluded that the pandemic not only adversely affected adolescent mental health but also accelerated brain maturation, potentially leading to increased stress and negative emotions. Changes in the cerebral cortex, hippocampus, and amygdala could have drastic impacts on individuals' higher-order processes.

Premature brain development is closely related to the concept of epigenetic aging, which is the degree of biological aging based on DNA methylation,

which alters gene expression and is a key process in normal development. An individual's epigenetic age may be older than their chronological age if they have experienced potentially harmful environmental factors, such as extreme stress or a serious disease.

A team of researchers led by Xue Cao at the Guizhou Provincial People's Hospital in Guizhou, China, conducted DNA methylation experiments to compare epigenetic age acceleration in healthy individuals to COVID-19 patients. Those with COVID-19, especially severe cases, demonstrated accelerated epigenetic aging. Interestingly, Cao's team also found that those with shorter telomeres tended to be at risk for more severe cases of COVID-19. Telomeres are DNA-protein structures on the ends of chromosomes that protect genetic information from deterioration, unnecessary combination, and other dangers. The gradual shortening of telomeres, called attrition, occurs naturally with age, but the association between telomere attrition and the severity of COVID-19 gives an early insight into the connection between COVID-19 and epigenetic age.

Another important conclusion that Cao's team reached was that accelerated epigenetic aging could contribute to post-COVID-19 syndrome in severe cases, impacting multiple body systems and possibly causing autoimmune conditions. Understanding the association between telomere attrition and severe COVID-19 cases could improve risk calculators and better prepare doctors for complications.

The two studies led by Gotlib and Cao show a few of the far-reaching impacts that the pandemic had on the human body, accelerating both adolescent brain maturation and aging. It is important to consider the implications these results have for future studies. Researchers must consider whether these changes are temporary, particularly when establishing baseline or control groups for future anatomy or brain imaging studies. Future research must explore the longevity of these changes and their implications for generations to come.

# Northeastern professor collaborates with Tufts' division chief of pediatric oncology in preliminary study

BY MACKENZIE HEIDKAMP, BIOCHEMISTRY, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

With Northeastern University having recently climbed the academic ladder to become a tier one research institution, hundreds of projects are simultaneously emerging with the aim of publishing innovative information. In a newly published study, Northeastern Research Associate Professor Christine Lary collaborated with the Division Chief of Pediatric Oncology at the Tufts University School of Medicine, Dr. Aaron Weiss. Using Lary's knowledge in biostatistics and Weiss's clinical experience, they explored the use of an immunosuppressive drug called sirolimus on patients with desmoid-type fibromatosis.

Primarily affecting young adults and children, desmoid tumors are soft-tissue, non-cancerous growths with a high incidence of local-recurrence and aggression. This means that the mass often grows back after removal in the same spot, or very close to its original spot. Due to the tumor's aggressive nature and specific demographic, the pair directed their research to discover if the drug sirolimus could be used to block the mTOR signaling pathway that is often associated with tumors. mTOR plays an essential role in tumor metabolism as it leads to gene transcription and protein synthesis, both of which are essential processes for cell growth and tumor expansion. More cells means more tumor cells, which is why Dr. Weiss aimed to discover how to block a pathway responsible for cell expansion. Sirolimus was selected as the drug of interest due to its relatively low cost and ability to be administered orally. Typically used to

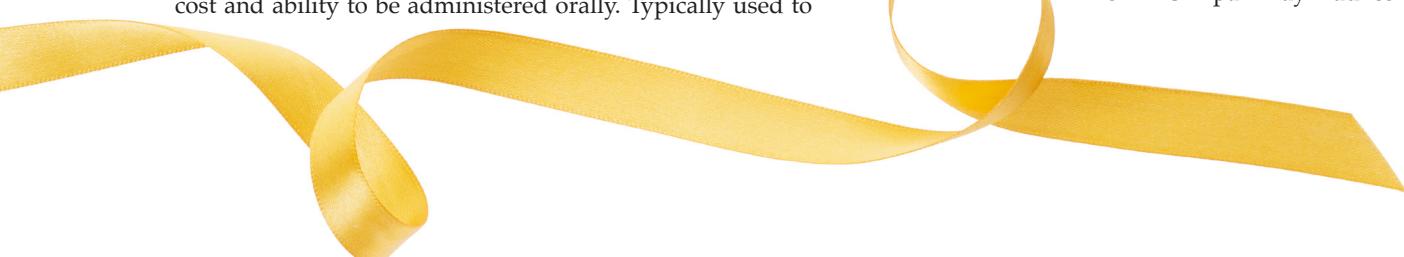
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The intent of research is to better the scientific community's collective knowledge; each study is simply a piece of the puzzle.”

suppress the immune system after a transplant surgery and prevent the rejection of a new organ, the drug also targets the mTOR pathway.

The study consisted of nine subjects under the age of thirty with desmoid tumors at a low risk of recurrence, which is determined by factors such as size and anatomical location. The participants took sirolimus orally for three days before surgical removal of the tumors. Over four weeks, the researchers observed the patients for instances of recurrence and noted their reported levels of discomfort to test if the drug helped to improve any pain derived from the tumor.

After tumor removal, the data indicated that the drug had no noticeable influence on pain, and the reported levels of proteins involved with the mTOR pathway had conflicting



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'If you're going to make advances in the field, you're going to have to collaborate,' said Dr. Weiss."



results. It was discovered that there was an increase in one downstream protein (p4EBP) and a decrease in the other (pS706k). Theoretically, both should have decreased due to their functions in the pathway, so the observed levels were a little confusing.

"It's hard to gauge the exact reason why one protein decreased and not the other," Dr. Weiss said. "When you do these types of studies, you never know what you're going to find. If we could have adjusted the doses during the study and got certain patients to higher levels, maybe we would have seen an impact on the proteins."

Dr. Weiss hypothesizes that both the drug's dosage and duration of administration may have been significantly too low. Additionally, he acknowledged that the sample size for the trial was smaller than originally anticipated, given that the modern field of oncology is generally moving away from surgical resection if possible. This is because the risks of surgery, including infection or other complications, may not outweigh the potential benefits. In oncology, a tumor has to be completely removed with no leftover mass to ensure no regrowth. For this reason, treatments such as chemotherapy or other targeted therapies are occasionally preferred. Moreover, some tumors, including desmoid tumors, are known to sometimes spontaneously regress or shrink in size. The reasons behind spontaneous regression are not entirely clear, but it is clear that most surgeons would rather observe their patient than perform an operation when possible. As this trial was initially structured back in 2011, Dr. Weiss could not have foreseen this shift in general practice.

"In an ideal world, I would love to be able to still answer the question of whether sirolimus — or a drug that impacts this pathway — would be beneficial for patients with desmoid tumors," said Dr. Weiss. "You need a lot of money in order to do a real study, and that's hard to get."

Overall, the researchers acknowledged the study as exploratory research, and they established that the drug could be safely administered to children and young adults: their target demographic. Although Lary and Dr. Weiss may not have been able to reach any definitive conclusions, they established the groundwork for future research into sirolimus and the mTOR signaling pathway. If sirolimus is discovered to impact the pathway, thousands of non-desmoid-tumor patients could benefit as well, since mTOR has been connected to breast, lung, prostate, gastric, lymphoma, urinary, neck, and many other cancers.

Applying for research funding is notoriously competitive and time-consuming. So, "if you're gonna make advances in the field, you're going to have to collaborate," said Dr. Weiss. After all, research is a collaborative effort. The intent of research is to better the scientific community's collective knowledge; each study is simply a piece of the puzzle.

*Pediatric Blood and Cancer* (2023). DOI: 10.1002/pbc.30466  
*Cell and Bioscience* (2020). DOI: 10.1186/s13578-020-00396-1  
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PHOTOS VIA SHUTTERSTOCK

# The promise of machine learning in predicting the outcome of cardiac surgery

BY AARON BHATTACHAN; BIOENGINEERING, BIOCHEMISTRY & MATH; 2027

DESIGN BY KATHRYN FURMAN, COMPUTER SCIENCE & MATH, 2025

**O**n Sept. 3, 2023, my grandpa suffered a minor acute heart attack. Left without many options, we turned to a form of cardiac surgery called an angioplasty. Despite the doctor's initial confidence in the surgery, the heart attacks intensified, and my grandfather fought hard until the moment he passed away. After the surgery, the doctors told us that plaque had accumulated in all three of his major arteries, each 98% closed.

Atherosclerotic cardiovascular disease (ASCVD), caused by a buildup of plaque in the arteries, stands as the silent architect of heart disease and heart attacks, contributing to 32% of the world's deaths in 2019. With about half of Americans over 45 having Atherosclerosis, surgical techniques such as angioplasties are becoming increasingly common. However, these surgeries are risky: 1 in every 50 angioplasties ends with the patient experiencing major complications leaving many patients and doctors unsure of how to go about cardiac surgery.

Having been through this experience with my grandfather, I wondered if there was a way to predict the outcomes of these surgeries for ASCVD, and as a result, if perhaps we could better prepare and make more informed decisions in the fight against this deadly disease. Now that researchers have begun to examine machine learning's predictive power, a new study has applied the method to predict the outcome of ASCVD surgeries. The researchers say the results are promising.

In their new study, the team of researchers from Brown University, led by Dr. Adeel Abbasi, put machine learning's prowess in predicting cardiac surgery postoperative outcomes to the test. Focusing on identifying complications such as postoperative hemorrhage (bleeding from a damaged blood vessel), venous thromboembolism (when blood clots form in the veins and block blood flow), and stroke, the team used a dataset boasting 662,772 subjects and 240 patient variables to unmask the greatest risk factors for ASCVD surgery complications.

The remarkable accuracy of the model — ranging between 92% and 97% accuracy in ranking the severity of postoperative outcomes within the dataset — highlights its robustness and dependability in predicting patient outcomes after cardiac surgery. What distinguishes this

model's effectiveness is its emphasis on postoperative variables as the primary contributors to outcome prediction, surpassing the significance of preoperative and intraoperative factors. More specifically, the model identified two key postoperative variables, including the quality of mechanical ventilation and the early detection and treatment of new postoperative arrhythmias.

To improve postoperative surgery outcomes and enhance patient outcomes, researchers and doctors can focus on these areas as they currently stand and how they can be developed even further. While the expanding horizon of artificial intelligence in healthcare begs further exploration, ongoing initiatives aiming to identify ASCVD demonstrate promise in reconstructing the traditional landscape of cardiac care. In this ever-changing world, contagious hope persists in the minds of patients' families all over the world. If you ask any patient what their greatest accomplishment in life is, so many will say that it's their family. Sharing my grandfather's heartbeat is mine.

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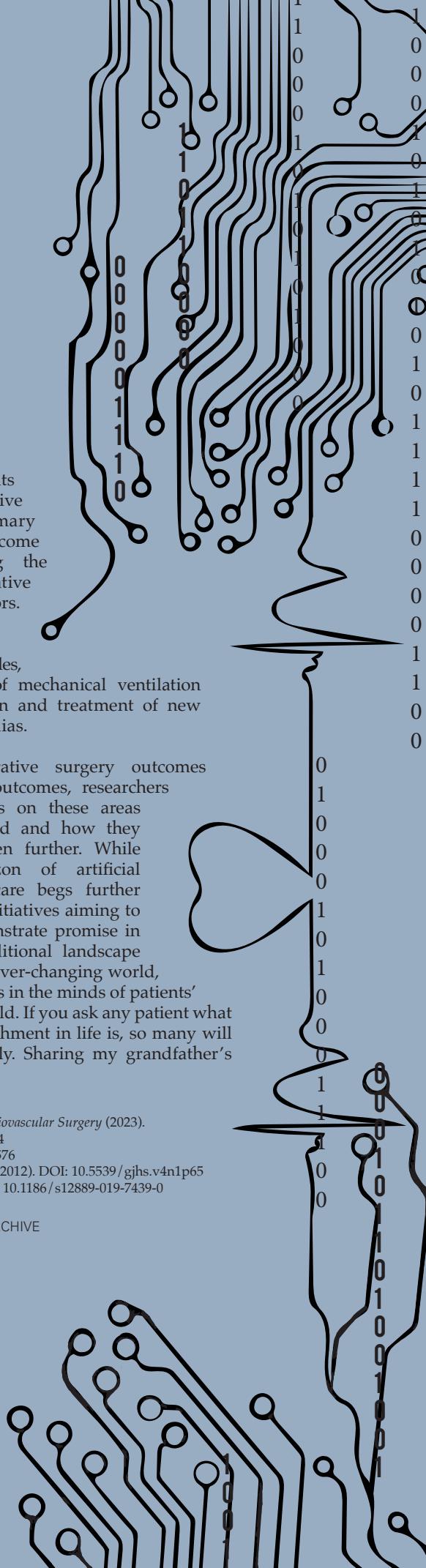
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PHOTOS VIA FLICKR & GETARCHIVE



# Could fractals be the cure for Alzheimer's disease?

BY ISABELLE KESOCK, BEHAVIORAL NEUROSCIENCE, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

**B**eginning signs of dementia and Alzheimer's disease can start up to 18 years before a diagnosis ever occurs. In the almost two decades it takes to receive a diagnosis, so much damage has already taken place in the brain that treatment measures can only alleviate symptoms and extend life expectancy by a few years. But, if a diagnosis were to occur earlier in the disease's progression, could we extend this expectancy further or increase the chance of finding a true cure at last?

Neurons underlie neurological diseases, and they rely on fractal geometry for their connectivity and function. Dendrites are the communication hubs of neurons and have a branch-like form that allows for optimal information transfer. Consequently, they are an integral player in brain function. Used similarly in lightning, rivers, and trees, this fractal branch pattern is used specifically by dendrites to extend their reach as well as increase the surface area for incoming synapses, the actual site of message transmission. All in all, this geometric pattern allows for more efficient communication between neurons in the brain.

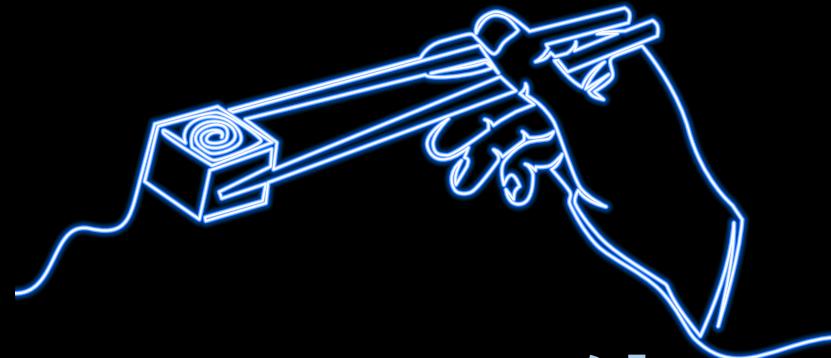
Over time, new technology has emerged that allows for earlier diagnosis of Alzheimer's disease. More recently, certain positron emission tomography (PET) tracers have been able to show amyloid buildup and increased amounts of tau protein. In normal circumstances, amyloid is essential for neuron growth and repair, but in Alzheimer's, abnormal levels of the protein build up into plaques which disrupt critical neuronal function. Tau protein is responsible for maintaining neuronal signaling and structure, but its dysfunctional state causes neurofibrillary tangles. As hallmarks of Alzheimer's, both amyloid plaques and tau cause a decrease in neuron signaling and massive neurodegeneration, eventually leading to brain atrophy. This consequently translates into traditional Alzheimer's symptoms related to impaired memory, thinking, and execution of everyday activities.

While PET scans can detect unusual cellular activity, like amyloid plaques and increased tau presence, they are not commonly performed. Instead, magnetic resonance imaging (MRI) scans are heavily favored and already prevalent within medicine and research. MRI scans do not provide the same insights as PET scans but instead offer very high spatial resolution. Within our understanding and interpretations of MRI scans, a new metric called fractal dimension is emerging as a forward method for early diagnosis of neurodegenerative diseases such as Alzheimer's. Fractal dimension is a numerical representation of the structural complexity between neurons' communication points and also gives a more quantifiable understanding of the signaling occurring.

It has long been understood that fractal dimension decreases with age alongside other factors like gender, but in his 2014 study, Richard D. King, a professor from the University of Utah, showed that diseases like Alzheimer's can also influence fractal dimension values. He found that when compared to a healthy adult, those with Alzheimer's have lower local fractal values in the brain's cortex. Additionally, a study by Ryuta Kinno and his team at Showa University School of Medicine found a significant correlation between the metric and memory evaluation techniques like subject recognition and paired associate memory abilities. The lower fractal values reveal a decrease in neural communications and indicate that the signals being sent are less efficient. This again supports the idea that a decrease in fractal dimension could be indicative of Alzheimer's disease.

By continuing to study and one day incorporating this fractal dimension into everyday diagnostics, perhaps we will be one step closer to finding a true cure for this harrowing disease.

# WHAT DO YOU MEAN, ELECTRIC CHOPSTICKS?!



BY BRYANNA UPTON, CELLULAR & MOLECULAR BIOLOGY, 2027

DESIGNED BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

**Y**ou have just gotten back from a long day of work to eat dinner. You pick up your fork, take a generous scoop of food, and are instantly disappointed. Where is the flavor? Where is the satisfying reward of a savory meal? Luckily, the saltshaker on your table is an easy fix. However, this common flavor enhancer could cause health problems for millions around the globe.

Researchers from Meiji University in Japan may have a solution that does not result in disappointing dinners. According to a News Atlas article, these researchers have developed a pair of chopsticks that use electrical stimulation to enhance a food's flavor. Therefore, the public can reap all the health benefits of maintaining a low-sodium diet but can enjoy the saltiness they so desire.

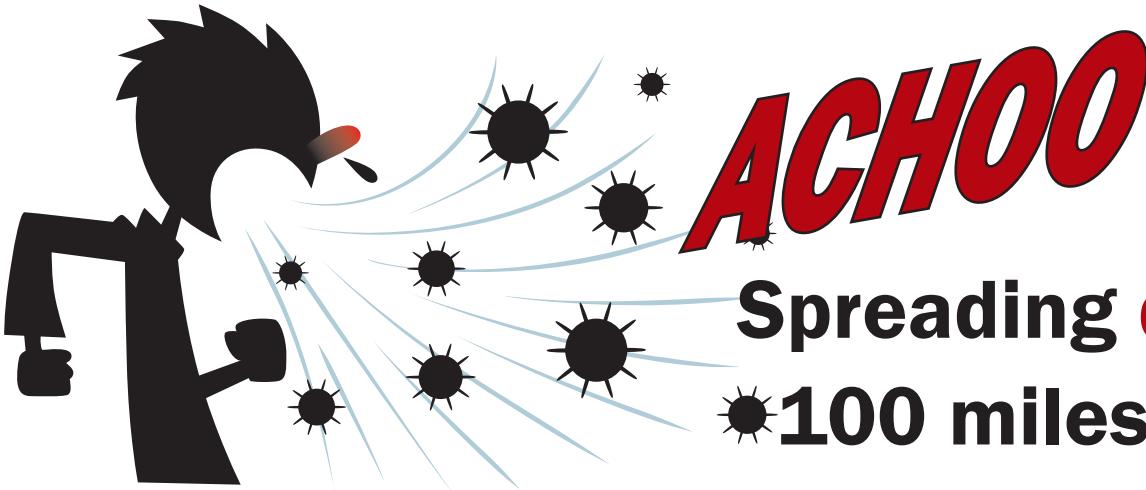
The excess intake of sodium is a huge health concern, especially in the United States. According to the CDC, a high-sodium diet can raise blood pressure, increasing the risk of heart disease and stroke. This immediately raises some red flags in most Americans. We often hear about how heart disease is a rising crisis and how fatty diets are to blame. According to the FDA, the average American eats 3,400 milligrams of salt per day. This number means nothing to most people until you compare it to the recommended 2,300 mg per day. That is 1,100 mg over average! Many people are surpassing this excess of 1,100 mg, creating a serious risk of heart disease. Reduction of this risk is what makes these electric chopsticks so promising.

The chopsticks connect to a small computer worn on the wrist, similar to a watch. The battery sends an exceedingly

small -0.5 ampere electric current through the sticks to prepare the food. Table salt, or sodium chloride, exists dissolved in most foods. The current breaks up the molecule into two ions, a positively charged sodium ion and a negatively charged chloride ion. It also stirs the food around, drawing up any sodium ions. The positive sodium ion is majorly responsible for the taste we perceive as salty.

While the exact science of the chopsticks has not been fully explained by the researchers, News Atlas suggests that the electrical current pulls all these positively charged sodium ions to the surface of your food. Instead of the sodium ions present in your low-salt dinner completely missing your tongue, they are now all concentrated in one spot, making them much more likely to reach your taste buds. According to the Asahi Shimbun, one of Japan's largest newspapers, the team has expanded their electric cutlery to include straws, forks, and spoons. Also, when adjusting the direction and layout of electrodes, they were able to change certain foods' acidity and bitterness.

On Sept. 14, 2023, the chopsticks won the Meiji University researchers an Ig Nobel Prize. The parody award famously goes to research that at first seems laughable, but then makes people think. While electric chopsticks may seem like clickbait, they could potentially change the lives of billions worldwide. In a world of ever-improving technology, we get to watch something as simple as electrical currents entangle with public health.



# ACHOO

## Spreading disease at 100 miles per hour

BY HEIDI HO, PUBLIC HEALTH & JOURNALISM, 2027

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

**W**hile you are trying to listen to your professor lecture about derivatives and integrals, the person sitting less than three feet away from you sneezes: "ACHOO!" You shudder. Perhaps hold your breath. Or scoot your chair a few inches away from them.

One person infected with an illness has the potential to infect 15 out of 100 people within two weeks. While that may not seem like much, this means that up to 15% of the student body of schools that contain thousands of students could be out of commission for a while. To make matters worse, the population has experienced firsthand how the COVID-19 pandemic has negatively affected the economy with temporary and permanent closures of schools and businesses.

With that being said, how are sneezes contagious? And what makes them unique from other modes of transmission?

A sneeze, or sternutation, is a way for the body to get rid of irritants by expelling mucus via the nasal and oral cavities. A sneeze releases 40,000 droplets compared to a cough's 3,000, which is especially scary for a short person, who is more likely to inhale infected droplets.

Many factors, such as the force of a sneeze or the environment, affect the velocity of a sneeze. According to a study led by MIT fluid dynamics scientist Lydia Bourouiba, sneeze velocities can reach up to 100 miles per hour.

Larger droplets, more than five to ten microns, usually travel three feet before they fall to the ground due to their density. While their area of impact is smaller, they carry more infectious particles and are more likely to get someone sick. Small droplets, or aerosols, travel further and remain airborne for up to two weeks. They can travel through air vents and make their way into another room, where more victims may lie completely unaware. The more humid a room is, the longer those particles will linger in a cloud of sneeze content.

These pesky aerosols are tiny enough to easily travel deep in a person's lung. Researchers at the Wake Forest School of Medicine in North Carolina found 89% of flu viruses in particles less than 4.7 micrograms up to 6 feet from a person's face.

These numbers and statistics can be alarming, but there are many ways to reduce infection transmission. People are taught to cover their mouths and noses when they sneeze, but the angle of the head during a sneeze also plays an important role in reducing the spread; by bending our head down at an angle of 3–43 degrees, people can reduce a sneeze's infectious distance by 22%.

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**One person** infected with an illness has the potential to infect **15 out of 100 people** within two weeks."

Droplets move towards the path with the least resistance, meaning that any open area is likely to be the path of a sneeze. One way to minimize open areas is by wearing a mask. While surgical masks like an N95 provide the most protection, even one cloth covering reduces the risk of infection.

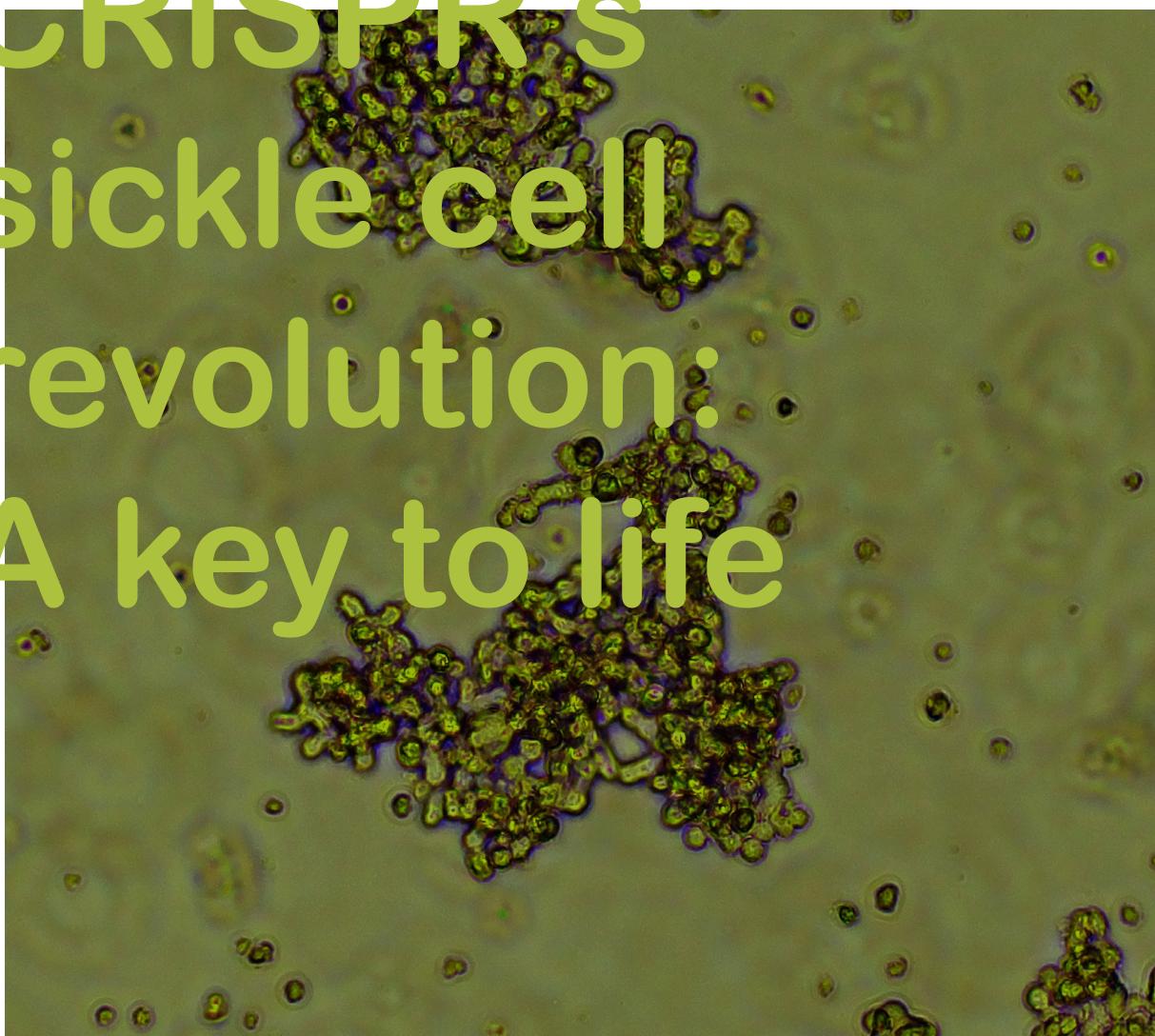
One way sickness can spread is by physical contact of droplets to the face. People touch their faces an average of 16 times an hour, so finding other ways to occupy the hands reduces the chance of spreading infection.

Everybody sneezes. It's one of the body's mechanisms that free it from irritants and disease. Unfortunately, one may spread such infected particles to others in the process of doing so. The COVID-19 pandemic has been a reminder of the incredibly infectious nature of some diseases. While people may not have batted an eye at someone sneezing in 2018, the pandemic greatly altered the level of caution. Luckily, everyone can reduce the spread, whether that be by wearing a mask or taking a day off when they first feel that tickle in their nose.

*National Library of Medicine* (2020). DOI: 10.1164/rccm.202004-1263PP  
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*JAMA Insights* (2020). DOI: 10.1001/jama.2020.4756

PHOTO VIA SHUTTERSTOCK

# CRISPR's sickle cell revolution: A key to life



BY RESHIKA SAI DEVARAJAN, HEALTH SCIENCE, 2025

DESIGNED BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

**R**ed blood cells (RBCs) are the single-most important factor in gas exchange with the environment and the key to sustaining life. With approximately 70-80 trillion red blood cells present in human bodies at any given time, these cells constitute 70% of all the cells in the body. RBCs are flat and disk-like, featuring indentations on both faces of the cell that give them a distinctive convex shape. Their unique shape optimizes their flow and allows for smooth, uninterrupted movement in blood vessels. Contained within the cell is an important protein group called hemoglobin, an iron-containing compound that carries oxygen. RBCs' structures are specific to optimize their function as a gas-exchange mediator in the body, and these cells lack internal organelles for the purpose of freeing up space to accommodate more hemoglobin. With RBCs' lifespans being 120 days, about 5 liters of blood circulate in the human body at any given time.

RBCs play a crucial role in the body's everyday functioning, providing it with oxygen that can be utilized via metabolism to produce energy. Mutations or abnormalities of function in these cells can influence the amount of oxygen delivered to other cells in the body. In other words, the health of every other cell in the body directly depends on that of its blood cells.

Sickle cell disease is an inherited RBC disorder. Affecting about 100,000 people in the United States, this condition is present at higher rates in African American and Hispanic Americans. Sickle cell disease is common in populations that live in areas where malaria is more common, such as near the equator, because one copy of the sickle cell gene confers a selective advantage and makes individuals less susceptible to malaria while the individual's health or blood carrying capacity is relatively unaffected. However, two copies of the sickle cell gene will manifest in the

phenotype, or the physical characteristics of the disease. The expression of the phenotype causes the production of blood cells that are sticky, hard, curved, and in a sickle-like shape. This change is due to an amino acid mutation in a gene that codes for RBCs. The oxygen-carrying capacity of sickle-cell-shaped RBCs is significantly diminished, so these cells tend to die earlier than healthy RBCs. In addition, the shape of sickle cells is not conducive to regular blood flow, and these cells can get stuck in smaller arteries and veins, causing clogs and impeding flow. As a byproduct, there is a less effective gas exchange system in the body, which also affects the functioning of the many other cells that depend on blood to deliver oxygen. This can manifest in a variety of health effects including pain, fatigue, stroke, and even a significantly lower life expectancy.

Remarkably, a newly developed CRISPR-Cas9 gene editing therapy by Vertex Pharmaceuticals and CRISPR Therapeutics provides a novel treatment avenue for this painful disease. Scientists invented CRISPR technology a mere 11 years ago by repurposing the inherent defense mechanisms found in bacteria. CRISPR is a form of gene editing that can help remove and replace mutated or dangerous genes that can affect the health of an organism. In the context of sickle-cell disease, CRISPR does not target the mutated gene but instead increases the transcription of fetal hemoglobin, a substance whose production is normally limited soon after birth. Fetal hemoglobin has a higher affinity for oxygen than the adult counterparts, which makes it more likely that oxygen can be held onto and transported by blood cells in sickle-cell patients. Although the mutated cell shape is not directly affected through this therapy, the loss in RBC efficiency due to sickle cell disease is counteracted by promoting the oxygen-carrying capacities of the misformed cell.

However, trials with CRISPR are often costly and limited in scale. While the current approval for the sickle-cell treatment was based on a trial in which the therapy reduced the

prevalence of painful inflammatory attacks characteristic of sickle-cell disease in 28 out of 29 participants, the long-term effects of the therapy and its full safety profile are yet to be determined. Vertex has plans to enroll patients in human clinical trials in a 15-year safety study to track important longitudinal information about the drug efficacy, long-term effects, and safety. Current plans include the creation of 50 treatment centers to administer treatment, but due to high costs of personnel, materials, and more, these centers are expected to serve only about 12 patients a year.

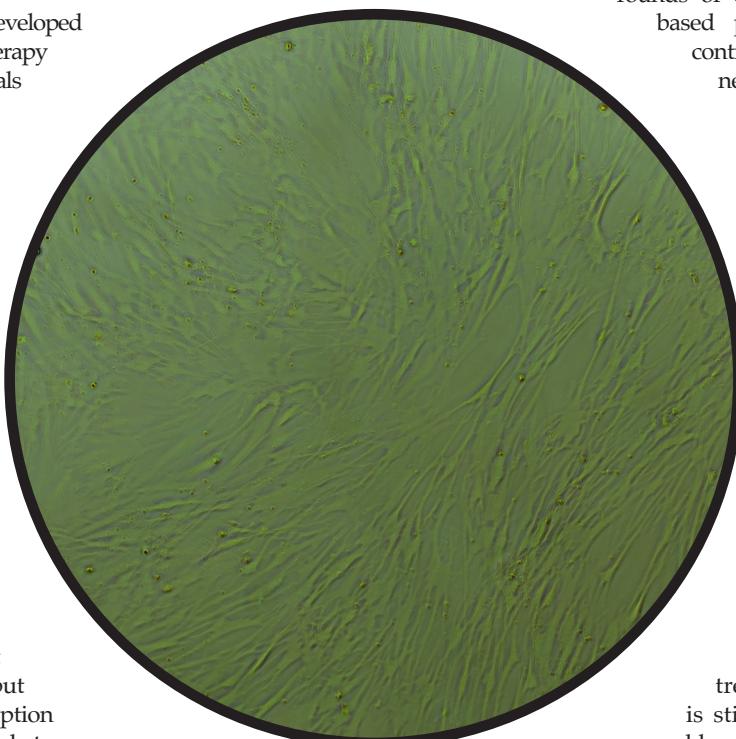
While promising, it is important to acknowledge the inherent challenges and financial implications associated with this advanced therapy. The extensive requirements, including multiple blood transfusions, rounds of cell mobilization, and toxic-based preconditioning procedures, contribute to an estimated cost of nearly \$2 million per person for the implementation of this groundbreaking treatment. Until CRISPR technology becomes more affordable, patient accessibility is severely limited, and the general public may have to look at alternatives to treat sickle cell disease.

Existing treatments remain viable, as hematopoietic stem cell transplant (HSCT) is already an important genetic treatment option.

However, the cost of this treatment, about \$400,000, is still a large financial burden and barrier for most. Another cost-effective alternative used in Nigeria is a drug called hydroxyurea, which increases fetal hemoglobin production. However, this drug is not widely available and does not have a lasting impact like other genetic technologies. Unfortunately, the continued focus on developing new biopharma technologies combined with the neglect of patient access and equity has resulted in a novel array of optimistic but highly inaccessible treatments

*Nature Biotechnology* (2024). DOI: 10.1038/d41587-023-00016-6  
*StatPearls* (2023). PMID: 30252333  
*Front Physiol* (2021). DOI: 10.3389/fphys.2021.655393

PHOTOS BY AMANDA MANTIONE, CELL AND MOLECULAR BIOLOGY 2024



# Restoring vision

## Recent research reveals stem cells could treat glaucoma-induced vision loss



BY ELIZABETH LUO, CELL & MOLECULAR BIOLOGY, 2026

DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

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

**G**laucoma is an eye disease where rear optic nerve damage causes a loss of vision. This damage can be caused by the buildup of fluid in the eye due to the inability to drain such fluid out of the front of the eye. The fluid normally travels through the trabecular meshwork in the anterior chamber, a drainage pathway located between the cornea and the iris. However, sometimes the trabecular meshwork becomes blocked, preventing drainage and causing a buildup of pressure from the fluid.

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Though this method for glaucoma treatment is still being researched, many promising results are produced that can eventually help in vision restoration for those with glaucoma.”

Treatment for glaucoma typically focuses on preventing the progression of the disease and includes prescription eye drops to decrease pressure in the eyes, laser treatment to drain fluid out of the eye, and even surgery. Currently, researchers at the Baranov lab at Massachusetts Eye and Ear are focused on a new type of treatment that utilizes the replacement of retinal ganglion cells, or neurons that connect the brain's visual processing regions and retinal input, with stem cells. Previously, many researchers pursuing this cell replacement therapy faced the dilemma of donor stem cells refusing to migrate to the optimal position in the retina for proper cell replacement treatment. To promote and direct cell migration of retinal ganglion cells, researchers at the Baranov lab applied chemokines to the donor stem cells. Chemokines

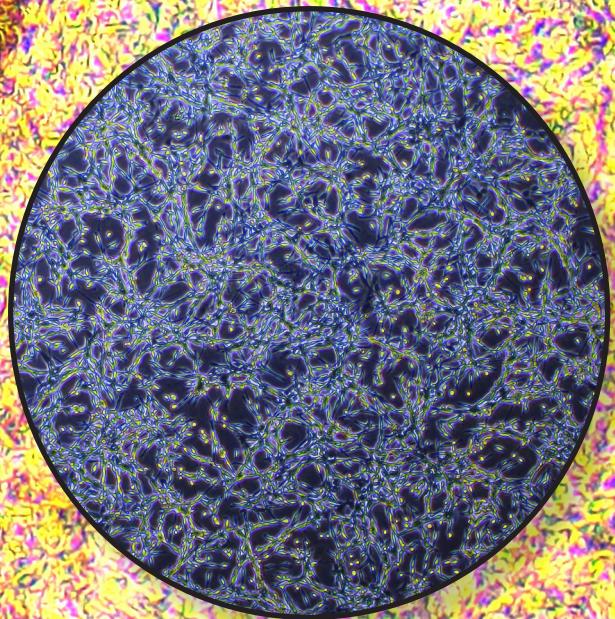
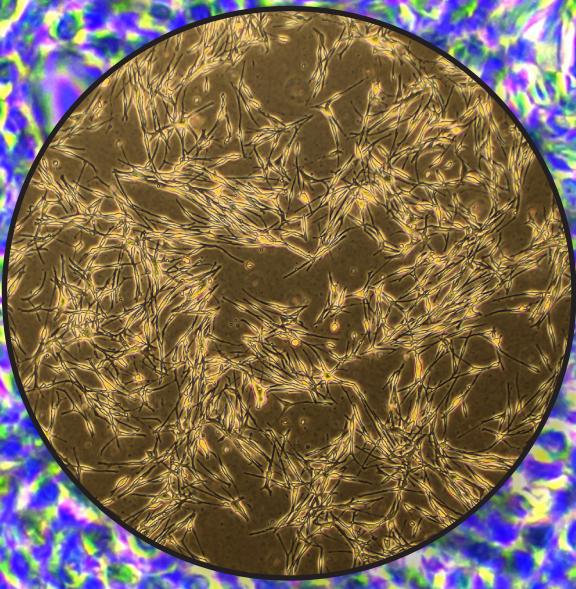
are small proteins that bind to surface-level chemokine receptors, promoting cell migration and adhesion. Of the many chemokines, they found that stromal cell-derived factor-1 had the greatest results in retinal ganglion cell recruitment. Though this method for glaucoma treatment is still being researched, the research so far yields promising results that can eventually aid vision restoration for those with glaucoma. Additionally, the researchers discussed the possibility of using this treatment method for other neurodegenerative conditions by employing stem cells promoted with specific chemokines to repair and promote cell behavior.

Eye health is essential to everyday life, and it is important to maintain good eye health through good habits. Zinc, lutein, and zeaxanthin, which are key to the retina, can be acquired by eating a balanced diet of fruits, vegetables, and supplementing seafood. Sunglasses are also a useful form of protection that blocks and reflects ultraviolet radiation from the sun, shielding eyes and maintaining eye health. Continuous exposure to sun ultraviolet radiation can modify proteins in the eyes' lenses, leading to a loss of vision and blurriness. These tips can also help prevent the onset of glaucoma. It is important to get regular eye checkups, regardless of the use of vision correction, to maintain and treat eye health.

*PNAS* (2023). DOI: 10.1073/pnas.2302089120

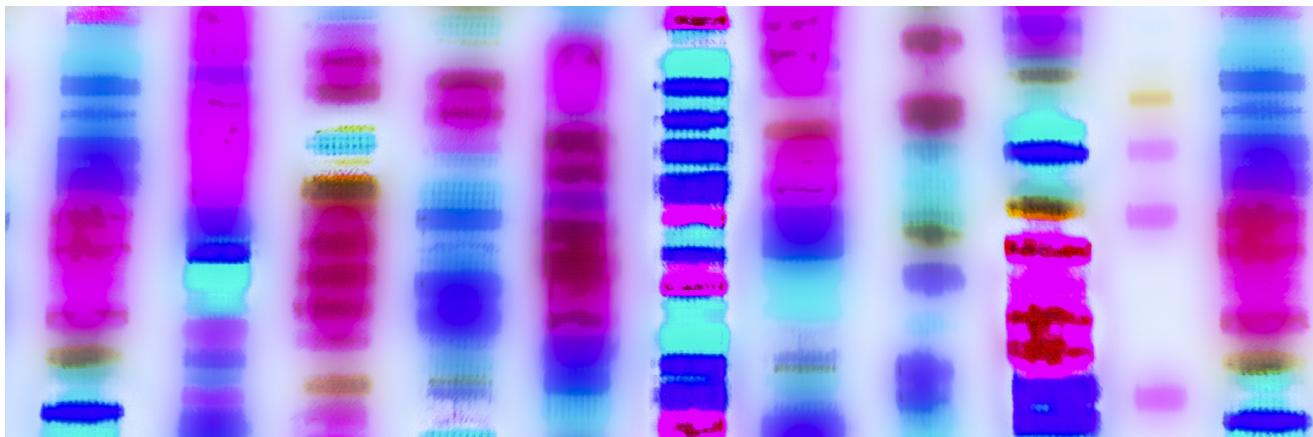
*The FEBS Journal* (2018). DOI: 10.1111/febs.14466

*National Library of Medicine* (2021). DOI: 10.3389/fneur.2021.661938



Just as plants have learned to grow into fractals to take up as much space as possible, human, animal, and bacterial cells have learned the same. Cells use simple repetitive rules to create similar splayed structures in the lungs and heart. Within cells, molecules move in fractal patterns, making themselves easily accessible to other molecules for chemical reactions.

# AN ECOSYSTEM OF ONE'S OWN: THE APPLICATION OF ECOLOGICAL THEORY TOWARD GENOMICS



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PHOTO VIA SHUTTERSTOCK

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**T**he ability to use language to establish relationships and dynamics within an ecosystem sustains the study of ecology. Charles Darwin's "survival of the fittest" narrative describes the tendencies of natural selection and the likelihood of survival based on an organism's environmental adjustment. Other terms used by ecologists to classify the relationships between species — mutualism, competition, and commensalism, for example — intertwine with the language of the age of Darwin to produce a modern conversation about the biosphere. Biology on such a large scale feels tangible to scientists and the public audience alike. Nearly anyone who cares to look can witness how an organism better suited for its environment becomes more successful in survival and reproduction. Lesser known is the versatility of the language of ecology and its usefulness when working on a microscopic scale.

The term "pan genome" may be unfamiliar to some, but the concept takes such recognizable theories as Darwin's and applies them to species's genomes. Prokaryotic genomes are of particular interest as scientists' understanding of symbiosis between their genes could contribute to more accurate and effective treatment of pathogens. This approach to genomics treats individual genes as organisms fighting for survival rather than a rigid code, which may better explain the overlaps or discrepancies of genes among different strains of the same species. The two academic journals referenced in this article examine the pan genome of *E. coli* due to the extensive knowledge about its genome and high degree of variability. The pan genome is easily identifiable in *E. coli* because of a core set of genes common to all prokaryote strains accompanied by varying "accessory" genes. Researchers obtained the genomes of several *E. coli* strains and compared them to each other, scrapping genes present in less than 1% of the subpopulation. Using the remaining

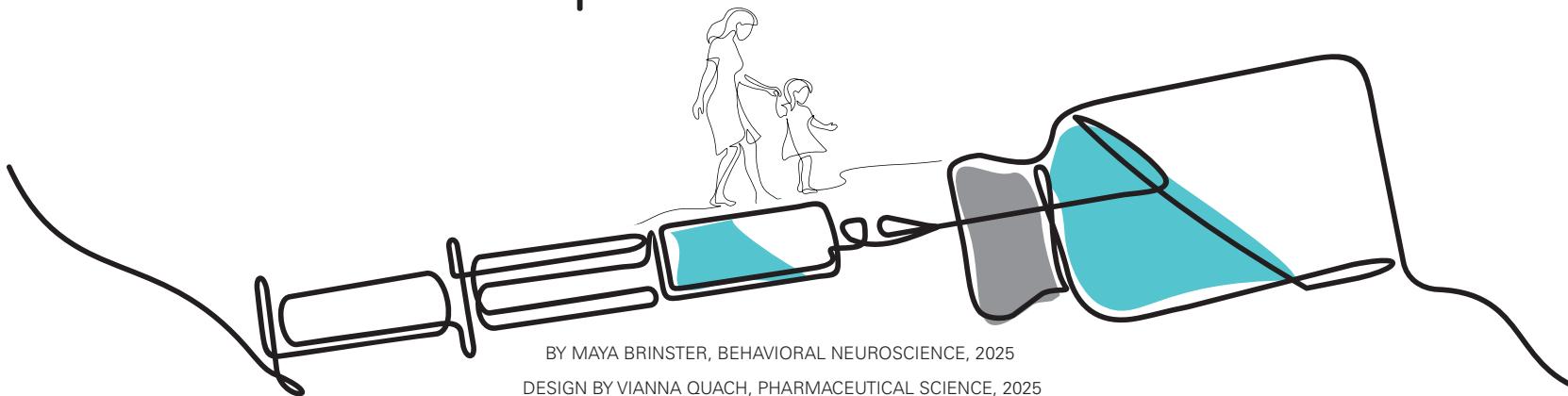
accessory gene alignments, the researchers detected patterns that they then compared to symbiotic relationships at the organismal level. Though not entirely capturing the evolving pangenome's complexity, the symbiosis analogy highlights that the presence or absence of specific genes represents a dynamic biome that does not promise survival.

As shown in the researchers' work, there are some cases in which the presence of one gene correlates with the absence of another. There are "mutualist" relationships in most *E. coli* genomes, in which several genes will cluster together and move between strains or generations as a single unit to ensure their survival. This gene cluster movement in a prokaryote such as *E. coli* is mostly due to horizontal gene transfer (HGT), a process in which one bacterial strain acquires new genes from another. HGT promotes a more rapid response to changing environments than the passing of genes through generations and thus plays a major role in the evolution of the prokaryotic microbiome.

Competition also exists at this genomic level: if two genes have nearly identical functions, for example, one will avoid entering a genome in which the other already resides. These relationships are grounded in the deep understanding of prokaryotic genetic mechanisms and construct a novel perspective that permits scientists to predict the genomes of specific viral or bacterial strains. Treating the prokaryotic pan genome not only as a topic in microbiology but also as a dynamic ecosystem may be the future of medical treatment.

# Combating aging

## Preliminary trials show just a single shot may be the key to youthfulness preservation



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The physical aging process is commonly dreaded; not many look forward to the decline of their strength or increased susceptibility to various diseases. These natural side effects of aging seem inevitable, but a recent study regarding the development of a novel therapeutic mechanism reveals that this may not be the case.

A team of researchers led by Corina Amor Vegas at the Cold Spring Harbor Lab recently discovered a life-altering treatment using engineered T-cells: white blood cells that play a central role in the immune system by attacking foreign substances. Incorporating these cells into laboratory mice increased their health spans by targeting cells that contribute to the physical decline associated with aging.

The targeted cells are “senescent” cells, meaning they have stopped dividing despite existing in optimal growth conditions. In younger people, senescent cells often arise in wound healing to support tissue regrowth or when suppressing a tumor that consists of rapidly dividing cells. An active immune system can clear such cells to restore normal function, but the immune system weakens with age and cannot clear senescent cells as efficiently. Accumulation of these cells leads to pathologies associated with old age, such as decreased fitness and metabolic dysfunction, which can increase the risk of diabetes, stroke, or heart disease.

The elimination of senescent cells can therefore decrease the risk of developing such age-related symptoms. Past research has shown that small-molecule drugs can target these cells and partially help reduce this risk, but they require constant administration and cannot target precise, well-defined senescent cell markers. Amor Vegas and her team discovered that the chimeric antigen receptor (CAR) T-cell, engineered

to target a cell-surface protein specific to senescent cells, can be administered in a single dose and provide lifelong treatment against such age-related disease.

The team found that the injection of aged mice with the CAR T-cells successfully aided in the elimination of senescent cells. This manifested in reduced physiological symptoms compared to the control. Treated mice showed lower inflammatory factors associated with old age and improved metabolic health, as indicated by reduced improved pancreatic cell function and glucose homeostasis.

Researchers also injected young mice with CAR T-cells and discovered that such treatment has preventative effects as well; when the treated mice reached nine months, they experienced higher exercise capacity and, similar to those injected at an older age, limited metabolic decline compared to the control. The CAR T-cells both persisted and expanded over the mice's lifespan, meaning that only a single treatment of CAR T-cells is necessary for lifetime effects.

Expanding the health span using T-cells lays a preliminary foundation for further discoveries that could unlock the secrets of slowing the entire process of aging, such as whether they can also expand longevity. At the very least, these cells have the potential to be a powerful therapeutic tool for the treatment and prevention of disorders associated with aging, significantly increasing well-being for a plethora of people worldwide.

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PHOTOS VIA SHUTTERSTOCK



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