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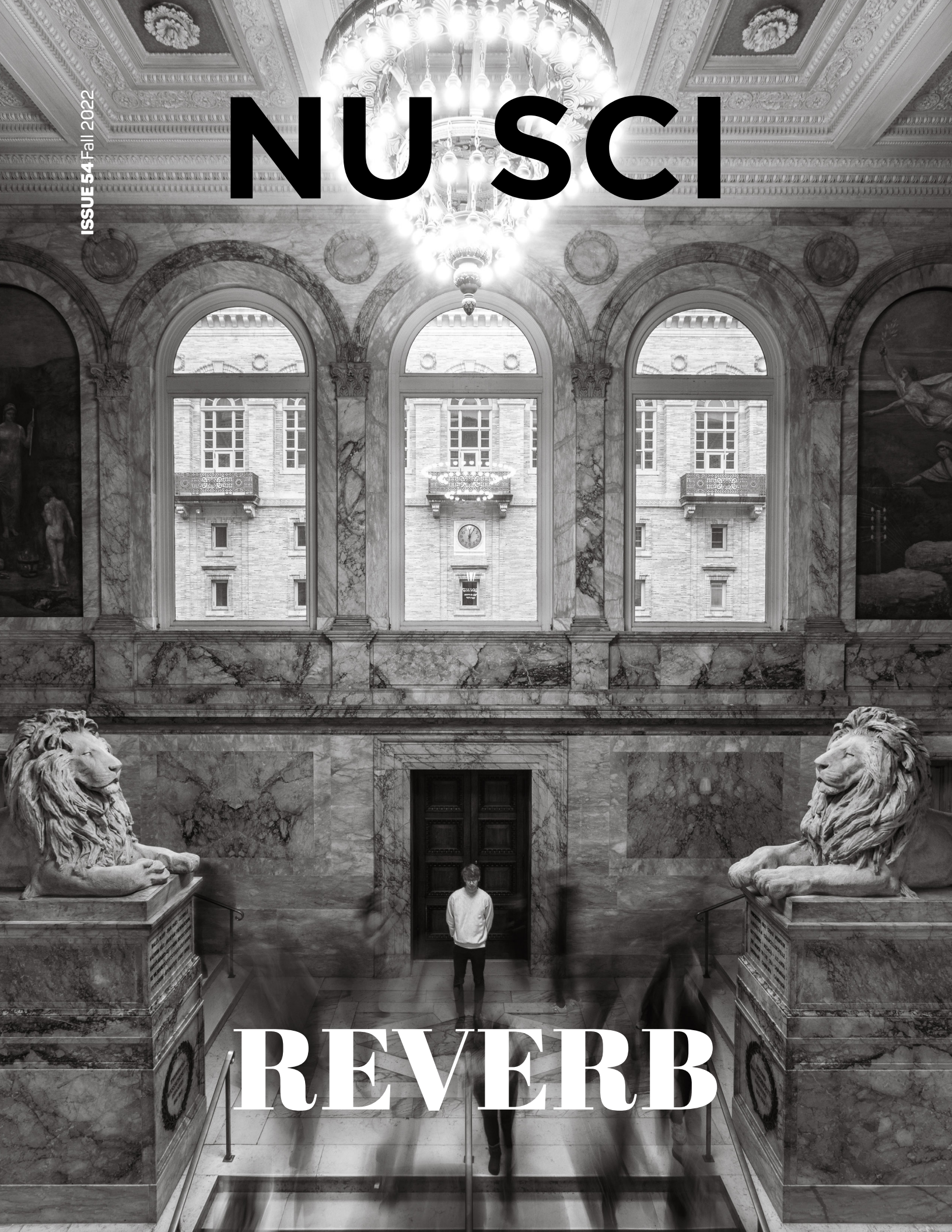

REVERB

Fall 2022

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LETTER FROM THE EDITOR

We live in a densely connected world. Over the past century, we've created a network of incredibly interdependent systems on which modern society has been built, and we've provided everyone with radically open and easy access to other people and these systems. The internet; governments; the stock market; global trade for supply chains; and global corporations like Meta, Amazon, Johnson & Johnson, Visa, and Chevron allow the actions of almost anyone to impact all of society, propagating through these networks at the speed of light — literally. It means that actions don't simply have impacts, they have reverberations.

In music, reverberation is a term of art. While an echo might be a single resound a fraction of a second after the original sound, reverberation is an almost immediate chorus of ricocheting sound, slowly softening with the dissipation of its energy. Sound engineers and music technologists very intentionally design mechanisms to create this effect in the architecture of concert halls and the electronics of guitar pedals. "Reverb" isn't just a reverberation, it's the purposeful and mechanistic creation of reverberations.

Science as a practice has been studying reverbs in the world, literal and figurative. In "Reverb," we share stories of scientists studying sound and humanity's relationship with music. We look at scientists who have studied the complex repercussions of human activity on the climate and, in turn, the climate's repercussions for wildlife. Our writers critique sexism in medicine and the recent overturning of Roe v. Wade in the U.S., exposing their impacts on women around the world.

Science as an institution has also become an instrument — and in some cases, a victim — of societal reverb. We explore the repercussions of new scientific knowledge, from Galileo to quantum mechanics to Alzheimer's research and how the internet and political and societal polarization are shaping science and our mental health in the 21st century.

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

Noah Haggerty
Editor-in-Chief

STAFF

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Cover Photos by Ian Hay and Gus Mueller

THE NOBEL PRIZE IN PHYSICS 2022

and the fight to prove quantum entanglement

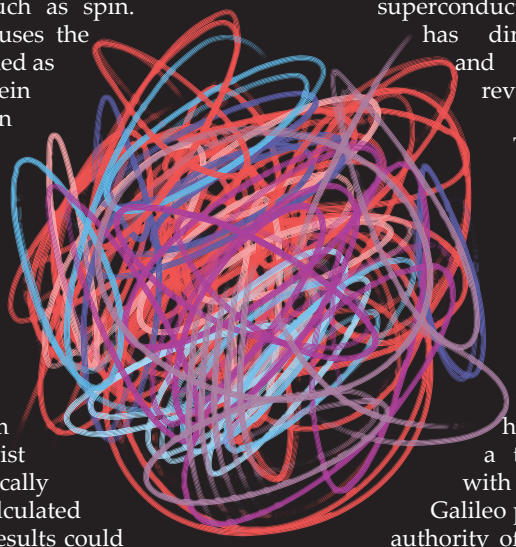
BY KEVIN LU, COMPUTER SCIENCE & MATHEMATICS, 2026

DESIGN BY PARKER HITT, BIOLOGY, 2023

"**Heresy.**" That is what the Catholic Church called Galileo's book, "Dialogue Concerning the Two Chief World Systems," which provided evidence for a heliocentric solar system. Astronomy at the time was rooted in the teachings of Ptolemy, and an Earth-centered view of the universe the Catholic Church embraced. Unwilling to examine Galileo's proof, the Church persecuted him in court and forced him to renounce his claims publicly. Only through years of debate and rigorous observation have we come to recognize the validity of Galileo's arguments.

Amid World War II, scientists began researching a micro-world with devastating implications for macro-society. Atomic theory and radiation took the spotlight on the global stage. Despite Newtonian physics accurately describing much of the universe then, certain behavior by particles seemingly defied fundamental laws of the current model. For example, the wave-like nature of particles required scientists to think outside of the box. Quantum mechanics explains such behavior through the ability of particles to exist in multiple states before measurement, through superposition and quantum entanglement.

Entanglement is the phenomenon in which the properties of two objects are linked. Imagine you rolled two dice in separate boxes and know the number of dots equals seven. If you see that one die shows only two dots, the other die must show five dots. No matter how far the dice are from each other, looking at one die instantaneously provides information on the other. Similarly, quantum entanglement examines this behavior in particles with linked properties such as spin. Measuring the spin of one particle causes the spin of the other particle to become defined as one state instantaneously. Albert Einstein famously dubbed this phenomenon "spooky action at a distance," as he opposed the idea that this effect could "travel" between particles faster than the speed of light. Einstein was averse to the idea that uncertainty was fundamental to quantum physics and instead asserted that quantum particles had set properties before they were measured, or "hidden variables."



Thus the fight over the fate of quantum entanglement began. In the 1960s, physicist John Bell developed a mathematically rigorous test, Bell's inequality. Bell calculated the maximum limit that experimental results could be correlated if "hidden variables" existed. The Nobel Prize in Physics 2022 winners John Clauser, Anton Aspect, and Anton Zeilinger began the foundational work with Bell's inequality in the late 1900s. However, many physicists saw the Bell experiments as taboo. Like the Catholic Church, academia was willing to accept quantum entanglement as a fundamental characteristic of physics without proper proof.

However, many loopholes can reduce the validity of these experiments. Separating atoms too far apart in an experiment can destroy their entanglement. Yet, if entangled atoms are too close together, the measurements made on one can affect the other: thus the "communication loophole." Aspect set out to close these loopholes in the 1980s by using super-fast switches to change particle paths. The two measuring stations were far enough apart to close the communication loophole yet accurate enough that nearly a trillion pairs of particles were detected. Aspect conclusively found the correlation levels to be "spooky," precisely as quantum theory predicted. However, these experimental results were met with indifference from the academic community. Quantum entanglement was considered trivial with respect to atom fission and other eruptive phenomena. Clauser and Aspect became frustrated with the lack of response as academic leaders questioned whether investigations of entanglement counted as "real physics."

Zeilinger also continued to publish against the storm as he explored applications of quantum entanglement. Along with further refining the Bell tests, Zeilinger and his colleagues at the University of Vienna demonstrated "quantum teleportation" by using entanglement to transmit quantum states from one location to another. Since Zeilinger's initial experiments, physicists have succeeded in teleporting electrons and superconducting circuits. Quantum teleportation has direct applications in cybersecurity and information systems, potentially revolutionizing how the internet works.

The story of the Nobel Prize in Physics 2022 winners is one of trailblazing tenacity. Despite the disdain from the scientific community, they pushed on to lay the groundwork necessary for further research. Their perseverance in the 1900s has echoed and multiplied over the years to explode into the modern technological theater. Today, quantum entanglement has become a resource rather than just a theory, establishing a research field with over $1 billion in yearly expenditures. Galileo put it best: "In questions of science, the authority of a thousand is not worth the humble reasoning of a single individual."

PHOTOS BY SHUTTERSTOCK

Nature (2022). DOI: 10.1038/d41586-022-03088-7
Nature (2015). DOI: 10.1038/nature.2015.18255

Quantum physics of bird migration

BY CLAIRE MA, HEALTH SCIENCE, 2025

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING & DESIGN, 2024

When calling someone a "bird-brain," it's most often used as an insult: They're silly, immature, or childish. Perhaps it doesn't help that bird brains are known to be around the size of a large nut. However, a bird's brain is more powerful than we think. Every year, migratory birds travel up to 60,000 miles for seasonal migration and breeding. Humans have always chalked up this special ability to celestial navigation and geomarkers, but only in the past 50 years have researchers discovered birds' use of the Earth's magnetic fields and even quantum physics to guide their migration — a process that's all guided by their brains. Even so, researchers have been hard-pressed on what mechanisms birds' brains use to harness the magnetic fields of the Earth for navigation … until now.

Of course, humans have used the Earth's magnetic fields as well for thousands of years in the form of compasses, but it turns out birds don't use magnetism in the same ways as we do. If we invert the magnetic field for a compass, an effect called "reverse polarity" would occur, and the red end of the compass would end up permanently pointing south instead of north. However, birds use what's called an inclination compass, which detects the axis of the Earth's magnetic field and the angle it makes with the ground. This means that inverting the magnetic field does not disorient the bird's navigation. So how does it work?

The earliest theory originates from scientist Klaus Schulten in 1978, who used quantum mechanics to postulate that birds use a pair of singled electrons called radical pairs to harness the extraordinarily weak magnetic fields the Earth produces. Electrons have a property called spin angular momentum, or spin, and this property creates a momentary magnetic force. These radicals can have a parallel (same) spin or antiparallel (different) spin, which are respectively called triplet and singlet states. As internal magnetic forces created by the electrons switch them between triplet and singlet states, it is able to be influenced by the weak magnetic fields of the Earth, allowing birds to "sense" the magnetic field of a region. When birds sense a magnetic field they sensed before, it can trigger brain signals that tell them to stop and land within feet of accuracy. This sense is largely unaffected by the environment, as researchers have found that birds in windowless boxes can still reorient themselves correctly. Additionally, whereas inclination sensing can only really tell a bird when to stop, a study from 2021 has suggested that birds can also use "true navigation," with which they can use the magnetic fields they sense to pinpoint their exact location.

More recent research has supported Schulten's hypothesis, as radical pairs are known to remain unaffected by magnetic field reversals, thus explaining why birds are not affected by reverse polarity and have been unaffected by the fact that the Earth's magnetic field has reversed 183 times. Radical pair production and magnetic field navigation are also known to be dependent on blue light, which triggers the biochemical formation of radicals, giving the electrons enough chemical energy to break apart. In birds, this process occurs in a protein in the retina called a cryptochrome, and as the eyes receive light, the navigation mechanism is triggered. Additionally, birds can be disoriented by weak radio-frequency noise, known as "electrosmog," which is another known characteristic of the radical pairs, furthering support for Schulten's hypothesis.

Urban development, increased use of broadband radio frequencies, as well as human-worsened climate change have all been critical, human-made factors in disrupting avian migration. Magnetic sensing is dependent on light, and large clusters of artificial light at night heavily disorient night-migrating birds. The increase of radio and cell towers also increases the amount of electrosmog in our airspace. A 2014 study in *Nature* by Mouritsen showed that European robins were not able to orient themselves correctly due to the electrosmog. Mouritsen denoted "The effects of these weak electromagnetic fields are remarkable: They disrupt the functioning of an entire sensory system in a healthy higher vertebrate."

So the next time you want to call someone a bird-brain to criticize their brain capacity, maybe reconsider. The bird's brain is much more complex and intricate than researchers could have imagined. It's complex enough to harness the quantum effects of the world, concepts that took human brains thousands of years to even describe.

Nature (2021). DOI: 10.1038/s41586-021-03618-9
Current Biology (2021). DOI: 10.1016/j.cub.2021.01.051
Nature (2014). DOI: 10.1038/nature13290
Zeitschrift für Physikalische Chemie (1978). DOI: 10.1524/zpch.1978.111.1.001

PHOTO BY SHUTTERSTOCK

Breaking records and taking names

How gamma-ray bursts explain the universe

BY KYLE KIRSHEN, BIOCHEMISTRY, 2025

DESIGN BY ANANYA JAIN, BEHAVIORAL NEUROSCIENCE, 2025

Some people are familiar with gamma rays, known as gamma radiation, from their high school science courses or as what caused Bruce Banner to turn into the Hulk. This energetic form of light is the result of the decay of atomic nuclei. It is most common in space and usually ends up being absorbed by the Earth's atmosphere. In order to see gamma rays, satellites or high-powered telescopes are needed. This is due to the fact that the radiation can originate thousands of light-years away from Earth and shine about a million trillion times as bright as the sun. Differing slightly from gamma rays, these "gamma-ray bursts" are intense blasts of gamma rays found in high-energy explosions. Furthermore, gamma-ray bursts can transcend galaxies and can last anywhere from a millisecond to a few hours.

Gamma-ray bursts were first found in the 1960s by United States satellites as they tried to see if nuclear weapons tests were still occurring in the Soviet Union. These bursts can be categorized into distinct groups. Seventy percent of bursts last for more than two seconds and are followed by a measurable afterglow, which is considered the brightest source of cosmic photons in the universe. These bursts are believed to be the result of the collapse of large stars in a supernova event that creates neutron stars or black holes in space. The other group of bursts is those that last under two seconds and result from mergers between stars. Specifically, evidence has emerged linking these collisions to mergers at various burst frequencies. These mergers can involve two neutron stars crashing into one another or a neutron star being swallowed into a black hole, in an event known as a "kilonova."

On Oct. 9, 2022, the largest and most powerful gamma-ray burst ever was recorded passing through the solar system. Nicknamed "GRB 221009A," the burst was so massive that it was estimated to be the result of a black hole's birth, formed in the heart of a massive star collapsing from its own weight. According to NASA, this occurs as "a nascent black hole drives powerful jets of particles traveling near the speed of light" and those jets pierce the star, emitting observable energy.

> "Nicknamed 'GRB 221009A,' the burst was so massive that it was estimated to be the result of a black hole's birth, formed in the heart of a massive star collapsing from its own weight."

The burst set the record with its afterglow, and data is currently being studied at universities across the world through the use of multimillion-dollar equipment. It is estimated that GRB 221009A came from the constellation Sagitta, which can be found 1.9 billion light-years away from Earth. And while that distance may be unfathomably far, the burst lasted for over 10 hours. According to Brendan O'Connor, who led a team from the University of Maryland and George Washington University to study the afterglow, said it had smashed "all records at all wavelengths."

But why does this burst matter? Despite being a once-in-a-lifetime event, the close proximity to the Earth makes the data easier and more clear to understand. And yes, in terms of the massive scale of the universe, 1.9 billion light-years is considered relatively close to Earth. While that may seem far-fetched, there is comfort in knowing that bursts like these are so far away. If a gamma-ray burst occurred within 5,000 to 8,000 light-years away, there would be catastrophic consequences to life on Earth, from DNA damage to chemical reactions in the atmosphere. One even closer and at the magnitude of GRB 221009A could even cause a mass extinction level event.

So while gamma-ray bursts occur billions of light-years away, the hope is that perhaps the data can provide concrete evidence of these explosions and how they relate to the birth of black holes. More importantly, the cause of these bursts could be used to help revolutionize research into dark matter models or understand the behavior and interaction of matter at the speed of light. Either way, the close proximity of this burst allows scientists to test and observe various details that would otherwise be unseeable. This could change the trajectory of human understanding of the universe.

PHOTO VIA PIXABAY

Semiconductors: The backbone of the modern world

BY PATRICK J. DONNELLY, ELECTRICAL & COMPUTER ENGINEERING, 2026
DESIGN BY CARINA HALCOMB, EXPERIENCE DESIGN, 2024

Semiconductors rule the world. From smartphones, to traffic lights, to flashlights — if it is powered by electricity, chances are it uses semiconductors. It was not always like this, however; their creators, at one time, thought them to be a scientific novelty. Nevertheless, semiconductors have persevered, proving to be among the most formative and popular inventions in human history.

To begin, semiconductors rely on, as the name implies, semiconduction, a property of certain materials first theorized by Alessandro Volta in 1782 and proven by Michael Faraday in 1838 using silver sulfide. Semiconductors are materials that, depending on their formulation and environment, may act as either insulators or conductors.

The first widespread use for semiconductors was in rectification, the process by which an alternating current (AC) signal may be transformed into a direct current (DC) signal. In 1874, Karl Ferdinand Braun was the first to experimentally prove that metal sulfide semiconductors could act as rectifiers with Jagadish Chandra Bose obtaining the first patent for such a device, the lead sulfide point-contact rectifier, in 1904. These early devices were used in radar and other telecommunications to transform AC aerial signals into DC information.

The most common use for semiconductors, and the most likely reason for which one may be familiar with the term, is the transistor. Developed at Bell Labs in 1959 by William Shockley, John Bardeen, and Walter Brattain, the transistor is, at its heart, a digital switch. Though this may sound insignificant, the ramifications are huge; today's transistors can actuate a few billion times a second, allowing millions of times the computing power of mechanical machines.

Semiconductors also find extensive use in integrated circuitry, better known as microchips. For the same reasons as in transistors, the ability of semiconducting materials to actuate with great rapidity over mechanical means allows for the construction of highly optimized electronic systems, such as computer processors and graphics cards.

Though less widely used, semiconductors also find use in diodes. Diodes are devices that limit the flow of electricity to one direction. Leo Esaki worked heavily on the first commercial diodes, the germanium and silicon tunneling diodes, from 1957 to 1958, for which he received the 1971 Nobel Prize in Physics. The primary reason for using diodes over more conventional methods, is, again, their great rapidity.

Above all others, though, is the metal oxide semiconductor field-effect transistor, better known as the MOSFET. These simple devices are the most common transistors available and are the most mass-produced invention in human history, with over 10 sextillion having been manufactured.

The massive scale of semiconductor manufacturing cannot be understated; making a single semiconductor, due to its nanoscopic nature and complex architecture, is an arduous task, so they are made in large batches. At their heart, semiconductors are simply nanoscopic layers of semiconducting material arranged in a way to do what we want.

Thus, one of the most straightforward ways of manufacturing semiconductors is to simply layer the aforementioned materials using complex chemical processes. By aerosolizing these materials and depositing them onto thin chips of silicon, and chemically etching troughs where required, semiconductors can be manufactured at scale.

The principal of these semiconducting materials is n- and p-type compounds. In a process called doping, if a small amount of a group 13 element, usually boron, is introduced to a pure sample of silicon, the resulting material observes a positive charge parity, becoming a p-type compound; by contrast, if the silicon is doped with a group 15 element, usually phosphorous, the material gains a negative charge parity, becoming an n-type compound.

"These simple devices are the most common transistors available and are the most mass-produced invention in human history, with over 10,000,000,000,000,000,000,000 having been manufactured."

Layering alternating films of n- and p-type compounds, usually configured either p-n-p or n-p-n, forms the basis of arguably the simplest type of transistor, the bipolar junction transistor. More complex types of transistors, and even different shapes of the same type of transistor, can be manufactured by layering and etching the n- and p-type compounds in different ways.

Though quite simple, the difficulty in producing transistors and other semiconductors comes from their small size and even smaller margin of error. Even in a perfect clean room within a laboratory, integrated circuit manufacturers may still lose 20% or more of each batch to nanoscopic imperfections in the materials.

These remarkable devices ushered in the digital age. With each year, improvements in semiconductor manufacture and design continue to push beyond what was thought of as computationally impossible only thirty years ago. With this in mind, it is little wonder why semiconductors rule the world.

PHOTO BY CHRISTIAN WIEDIGE

Fundamentals of Semiconductor Manufacturing and Process Control (2006). ISBN: 978-0-471-78406-7
Fundamentals of Semiconductors (2005). ISBN: 3-540-25470-6
Journal of Telecommunications and Information Technology (2010). ISSN: 18998852
Reports on Progress in Physics (1985). DOI: 10.1007/978-1-4471-1033-0

Don't look, listen

Resonating with birdsongs to overcome stress

ARTICLE AND DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

Sounds are an important part of perception. For most, the sensation of hearing complements the view of their environment, helping them further immerse in it. Given this, living in Boston may prevent most students from experiencing nature to its fullest. While parks and gardens around the city allow people to view greenery, most still cannot say they wake up to the sound of chirping birds in the morning. Combined with the noise from city traffic, these gardens fall just short of imitating natural ecosystems, which is particularly important in considering Bostonians' well-being. It has been known that the presence of nature positively impacts mood. To further these claims, experiments over the past decade have also seen positive impacts of birdsongs on anxiety — a feeling known to intensify as project deadlines creep up.

A recent study performed by researchers from the Max Planck Institute and the University of Hamburg found that participants who listened to birdsongs, as opposed to city noise, reported a reduction in depressive moods, anxiety, and paranoia. It is not hard to imagine this effect — for most, the sound of birds would seem more pleasant and comforting than car horns and sirens. The question, however, is how this effect happens. The researchers suggested multiple reasons for this phenomenon, including positive associations with nature, diverting one's attention from stressors, and indicating low threat levels.

Having a connection with nature may be more important to some individuals than others, but nonetheless, studies have seen positive impacts of nature on people's moods and mental health. Listening to birdsongs can provide individuals with an auditory experience of nature, allowing them to immerse in a natural environment with their auditory senses. Based on a study conducted by researchers from the University of Surrey, some claim that feeling connected with nature by listening to birdsongs helped them disconnect from their stressors. Others reported feeling grounded, feeling this connection with nature helped put their stressors into perspective. These may be possible due to the difference between nature and the urban environment in which most people find their stressors. However, because each individual has a different experience with nature, the effects of this connection would differ as well. This would explain that while the reports of the participants were similar, they were not identical. For some, feeling connected to nature did not have an effect on their mood at all. This was particularly apparent in those who do not enjoy being in nature.

Daily stressors greatly contrast with birdsongs for city dwellers in particular. This makes birdsongs a good source of distraction from these stressors. Stressors indicate a degree of threat, which makes them energetically demanding to regulate. On the other hand, it can be easy to direct one's attention toward birdsongs as it requires little effort and can carry various positive associations. While listening to seagulls, for example, some individuals may remember a nice day at the beach. Some cultures may even carry important associations with certain birds, contributing to how individuals interpret and perceive certain birdsongs. These positive feelings can be effective tools for mitigating the fatigue brought upon by stress. Listeners can lift difficult thoughts from their minds, replacing them with low-energy thoughts that additionally boost their moods. In contrast to the threatening ambiance of stressors, the positive associations brought by birdsongs indicate low threat; after all, no negative consequence could arise from peaceful memories. These conditions bring about an ideal sensory stimulation promoting relaxation while the mood boost from positive associations may aid in fighting depressive feelings.

Not all birds are treated the same, however. One may note differences between the honks of geese versus the chirps of robins. Yet, it is difficult to generalize different birdsongs into categories. How individuals feel about these sounds may be a matter of association. Some could be reminiscent of a quiet meadow while others give the unpleasant image of predation or death. Birdsongs that bring peaceful memories to mind both provide positive associations with nature and signal a low-threat environment, which could aid stress recovery.

Life in the city can bring about many stressors, especially for students. With reminders of these appearing anywhere in sight, perhaps it would be best to close one's eyes, put on some earbuds, and listen to chirping birdsongs for a while.

Journal of Environmental Psychology (2013). DOI: 10.1016/j.jenvp.2013.08.004
Scientific Reports (2022). DOI: 10.1038/s41598-022-20841-0

Lullabies for adults

How white noise can improve sleep

BY SENAM APEDO, CELL & MOLECULAR BIOLOGY, 2025
DESIGN BY JOSEPHINE DERMOND, ECONOMICS & BUSINESS ADMINSTRATION, 2025

Over time, people have developed countless tips and tricks for falling and staying asleep through the night. Counting sheep, yoga, meditation, reading, watching ASMR videos, melatonin, and essential oils …

While some of these methods may work temporarily, they may not be the solution to long-term sleeping problems. All of these strategies share a common goal creating a comfortable and soothing sleep environment and routine. Some may turn to various calming sounds to help them fall asleep, but the simplest solution may be the most beneficial: white noise.

White noise is a sound that contains all audible frequencies of sound in an equal measure. The noise sounds similar to TV static or a quiet fan and may have a soothing effect on the brain. White noise works by acting on the Theory of Auditory Masking. This theory states that the detectability of sound is determined by the ratio of constant, consistent auditory stimuli to new auditory stimuli. Basically, the brain is more likely to pay attention to newer, recent noises than constant, older ones. The consistent humming of a white noise generator drowns out unwanted background noise by dominating new, noisy stimuli. Although it has been demonstrated to be beneficial in many situations, white noise works best when its ambient sound is louder than the disruptive surrounding noise.

"Some may turn to various calming sounds to help them fall asleep, but the simplest solution may be the most beneficial: white noise."

White noise has been proven to improve sleep for those that suffer from related disorders. Environmental sleep disorder is common in metropolitan areas and is caused by excess noise in one's environment. When tested on adults living in New York City, white noise decreased sleep latency, the time it takes a person to fall asleep. White noise was also effective at decreasing the chances of waking after sleep onset (WASO), the amount of times one wakes up during the night. This shows that white noise may be a beneficial tool for falling and staying asleep through the night.

During this study, researchers set the sound at different volumes depending on the distance between the source of the white noise and the participant's ears. When the white noise machine was 12 feet away from a participant, it was set to provide 61.5 Dba of sound. Dba is a decibel measurement adjusted to describe the hearing range of the human ear. A DBa of 60 is about the same volume as a normal conversation and not harmful or irritating to the ears. At six feet apart, the machine was set to provide 52.7 Dba, about the same volume as rainfall. While the Theory of Auditory Masking states that white noise is most effective when louder than outside stimuli, it does not have to be and should not be that loud. The average car horn is 110 Dba, which is more than double the recommended volume of a white noise machine located 2 yards away.

Approximately one in three American adults experience sleep deprivation due to increased sleep latency and WASO. Children experience this at similar rates. White noise is an effective resource for virtually anyone suffering from disordered sleep due to any condition, from infants to critically ill patients. Newborns and infants were found to have reduced sleep latency due to the effects of white noise. Researchers at the British Association of Critical Care Nurses found that white noise decreased WASO and improved sleep quality in critically ill patients in a hospital in the port city of Mangalore, India.

White noise machines provide the best quality white noise but are not always cost-efficient since they can cost up to $100. Fortunately, white noise apps or even YouTube videos are just as useful and effective. Getting enough sleep is essential for developing a healthy mind and body. Not getting enough sleep can often lead to various physiological detrimental effects and decrease quality of life overall. When utilizing white noise, a little bit goes a long way. The ambient humming of a white noise machine may be a lifesaver for anyone that regularly experiences sleep deprivation. So if you find yourself struggling to fall asleep, try listening to the tranquilizing lullaby-like sound of white noise.

Sleep Medicine (2021). DOI: 10.1016/j.sleep.2021.03.031

PHOTO BY SHUTTERSTOCK

FEELING THE VIBES

BY DIVYA RAVIKUMAR, BIOENGINEERING, 2025
DESIGN BY CARINA HALCOMB, EXPERIENCE DESIGN, 2024

While most people listen to music, deaf people *feel* it. Specifically, they can feel the vibrations produced by the sound waves, which are distinctive enough for them to process and translate into their own version of music. Deaf people often hold balloons at concerts to feel the acoustic vibrations, perceiving the rhythm of the music through the vibrotactile sense in their fingertips.

> "Both hearing and touch are facilitated by sensory nerves called mechanoreceptors that bend in response to pressure changes, resulting in a neural impulse sent to the brain."

People who are born deaf or become deaf early on in life naturally develop enhanced sensitivity to touch that manifests in different ways. The neuroplasticity of the brain helps to accommodate hearing loss by repurposing the auditory cortex to process other information in place of sound. Dr. Dean Shiabta's research demonstrates this phenomenon. He used functional magnetic resonance imaging (fMRI) to scan the brains of 10 deaf volunteers and 11 normal-hearing volunteers while they felt intermittent vibrations on their hands. All of them showed activity in the part of the brain that usually processes vibrations, but the deaf students also showed activity in the auditory cortex.

Every deaf or hard-of-hearing person is different, so their auditory cortex and vibrotactile sense adapt uniquely, changing the way they experience vibrations and music. Despite variations, there is definitely an overlap between senses that allows deaf people to rely on their touch to experience the sounds around them. The sensory systems for hearing and touch have a lot of similarities. Both hearing and touch are facilitated by sensory nerves called mechanoreceptors that bend in response to pressure changes, resulting in a neural impulse sent to the brain. In both normal-hearing and deaf people, signals from vibrotactile stimuli are detected by the auditory cortex and can be confused by the brain when both modalities are processed together. As vibrational information has the same features as sound information, for deaf people, one form of waves essentially replaces another form to be processed by the auditory cortex.

Through vibrations, it is even possible for people to distinguish differences in timbre, a characteristic that contributes to the "color" of a sound. While the vibrotactile sense cannot detect high frequencies typically within the range of human hearing, it can detect low frequencies even when they are not audible. This is how both hearing and deaf people have been able to distinguish between different instruments, as well as dull or bright sounds, by touching a vibrating device. Although the vibrotactile sense plays a large role in the musical experience of deaf people, there is still a lot to learn. A current study being conducted by Mario Prsa and his colleagues at the University of Fribourg in Switzerland looks to explore whether certain combinations of frequencies are more pleasing to experience through the vibrotactile sensory system than others. For example, the group is exploring if there is a possibility of having harmonious vibrations, a vibrotactile octave, or even dissonance that would be equivalent to sounds. Prsa's recent experiment involved observing how easily both deaf and normal-hearing participants could identify simple melodies, such as "Happy Birthday," through their vibrotactile sense. Converting audio into vibrations is a flawed process that inevitably produces some alterations of the notes, and Prsa wants to determine whether these changes would influence the participants' ability to recognize the tune. The results of the study are still in progress, but it opens up a new realm of sensory processing and communication.

Though some aspects may be fundamentally different, with vibrotactile sense, deaf people can enjoy music and even become artists and performers. Exposing deaf children to music would likely help develop their brains to process that information early on and encourage them to explore music. Either way, it seems that music remains universal in its ability to be heard.

Brain Imaging and Behavior (2021). DOI: 10.1007/s11682-020-00346-y

PHOTOS BY MATT BOTSFORD AND PIXABAY

Seeing sound

BY CURIE CHA, COMPUTER SCIENCE & BEHAVIORAL NEUROSCIENCE, 2026
DESIGN BY EVELYN MILAVSKY, CELL & MOLECULAR BIOLOGY, 2025

The words on this page are plain and black, and most likely, you see them as just that. Your eyes detect the pattern of light, and special cells in the eye's retina, known as rods and cones, turn these patterns into neural impulses. These neural impulses traverse through neurons and get transported to the brain via the optic nerve. The areas of the brain that the optic nerve reaches organize, associate, and comprehend the signals. This allows you to recognize individual words, connect them, and attach meaning and understanding to everything from Shakespeare's "Romeo and Juliet" to the lyrics of your favorite song to the words you are reading right now. The brain is able to filter through millions of stimuli and send them to their respective locations to be processed, conducting the perfect symphony of impulses needed to understand what you are seeing, feeling, hearing, and touching. Albeit fascinating, this is quite frankly boring for synesthetes.

Synesthetes represent the 2% of individuals who have synesthesia, a curious blending of the senses. Researchers of synesthesia are particularly interested in the overlapping of a stimulus that is already so sensationally stirring: music. Upon hearing a note, synesthetes will see shapes and colors that are associated with that specific tone. When hearing a sequence of notes in a melody, these images interact to create a vibrant landscape of shapes and colors. This type of synesthesia is known as auditory-visual synesthesia, and much of the phenomenon can be traced back to neural connectivity and genetics.

When someone without synesthesia listens to music, signals follow a consistent, direct path to the brain. When music enters the ear, sound waves reach the eardrum, causing it to vibrate in response. This vibration causes tiny bones attached to the cochlea, known as ossicles, to vibrate as well. This in turn induces the movement of fluid in the cochlea. Special hair cells line the walls of the cochlea and sway with the fluid. This physical swaying triggers the production of electric neural signals; the sensitivity and response to changes in physical posture is known as mechanoreception. The neural signal gets transported to an area of the brainstem known as the pons, and eventually reaches the primary auditory cortex where the sound is consciously processed and recognized. In essence, every sound has a unique sound wave that produces a different type of vibration and distinctive pattern of swaying. That is how the human brain is able to recognize all different types of music. However, there is a strong basis for the cause of synesthesia in the alteration of this auditory pathway.

During infant years, the human brain experiences the peak of its development. Much of brain development entails what is known as neural pruning — the optimization and rewiring of neurons to best adapt to one's surroundings as one grows older. During this process, the connections in an infant's brain that are consistently repeated and exercised will strengthen, while the neurons associated with unneeded and unused connections will essentially disconnect their axons from a synapse, removing the link. A comprehensive analysis of the genomes of a family with synesthesia revealed that genes associated with brain development (i.e. neural pruning) are inheritably linked. Some of these genes can lead to the failure of neural pruning, meaning that a plurality of excess connections remains even after infanthood. Some of these connections could be between the auditory cortex and the cortices of the other senses, such as vision. This means that neurons in the aforementioned auditory pathway will send signals to the auditory and visual areas of the brain just because these connections exist. This is why auditory-visual synesthetes can quite literally see what they hear.

Although statistically rare, auditory-visual synesthesia provides the unique ability to experience music through another dimension, so it is actually quite common for music artists to have this condition. Beyoncé, Billie Eilish, Billy Joel, Lorde, Olivia Rodrigo, and Frank Ocean all have auditory-visual synesthesia; perhaps a part of their musical talent and success can be attributed to the phenomenon.

So, while most of us can't see our favorite songs, we get to hear the creations of those who can. And still, these songs hold so much meaning and emotion, demonstrating that the impacts of synesthesia reverberate all around us.

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PHOTO BY SHUTTERSTOCK

LULLABIES

The unexpected predeterminer

ARTICLE AND DESIGN BY VY PHAN, BIOENGINEERING & BIOCHEMISTRY, 2025

Music knows no barriers. Its ability to touch people transverses age, culture, and language, starting as early as in utero. Before one is even brought into the world, music has already exerted its influence on them in unimaginable ways, even setting them up for the entire course of their life.

To understand the impact of music on a baby is to understand the origins of a lullaby. The word is based on the imitation of the "lala" and "lulu" sounds a mother makes to ease a restless baby and the word "bye," used to signal the end of a baby's waking period. As a result, lullabies are capable of doing exactly what the essence of their name suggests: to pacify an agitated baby and send them to a deep slumber. Researchers at the Indian Association of Health, Research, and Welfare recognized that environments with loud, sudden noises are not ideal as it increases a baby's heart rate and blood pressure. Certain genres of music such as rock or pop would be unable to provide babies with the same relief and soothing effect due to their abrupt shifts in melody and intense beats. Therefore, musical environments composed predominantly of lullabies or classical music are the best place to cultivate the well-being of a baby.

On the surface, lullabies have the capacity to calm a baby down; they are one of the most effective remedies to cure the wailing cries of a baby. This stems from the fact that music can stir up emotions. The kind of emotions that it incites depends on the melody and tune. In order to induce a baby to a serene state, the melody of the lullaby must be one that parallels a serene state and has elements of calmness, relaxation, and tranquility. As researchers at Harvard's Music Lab discovered, lullabies in any language will have the same therapeutic tendencies of decreasing a baby's heart rate and dilating their eyes, soothing the baby with the repose of the song, and allowing for deeper sleep sessions. Among the ways to execute a lullaby, none is as memorable or significant to a baby as the singing of the lullaby by their caregivers. In utero, the baby is conditioned to perceive and remember their mother's voice, including the language and rhythm; thus, the hyper-familiarity of a voice singing a song soothes a baby like no other. Ultimately, using lullabies to soothe a baby forges a bond with the parent based on love and desire to interact.

> "Lullabies are capable of doing exactly what the essence of their name suggests: to pacify an agitated baby and send them to a deep slumber."

The hidden powers of lullabies are exhaustive, given the way that they can nurture the brain development of a baby far before birth. It stimulates areas of the brain beyond the auditory cortex, such as the subcortical sensory circuitry, which contains areas associated with reading and linguistics. These specific areas of the brain are especially associated with academics and early learning. Most lullabies and songs contain lyrics, which propels babies to mimic them and expand their verbal skills and vocabulary through them. Likewise, a baby deeply engaged with music growing up will have tendencies to want to acquire the skill to play an instrument later in life. As Ibrahim Baltagi, the head of the music program and a lecturer at the Lebanese International University, noted, there is a correlation between playing a musical instrument and improvements in mathematics and test scores.

Music and lullabies have social benefits as well, enabling the baby to grow up and be able to develop meaningful relationships and connections with their peers through social interactions. A universal experience among all people, regardless of age, is the efficacy of music in serving as an outlet for emotions and as a form of expression. Babies move along to the music that surrounds them, learning to express themselves, first physically, and later on, emotionally, to normalize talking about feelings. Music teaches children how to connect with themselves, from which they can connect with others. Most significantly, music is engaged with brain circuits associated with feelings of trust and empathy.

Lullabies have a more profound impact on how one turns out in life than expected; perhaps the key to success has been lullabies all along.

PHOTOS BY SHUTTERSTOCK AND PIXABAY

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I can understand you

Language development in the womb

BY HIBA HUSSAIN, BIOLOGY, 2024
DESIGN BY DEYA ARNOLD, BEHAVIORAL NEUROSCIENCE, 2025

Conversation has arguably become entirely one-sided as a result of the pandemic. Gen Z can attest to spending the majority of their days on Zoom for classes, aimlessly watching people explain "life hacks" on Tiktok, or engaging in text conversations to avoid social interaction. Through limited face-to-face conversations during the pandemic, Gen Z has become isolated from the physical exchange of language. Scientists have discovered that this exchange is vital to development and humanity, even when one has yet to take their first breath.

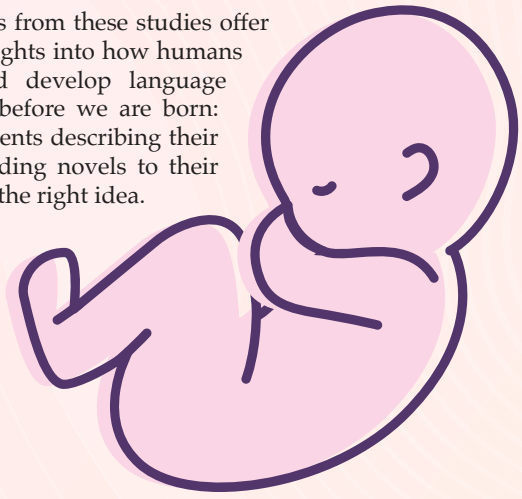
> "Scientists have discovered that this exchange is vital to development and humanity, even when one has yet to take their first breath."

Pregnant individuals often engage in one-sided conversations with their bellies by reminiscing on their days or singing lullabies. While seemingly illogical, recent research demonstrates that fetuses are perceptive to subtle differences in languages, including rhythm and pitch. A 2003 study performed by Barbara Kisilevsky and her team first observed this phenomenon when playing recordings of spoken English and Chinese at 95 decibels to fetuses in the third trimester. Significant differences were noted in fetal heart rate upon a comparison of the English and Chinese recordings, suggesting that fetuses are capable of discrimination between their native and foreign languages as a result of rhythmic distinctions between them. While the Kisilevsky study was eye-opening for its time, some researchers took issue with the use of different English and Chinese speakers and a fetal heart monitor, which often picks up on background noise.

To address the weaknesses posed by earlier research, Utako Minai and her team at the University of Kansas Medical Center conducted a similar study with 24 fetuses averaging 35 weeks of gestational age. Unlike the Kisilevsky study, Minai's team utilized the same bilingual speaker to read two-minute passages in Japanese and English. These languages are agreed upon to be rhythmically different in the linguistics community due to their vocalic interval disparities, or rate of vowel usage. A fetal biomagnetometer was then used to monitor changes in fetal heart rate, breathing, and body movement by analyzing changes in magnetic fields surrounding the electrodes placed on the parental abdomen. In using this tool, fetal R waves can be detected without picking up external interference from the parental body or the fetal vernix caseosa, a biofilm that covers the fetus in the third trimester. Taking all of these factors into account, Minai's team still observed a significant change in heart rate upon exposure to Japanese, demonstrating that fetuses are capable of detecting rhythmic differences in language.

Interestingly, the specificity of fetal language acquisition is further strengthened in the first month after birth. Eino Partanen and colleagues performed a study where fetuses were exposed to a word: "tatata." Over the first phase of the study, fetuses were exposed to the word hundreds of times. In some trials, the pitch of the middle syllable was raised or lowered. The next phase involved comparing the responses of neonates exposed to "tatata" in the womb and neonates that had not received any prenatal exposure. Partanen monitored for changes in electrical activity present in the brain through an electroencephalogram (EEG) in the two groups and found that infants exposed to the word exhibited stronger neural signals overall. Neonates that had previous exposure to the sound showed signals in the EEG for vowel and pitch discrimination within "tatata" when the pitch of the middle syllable was changed. This group was also markedly better at determining other differences upon exposure to language, such as vowel length. From these studies, it is evident that the fetus is capable of learning the nuances of language and remembering them well after birth.

The findings from these studies offer exciting insights into how humans process and develop language skills even before we are born: perhaps parents describing their days or reading novels to their fetuses had the right idea.



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OPINION
REPRODUCTIVE HEALTH IN A POST-ROE ERA

BY LILLY SCHAR; HISTORY, CULTURE & LAW; 2025
DESIGN BY PARKER HITT, BIOLOGY, 2023

It is a privilege to live in a country where modern medicine has helped stabilize the risky and life-changing processes that are pregnancy and childbirth. Developments, such as prenatal care, have been taken to make pregnancy as safe as possible. Prenatal care now routinely includes genetic screening and testing. While optional, credited medical societies highly recommend them to give a potential parent as much information as possible about their fetus — whether or not that information would lead to a decision regarding the pregnancy. In June 2022, the Supreme Court of the United States decided Dobbs v. Jackson Women's Health Organization, which overruled Roe v. Wade (1973) and Planned Parenthood of Southeastern Pa. v. Casey (1992). This decision stripped Americans of their federal right to abortion and returned the power to regulate abortion to each state. The effects of this decision have triggered expansions of abortion resources in a few states, tightened restrictions on abortion in some, and even led to the total criminalization of abortion in others. Beyond abortion, however, prenatal care and its stigma are also affected by this overruling, thus extending the reach of the Court's new holding to affect anybody who is currently pregnant or trying to conceive.

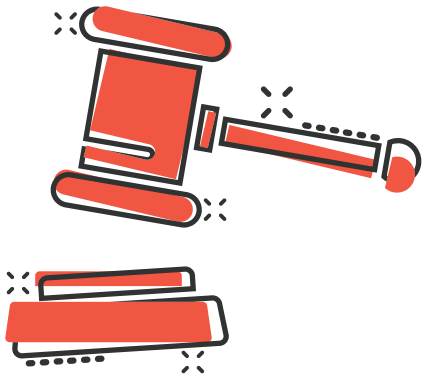
Prenatal genetic screening alone has come under ethical scrutiny by anti-abortion proponents. Anti-abortionists argue that some prenatal genetic screening is unethical because it could suggest actionability, especially if those tests reveal fetal abnormalities or lethal conditions. This argument is shockingly obtuse and blatantly disregards a parent's lifelong financial and personal obligations to their child. Setting aside the issue of abortion, an informed pregnancy is a healthier pregnancy. Full stop. Putting an end to all prenatal testing on this basis alone can and will have severe consequences on the health of a pregnant person and their fetus. A pregnant person has every right to know everything modern medicine can tell them about their fetus (and by extension the course of their pregnancy) if they so choose.

Bioethics studies from Mayo Clinic and Case Western Reserve foresee sweeping abortion restrictions that will seep into prenatal testing. Policymakers appear unaware of the consequences women experience through the lack of control over their reproductive health. An extensive study by Guttmacher Institute analyzed some of these social and economic consequences. The team found that women with access to reproductive care and contraception are more likely to pursue a college education and a professional degree, more likely to participate in professional occupations, and more likely to receive higher compensation for their work. The study also found that working women with access to reproductive care contribute greatly to decreasing the gender-based wage gap. According to the Casey opinion, "the ability of women to participate equally in the economic and social life of the Nation has been facilitated by their ability to control their reproductive lives."

Since Roe, women have relied upon abortion access when planning their lives, especially in unplanned circumstances. The majority responsible for the Dobbs v. Jackson Women's Health Organization decision barely acknowledged society's reliance upon reproductive care that has only grown since Roe and Casey, instead arguing the inexistence of that reliance. Overruling Roe and Casey leaves a fundamental factor of liberty vulnerable to the will of the states and their representatives.

PHOTOS BY SHUTTERSTOCK

Not only is it possible for prenatal care to be restricted in terms of physical access, but it is also possible that the medical education of OB-GYN will increasingly exclude abortion training. The Department of Obstetrics and Gynecology at UCLA found that 128 of 286 accredited OB-GYN programs are located in states that have promised to ban abortion or are likely to ban abortion. The same study reports the effect of this geography will mean that 44% of OB-GYN residents may lack in-state abortion training, changing the percentage of OB-GYN residents with abortion experience from 92% to 55% at best. This practice will only further distance an individual from a competent doctor. When doctors are not trained proficiently in safe abortion practices, they become less equipped to deal with pregnancy complications in the first and second trimesters. If not by choice, abortion may also be a necessary procedure in an emergent situation. In these cases, emergency doctors equipped with the proper knowledge to perform a safe abortion quickly would be difficult to find. When safe abortion is inaccessible, people resort to illegal and dangerous abortion procedures. The imminent danger is obvious.



Abortion restriction has implications far beyond abortion. When reproductive health care is restricted, the mental and physical health of pregnant individuals is more likely to decline. It is critical to remember that these restrictions will have the most detrimental effect on groups that have been historically, economically, socially, and medically marginalized. The history of medicine is deeply racialized. According to a 2017 study by the National Center for Chronic Disease Prevention and Health Promotion, people of color today experience morbidity and mortality three to four times more than their white counterparts due to pregnancy, regardless of socioeconomic status. This number is likely to be exacerbated with new abortion restrictions, says a 2020 study from Emory University, which found higher maternal mortality rates in states where abortion is restricted by counseling and waiting mandates, gestational age limits, targeted regulation of abortion providers, personhood laws, and insurance limitations.

State legislatures now hold the authority to control reproductive health care. As we look forward to public policy efforts to loosen restrictions on reproductive health care, the idea that, even when available, most people do not have the resources or time to access that care should be at the front of our minds. How many people will take on the financial and personal burden of child birthing and childcare because their state will not allow them to do otherwise? How many people will be forced to carry and birth their rapist's baby? Fifteen states have already banned abortion with no exceptions for rape or incest. The future of prenatal care and what defines a healthy pregnancy is fraught. It is unclear if state legislatures understand the positive and necessary impacts of prenatal care. That should terrify us. How, then, could it be a privilege to live in a free country that does not afford its citizens freedom? The responsibility to rectify the repercussions of state-regulated reproductive rights will fall upon doctors, legislators, and most importantly, voters.

For more information and ways to help, refer to the following organizations:

Repro Legal Defense Fund: Bail and defense for anyone criminalized for an occurrence during their pregnancy.
Repro Legal Helpline: Learn about abortion resources in your state, including judicial bypass.
Abortion Finder: Find abortion clinics and other reproductive care near you.
National Network of Abortion Funds: Provides financial and logistical help to people seeking abortions. Lists abortion funds by state with options to donate.
Center for Reproductive Rights: Educate yourself on state-by-state legislation, find abortion resources, and donate.
National Abortion Rights Action League: Learn about reproductive policy and legislation efforts in each state.

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AXOLOTLS AND BIRTH ABNORMALITIES

BY EVELYN MILAVSKY, CELL & MOLECULAR BIOLOGY, 2025
DESIGN BY PARKER HITT, BIOLOGY, 2023

Across fields of academia and within everyday life, the origins of scientific knowledge are often credited to European scholars, philosophers, and schools of thought. Embryology, the study of embryonic development, has been no stranger to this pattern of Eurocentrism, with Aristotle being widely considered to have created the field of developmental biology during the fourth century BCE. Modern accounts of embryological history mention the influences of English, German, and ancient Greek thinkers, but rarely make note of the theories that emerged elsewhere, particularly within ancient communities in Mexico and Central America.

Many Mesoamerican societies held detailed knowledge of midwifery, obstetrics, and embryonic development. In Mexico, artwork created by the Olmecs showcases statues of people with 1-to-3 and 1-to-4 head-to-body proportions, which are appropriate for fetuses ranging from 12 to 30 gestational weeks. These statues display developmentally incomplete craniofacial and limb details of fetuses as well, further promoting the notion that these were intended to be interpreted as embryos.

The ability of Olmec artists to create artwork following the pathway of fetal development is believed to be influenced by the presence of axolotls in Central America. Axolotls, a salamander that served as an important food source for the Olmecs, have large embryos that are easily visible throughout the period of embryonic development. Since many Olmec fetal sculptures resemble axolotl embryos with more humanoid faces, it is highly probable that these artists were able to observe the axolotls' development and conjecture that humans followed a similar sequence. Visually tracking embryonic stages of an organism was an opportunity that many early European embryologists did not have. Consequently, the realization that humans are primarily similar to many other animals was another major facet of early Mesoamerican embryology that European branches lacked.

Early medical journals from Oaxaca recorded a case of human conjoined twins that occurred in 1741. These journals also contained previous research about conjoined calves and chickens that was compiled alongside the human case to determine how the children may have developed. Between 1775 and 1800, medical publications throughout Mexico and Guatemala documented more than 50 cases of birth abnormalities that were compared to similar cases in animals to better understand the patients' conditions. Comparing newborns with congenital abnormalities to other natural beings stands in stark contrast to the mystique surrounding disability that was present in European "freak shows." This allowed for research of these conditions with less stigma than in European embryological spheres.

Though European thought has dominated modern developmental biology and embryology, consideration of the research and mindsets of other cultures may result in a multi-dimensional perspective on how best to use knowledge of embryonic development across species to respond to human development.

PHOTO BY SHUTTERSTOCK

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OPINION:
The silenced struggle of women with endometriosis

BY RESHIKA SAI DEVARAJAN, HEALTH SCIENCE, 2025
DESIGN BY PARKER HITT, BIOLOGY, 2023

What comes to mind when you hear the word "chronic disease"? Perhaps well-known diseases such as COPD, Crohn's disease, diabetes, or coronary heart disease cross your mind. But what about endometriosis? Despite affecting 1 in 10 women, this chronic condition is rarely spoken or researched about, creating a slew of negative repercussions for women around the world.

At its core, endometriosis is an inflammatory disease in which uterine tissue grows outside the uterus. This abnormal growth of tissue can affect other parts of the reproductive system and can even grow over and hinder the fallopian tubes and ovaries. Furthermore, the tissue can implant in other parts of the body and affect other organs, as well as interact with other bodily systems such as the endocrine, nervous, and vascular systems. Endometriosis brings with it a multitude of symptoms, affecting a woman's day-to-day functioning as well as long-term negative health impacts.

Common symptoms include chronic pelvic pain, extreme menstrual pain, painful sex and urination, lower pain tolerance, and a worse quality of sleep. More severely, abnormal tissue growth and spreading can result in adhesions, where tissue connects organs and areas of the internal body that should be separated. Not only do severe discomfort and stabbing sensations follow, adhesions often cause anatomical distortions, a primary cause of infertility. Women who suffer from this disease also face a higher rate of comorbidities, commonly suffering from conditions such as irritable bowel syndrome, depression, anxiety, and chronic stress. Aside from physical symptoms, women often suffer productivity losses, which may lead to less opportunity in the workplace, and often sacrifice the choice of having children due to the disease, affecting personal and family life.

PHOTOS BY SHUTTERSTOCK

These persistent symptoms place a lifelong burden on women, with one study finding that 70% of patients with endometriosis suffer from unresolved pain and believe the condition has negatively impacted all aspects of their quality of life. Despite the advancements of modern medicine, there is a delay of about 4–11 years for endometriosis patients from the onset of symptoms to diagnosis. This delay can be attributed largely to the lack of resources and attention devoted to the disease. Large waitlists exist for the instruments used to diagnose patients, and often doctors are not knowledgeable enough about the condition to treat their patients. A study conducted in Germany and Austria found that 74.3% of endometriosis patients had been misdiagnosed in the past. The barriers to care for women's health lead to the muffled voices of millions with their pain ignored, complaints rejected, and health neglected.

In addition to the limited care for endometriosis, there is also a gap in medical research about the disease. In 2022, Chron's disease, a chronic condition that affects 0.21% of the U.S. population, received about $90 million in funding for research through the National Institutes of Health (NIH). In contrast, endometriosis, which affects 11% of the US population, only received $16 million in funding. Endometriosis affects about 45 times as many people as Chron's disease, yet it receives a fifth of the funding. Similarly, diabetes is another chronic condition that affects about 11% of Americans — comparable to the incidence of endometriosis. However, diabetes research is awarded over $1 billion every year by the NIH, 62.5 times as much funding. These jarring statistics highlight the extreme underfunding of endometriosis research and the lack of priority that the disease takes in the world of biomedical science.

Women worldwide are at war with their bodies. In girls, mothers, and grandmothers alike, endometriosis creates and intensifies lifelong suffering. To promote the health of women, it is absolutely imperative to give this common yet disregarded disease the attention it deserves through focused clinical research, physician education, and the elimination of obstacles to endometriosis care.

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LAB-TO-TABLE

BY ABIGAIL POTTER, PHYSICS & PHILOSOPHY, 2023
DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Cloning is evolving from sci-fi movies into laboratories. The idea of creating life — or even creating products of life — has always enticed humanity. Despite this fascination, the concept of cloning; whether of cells, animals, or humans; still fills most with unease and even disgust. Despite its unsettling connotations, billions of dollars have been invested into cloning research and potential applications. From curing illnesses to continued living with beloved pets, cloning has come a long way. The next destination on its path? Our stomachs.

Vegetarianism (and veganism) is on the rise. Arguments for why eating meat poses concerns — both physical and moral — are gaining traction. Current livestock farming takes up huge amounts of land and water when compared to crops, siphoning resources and reducing land available for crops to grow. It is also estimated to account for a third of all anthropogenic carbon dioxide emissions to date.

Meat eating also raises concerns beyond the environment. Animals in livestock farms are often gravely mistreated. The cramped and stressful conditions are ripe for disease outbreaks — sometimes so intense that illnesses spread to humans. To maintain meat production levels and animal health, antibiotics are given to livestock. Microorganisms capable of becoming resistant to antibiotics are spread through this use. Whether through the meat itself or other methods, such as soil, water, and crops, antibiotic resistance can spread to any animal, including humans. With 70% of antibiotics that are medically important for humans used on livestock, antibiotic resistance is only increasing. In 2019 alone, at least 1.27 million deaths were attributed to antibiotic-resistant infections. With meat production showing little sign of slowing down, this number is likely only going to increase.

Despite these concerns, meat-eaters still make up a majority of the population. To understand this, *The New York Times* invited readers to make the strongest moral case they could for eating meat. The results said "surprisingly little." A panel of judges chose the winning essay, but the public was also encouraged to vote on their favorite. The essay chosen by the panel claimed eating meat was fine because life and death are natural and inevitable. It also claimed that giving thanks and choosing ethically raised food are the necessary steps of morally eating meat. The essay that won the public over, however, was written by Ingrid Newkirk, a vegetarian about to go back to meat after 40 years because lab-grown meat is allowing for the consumption of real meat "without the mess and misery."

The lab-grown meat Newkirk is referring to is also known as in vitro meat, synthetic meat, clean meat, or cultured meat and is created by taking muscle cells from a live animal. These cells are injected with a nutrient-rich serum that causes the cells to double in number every few days. Once formed, the cells are encouraged to form muscle-like fibers, which are then artificially "exercised" like muscles to increase protein content and size. The tissue is then harvested and sold as regular boneless meat. In November 2022, the FDA approved a San Francisco startup to sell cultured meat. This was the first FDA approval for cultured meat, but the industry still needs to pass through USDA regulations before sales can start.

Newkirk's view is based on the diminished harm cultured meat poses when compared to farmed meat. Without large amounts of livestock farming, animals are subject to significantly less (though not nonexistent) cruelty. There is less water use, less disease, less antibiotic use, and less deforestation. A 2011 life cycle analysis predicted the transition to cultured meat to reduce energy use by 45% and greenhouse gas emissions by 96% in the meat industry. A 2021 study revealed that recovering the 30% of Earth's land surface currently used for livestock farming could be used to resolve 800 gigatons of carbon dioxide via photosynthesis.

Cultured meat is not without flaws. Due to it being early in the development process, concerns around the safety of consuming cultured meat are still prevalent. Some are concerned with the idea of corporations controlling our food. Others are concerned with decreased genetic diversity — a problem we've had before with crops like bananas. Even more are concerned with what is in cultured meat. Cultured meat is suspected to have unhealthy ingredients such as yeast and heme. Heme, when consumed in excess, is linked to colon and prostate cancer. Even the FDA has set limits on heme in cultured meat: The protein cannot exceed 0.8% by weight of cultured meat to be safe for human consumption.

Regardless, cultured meat has a lot of potential. It could optimize diets, reduce the suffering of farm animals, and even help the environment. Cultured meat allows meat eaters to no longer face the severe moral consequences that eating meat poses, whether due to religious reasons, health concerns, or environmental awareness. Those who are too attached to the taste will have a new, potentially culturally accepted, option for their meals.

For those who have already given up meat? Keep doing so. Mark Post, the first presenter of cultured meat, has famously gone on record to say "vegetarians should remain vegetarians." Even with decreased harms, the best thing one can do for both the environment and the suffering of animals is to continue not consuming meat — bred or bioengineered. While suffering is reduced, some animals are still harmed in the creation of cultured meat. Similarly, while environmental concerns are less severe, the production still has flaws.

A future with cultured meat feels imminent and, when it finally becomes available to the public, already polarized responses are likely to skyrocket. A 2016 survey found that two-thirds of Americans were willing to try cultured meat, a third of which were definitely or probably willing to eat cultured meat as a replacement for farmed meat without even trying it. The willingness to try cultured meat suggests hope for the product. Assuming the taste and price of cultured meat compare to that of farmed meat when it is ready to hit the market, cultured meat has a higher chance of success than one might think.

The morality of meat-eating seems to exist on a scale. While one can view it as right or wrong, the logistics of the real world suggest that even the strongest moral case stands no chance against the most avid meat eaters. Cultured meat is providing a lesser wrong to those still seeking to eat meat. However, the existence of cultured meat is raising more questions about how we think about food and our willingness to consume it. Does where our food come from impact our morals when it comes to consumption? The answer to this question and similar ones is something we should all ask ourselves. How different is a lab from a factory? How do food corporations differ? Knowing the history and science behind the development of both farmed and cultured meat is an important piece of making the essential choice of what to put in our bodies.

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PHOTOS BY JIAJIA FU, BIOENGINEERING, 2026

THE TWO-DIMENSIONAL WORLD OF SCREENS

BY LILY GARRETT, BIOCHEMISTRY, 2025

DESIGN BY EVELYN MILAVSKY, CELL & MOLECULAR BIOLOGY, 2025

Many of us often find ourselves lost in a trance, sucked into spending hours and hours on our devices without even realizing it. While screens have benefited the world in copious forms in the past decade, they have concurrently created harmful widespread effects on the well-being of humans. The recent global pandemic quarantined families and secluded individuals to the confines of their homes. Unprecedented times inspired original ways to stay in touch and shape the "new normal" in life. It is clear that digital screens have positively changed the world in many ways. Nevertheless, extensive use of screens and technology can have adverse effects on human well-being and it is valuable to keep screen time in check.

Apart from the spike in screen usage due to the COVID-19 pandemic, we live in a growing age of social media and technology. Screens are increasingly prevalent in everyday life beyond the practical uses for work and academics. Poet Oscar Wilde stated "Everything in moderation," which is a common life mantra that rings true to even screen time. Excessive usage can be detrimental on both physical and mental health, yet a refined amount can in fact be beneficial.

A research study conducted in *npj Mental Health Research* published on Oct. 12th, 2022 examined how well-being, mood, and stress biomarkers change in response to lowering screen usage in adult populations. From a total of 89 families, 164 adults were chosen to monitor their major screen usage reduction from June 2019 to March 2021. Each individual was limited to three hours of screen time per week and compliance was monitored using apps and TV monitors. The participants' mental health, disposition, and daily stress biomarkers of cortisol and cortisone were assessed at baseline and two weeks thereafter.

It is ubiquitously known that screen time can have poor effects on overall well-being, yet a causal relationship had never previously been established. The results of the study provided a clear answer: substantial reduction of recreational screen time led to considerably improved self-reported mood and overall mental wellness. Biomarkers for cortisol and cortisone were not specifically affected, yet well-being was clearly influenced by time spent scrolling and staring at the screens.

The negative effects of digital screen time are wide ranging: heightened perceived stress, depression, and overall negativity. The significant reduction of screen time to three hours per week adopted by participants in the study generated outcomes that should spark all people to take a second look at the hours spent on screens each day and week. Participants reported widespread increases in their mental health states and experienced improved mood disturbance scores computed by a mood test regarding depression, anger, fatigue, confusion, and vigor. These adverse feelings and emotions play a role in the stress of daily life, all of which most people would like to reduce. Although said feelings and emotions cannot be prevented, this study and numerous others in the scientific research fields contribute increased mental well being and resulting higher quality of life to reduced screen time.

Physical well being, body composition, diet, and energy levels can also be dictated and affected by screen time as well; it is integral to live actively and presently in our daily lives, and the alternate world of technology and screens can often prevent individuals from living as actively and healthily as they should.

Although excessive screen usage can isolate one from the world, increase negative mood, and lower overall mental well being, screens can improve life in a plethora of ways when used in a balanced way. Utilizing screens to connect with friends and family over Zoom, FaceTime, online multiplayer games, and social media can strengthen interactions and foster greater community. Screens allow us to stay in touch, create art, study, learn, read, relax, and provide so many other positive outlets. Nonetheless, it is integral to practice restraint with screen usage. As we utilize screens each day and discover all of the wonderful things they have to offer, we all must remember to live presently in the three dimensional world in order to maintain health and happiness.

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PHOTO BY SHUTTERSTOCK

Opinion: Why science communication is failing and how we can fix it

BY NOAH HAGGERTY, APPLIED PHYSICS, 2024
DESIGN BY AMANDA BELL, DATA SCIENCE & BEHAVIORAL NEUROSCIENCE, 2023

For a recent article, I read scientific paper after scientific paper that all arrived at the same conclusion: Climate change in New England is already here, and the region had already warmed by 1.5 degrees Celsius. I accepted these conclusions without much thought — after all, I'm a science writer.

But then I met a local ecologist who had spent the last decade working in a New Hampshire research forest collecting climate data. He carefully and humbly put any biases and preconceptions behind him, and after analyzing the past five decades of his thermometer data, he came to the same conclusion as the other papers. Only then did it really hit me. This isn't an abstract concept or lofty theoretical armchair discussion. This is the grounded, tangible, physical reality.

As America becomes increasingly polarized, grid-locked, and focused on national politics, science has become swept up in the charged discussion. The connections of politics with climate change, vaccines, evolution, and the social sciences have caused these issues to become borderline impossible to effectively communicate, and the polarization creates the risks of the concept of science itself becoming polarized, further isolating large swaths of the population. Combating this requires humbling the practice of science, and focusing communication on local, tangible stories in science, told through community organizations such as public schools, local papers, and local social groups.

I grew up in a different America than the Americans before me — with unfettered access to social media, very little remaining local journalism, and increasing polarization in the alignment between the political divide, urban-rural divide, social divide, and educational divide. This societal structure encourages focus on nationalized groups of people much more than multi-dimensional individuals in our community: our neighbors, classmates, mentors, and family. In my experience, the vital, good-faith, and productive conversations that happen across these divides and engage with science have become few and far between, and they almost never happen online or with strangers. They happen with people in my community who I have built up trust with over years.

In nationalized, polarized thinking, scientific concepts like "climate change" quickly become abstract, looming, and intangible concepts, in the likes of "Democrats" and "Republicans." It represents nothing physical or real, but an almost-religious dogma. Once it achieved this status, it immediately became a threat to everyone who perceived its manifesto to be in direct conflict with their way of life. It moved beyond logical reasoning and the principle of rationality: that one is always open to persuasion by a strong, sound logical argument.

Then, to build productive and good-faith discussions and interactions with science in the diverse range of communities in our society, we must break, destroy, and humble these dogmas. We must ground these unphysical, abstract global ideas in local stories about real people, told by trusted local institutions with visible, real people behind them.

People's openness to listening to trusted community members is the reason why local doctors across the country, not national news sites or the federal government, were able to convince vaccine-hesitant people to get the COVID-19 shot. It's also the reason that middle and high school history teachers can teach young people about the societal challenges of gun violence in our country better than nationalized Facebook and Twitter arguments can.

Telling these stories locally not only destroys the dogmas around climate change, vaccines, and evolution. It also destroys the dogma around science itself. Many see science as being esoteric, performed by the elite, but anyone who's talked to a working scientist knows that scientists are, truly, average people. We can break this mask by talking about scientists at local research institutes or in non-traditional settings, such as a group of surfers who collected beach trash to find the biggest-polluting companies in their community, or a grassroots survey for people with schizophrenia, challenging traditional scientific thinking on the mental condition.

While there are benefits in free-form, ad hoc science communication on social media, the most effective methods for mass change will be from institutional responses. Accordingly, a new focus on local science communication will need to capitalize on other institutions. This includes engaging in scientific discussion at school districts, churches, and other community organizations and inviting local scientists, educators, and doctors to speak. Journalists and scientists should look at how they can contribute in their current communities and their often more-rural hometowns. Focusing on local stories and communication won't solve everything, but it's a concrete start to revitalize healthy local conversation around science and work to build a shared foundation of fact.

PHOTO BY SHUTTERSTOCK

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PSYCHE LOUI

The hidden harmonies of the brain

BY EMMA TUSUZIAN, PSYCHOLOGY, 2023
DESIGN BY PARKER HITT, BIOLOGY, 2023

"How much do we have to pay you to lighten it up?" a nurse asked Loui, who was flooding a nursing home cafeteria with the dark tones of a Beethoven sonata. Loui had been volunteering at the nursing home after her high school classes and only moments before discovered they had a piano. Challenged to switch to a more uplifting piece, Loui sought inspiration from the inside of the piano bench, where she found music books of folk tunes. She propped the books up against the piano. As her eyes darted through the pages in front of her, her fingers quickly followed, skipping from key to key in a friendly rhythm. The nursing home residents in the room, who were normally unresponsive due to conditions like late-stage dementia, suddenly came alive with song. Lyrics and harmonies poured out of them as Loui played. Her music was transformative, triggering a switch from unawareness to alertness. Though she did not know it at the time, this moment would help motivate her career, remaining close to her heart even today.

From student to maestro

Loui has always played music, enjoying piano and violin growing up. She also enjoyed her science classes and considered applying to medical school. However, she realized research could make an even bigger difference and explored its possibilities through her undergraduate neuroscience courses. While working on literature review assignments, Loui discovered the emerging field of music cognition, which merged her interests in music and neuroscience. Cognitive neuroscience particularly drew Loui as it allowed her to ask questions about seemingly subjective or abstract concepts with rigorous scientific tools. As she took music theory courses alongside her neuroscience courses, she began finding fascinating connections. For example, she would read papers about using chord progressions to define brain processing of musical syntax.

Her growing interest in this intersection led her to complete a PhD in psychology with a specialization in cognition, brain, and behavior at the University of California at Berkeley. She then expanded her academic work at the Beth Israel Deaconess Medical Center, Harvard Medical School, and Wesleyan University. Currently, she is an associate professor of creativity and creative practice in the Department of Music at the College of Arts, Media and Design. She is also the director of the Music, Imaging, and Neural Dynamics Laboratory (MIND Lab) at Northeastern University. On top of her academic endeavors, Loui has remained a musician, playing in the Duke Symphony Orchestra throughout her undergraduate education and in the Longwood Symphony Orchestra since 2007.

Her day-to-day schedule varies, but it remains a blend of family, music, and academia. Loui teaches a CAMD course twice a week, which covers an introduction to research for PhD students in arts, media, and design. Days she does not teach are filled with meetings, writing, and data analysis. After work, she regularly practices violin with her daughter after dinner. About twice a week, Loui goes to evening rehearsals for the Longwood Symphony Orchestra. Occasionally, she also enjoys Boston's bluegrass music on Tuesdays, which is a genre she has recently found interesting. On the weekends, Loui often spends time with her family and plays in a band. Since her undergraduate beginnings, Loui has maintained her roles as a musician and scientist throughout her daily life, which she now balances with parenthood.

Fusing genres

Loui's seemingly separate roles as a researcher and musician have only grown more harmonious as her career has progressed. As an undergraduate, she would be found either in her dorm, in a practice room, or in a lab. Her neuroscience and music theory courses were tightly linked to her experiential work. This linkage equipped her to write her undergraduate thesis, which involved recording electroencephalography (EEG) while participants listened to Neapolitan sixth chords and analyzing EEG into event-related potentials (ERPs). Now, the individuals she meets from playing or discussing music often become collaborators, consultants, or co-advisors on her

students' projects. One of the first people she met through the Longwood Symphony Orchestra was Dr. Lisa Wong, a pediatrician, violinist, and violist who also teaches a class related to music and health at Harvard University, for which Loui guest lectures annually. This connection has allowed students interested in this intersection to pursue their thesis in Loui's lab and be advised by both Loui and Dr. Wong.

From meeting musician-professors to musician-doctor-parents to other combinations of shared life experiences and passions, the meaningfulness of such connections is clear. "There's something about playing music together or having played music together that just feels very personal — so socially bonded," Loui said.

Loui and her colleagues take the stance that music co-evolved with society as a product of genes and culture in a way that subserves social bonding. This is in contrast to the ideas of those like Steven Pinker, who famously stated there is no evolutionary reason for music, and deemed it "auditory cheesecake" that is enjoyable but not necessary. Broadly, Loui explains that we have music because its features, such as pitch, harmony, or rhythm, encourage social bonding, learning, and forming predictions. These predictions help establish the dopaminergic reward system to learn more and seek out new experiences, particularly social experiences such as sounds.

The reason we have music is that "musical sounds set up predictions and rewards in ways that also direct attention across people," Loui said. Considering this role of music as being integral to society, Loui has explored many different topics in perception, underlying neural systems, and the translational capacity of music.

Lyrical moments for the compositions ahead

Given her broadly-ranging accomplishments in ever-expanding topics, I wondered what Loui would describe as her highest or proudest career points, especially in capturing her enduring personal connections to her work. During our discussion, she recounted the external validation of getting her first paper accepted by a journal as a postdoctoral researcher, which was reassuring amid the constant pressure to be working on new grants and papers. Loui quickly knitted her eyebrows in thought as she spoke, sharing that such acceptances were not as motivating as times when unique concepts fell into place. "I think the moments that really inspired me were when I had a new idea," she resolved with a nod. For her PhD dissertation, Loui formed the idea of using musical structure as an artificial language, which has become part of her current work revolving around a new musical system that can help researchers understand the brain. Knowing she discovered a tangible, innovative, and potentially impactful line of research was truly encouraging for her continued work.

Loui's intrinsic motivations for discovery are undoubtedly inspired by her encounters with music and people. High-school-aged Psyche did not know the individual nursing home residents who sang along to her piano playing, yet much of her current work as a researcher includes finding brain mechanisms underlying switches in alertness, especially in how they relate to music-based interventions. "I didn't realize how formative or how precious of a moment that was," she added after having described this meaningful experience. Loui is now collaborating with Edward Large, a theoretical neuroscientist at the University of Connecticut, to develop new interventions for Alzheimer's disease by combining theoretical models of rhythmic predictions with brain imaging in patients to test these models.

Looking ahead, Loui's lab has become interested in multiple areas related to systems and cultures. One of these topics is the ability of music to help those who experience early life adversity. In collaboration with Laurel Gabard-Durnam, an assistant professor in Northeastern's psychology department, Loui is tackling questions including: "How can music be used as a way to probe how early life adversity affects the brain? If someone's childhood was uncertain, do they hold on to certain pieces of music like a security blanket? If someone experienced uncertainty or trauma in adolescence, do they not form the pleasant associations with music from that period of life that most people tend to find pleasurable?"

Loui also aims to ascertain cross-culturally appropriate ways to understand music in order to address the field being largely Western-centric. By creating a new musical system, part of her goal is to "ask questions that are relatively culture-free," she said. She shared a finding from recent research, in collaboration with Elizabeth Margulis from Princeton University, on the phenomenon of imagination while listening to a piece of music. It was found that music with a twangy banjo sound conjured images of cowboys for people in Western societies, whereas a group of people from China who were not familiar with cowboys reported it made them imagine mountains. "Can we take music that is from neither culture and see how they can be used to inspire imagination and creativity?" Loui posed. She also wants to lower the interdisciplinary barriers of entry in music research so the musical experiences being investigated do not depend on an expensive music education or access to certain opportunities. Loui, Margulis, and Deirdre Loughridge, an associate professor in Northeastern's music department, are publishing "The Science-Music Borderlands" with *MIT Press* in the spring of 2023. The edited volume will tackle the disciplinary boundaries between humanities and sciences in music research.

Overall, Loui would like to create a form of music research that "addresses systemic differences or systemic inequalities, either across cultures or even within a single culture," she said. Loui has powerful visions for the future of her lab, hoping to "think through more socially-just ways to conceptualize research."

PHOTOS BY SHUTTERSTOCK

Rob Leeper

A Boston Navy veteran's journey through angry seas

BY NETHRA IYER, CHEMICAL ENGINEERING, 2024

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

I met Rob Leeper at my first co-op. When I started working, I was overwhelmed, to say the least. I did not know what I was doing or how to operate any sort of machinery for the first couple of weeks and although everyone I knew encouraged me to ask for help, it was difficult for me to do so without a pang of guilt. Rob noticed my hesitation and kindly told me "you can ask an old sailor anything." Intrigued, I asked what he meant when he said "old sailor." That was when he turned to me, his eyes glistening. He recounted his days in the Navy, his time away from his family, and all the lessons learned over the decades. This brief 20-minute conversation already had me hooked — I spent the next month getting to know Rob and learning his story.

Low tides: Rough beginnings

The story is of a man who started from nothing, working in a slum area, and went on to join the Navy. It was his will to survive and his penchant for electronics and building machines that allowed him to get to where he is now: one of the most ingenious mechanics at Nano-C, an MIT startup that focuses on organic solar cells and carbon nanotubes.

Rob's story starts in Pittsburgh, Pennsylvania, where he was born when his parents were in their forties. With his father airdropped in Normandy, and his mother telling stories of the Great Depression, Rob's childhood was anything but regular. From kindergarten to 12th grade, he had gone to 12 different schools in seven different school districts. Needless to say, friends were "not on the menu" — except for a mutt that kept a lonely boy company. Unfortunately, when Rob's family had to move once more to a poor neighborhood in Pennsylvania, his sole companion was left behind.

It was not until fourth grade that Rob's talent for mathematics was discovered. His teacher had accused him of cheating on long division problems — problems that even she could not solve in her head — as he was not showing his work. His father, a man hardened by his experiences in World War II, got involved. He demanded the principal make up math problems on the spot and use the desk calculator to verify the answers.

"For the first time, I saw that rage used to defend me," Rob said. as. Rob's father then got his IQ tested, for which he scored a 136.

Rob's penchant for fixing and building things came when his grandfather offered him an old radio that had not worked in years. Albeit young, Rob knew exactly how to take the cover off, how to clean the electrical connections, and how to fix the tubes. He now had music to ultimately "drown out the constant wail of police car sirens" from outside in the ghetto.

While school was anything but challenging, Rob's life after graduation was when things absolutely fell apart. His long-term girlfriend left him, and he realized he was studying at a diploma mill, preventing him from furthering his education for computer-aided design (CAD). With no job and a broken heart, Rob moved to a "pre-crack den apartment" in the ghetto, where he worked the night shift at a 24-hour convenience store, selling hot dogs. He then got a job as a dishwasher at a restaurant two miles away; he wanted to

escape the tirade of drunks after bars closed at night. Barely an improvement, Rob went from having a promising future to not eating every few days, waiting desperately for each paycheck. Not wanting to give up on his life, Rob did something he never imagined he would ever do: he called the Navy recruiter.

Currents: An uphill battle

Rob had actually been recruited multiple times in high school because of his score on the ASVAB test, a very challenging military exam. Although having scored in the 99th percentile, Rob turned down all the offers as he planned to work on CAD after graduation. Nevertheless, without any other viable options at this point, Rob signed up for the hardest academic program in the United States: The United States Navy Nuclear Propulsion School.

It was at this point that Rob's true determination and will to survive emerged from within. Boot camp started in Orlando, Florida, and within the first three weeks, his group of 110 recruits started dwindling. By graduation, a mere 55 remained. After boot camp, Rob entered the Navy training pipeline, where he took three classes and studied to become an Electrician. Rob could clearly remember the first day of school when the class leader came out and warned that half of them wouldn't survive the next three months. And it wasn't an empty threat: the class size dropped from 48 to 24. This did not stop Rob, who graduated third in the class and moved on to the Naval Nuclear Propulsion School.

"I was handed all of the piping system drawings for all of the subsystems that are involved for a nuclear reactor," Rob recalled, from a class at the Nuclear Propulsion School. These systems were filled with intricate layouts of thousands of gauges, valves, and tanks. He had to memorize them by the following Monday.

With five more classes following the same pace and difficulty, Rob explained with a heavy heart how three classmates died by suicide within a span of just six months. This program essentially taught three and a half years of college coursework in just six months — it was beyond onerous. Again, the class was reduced by half.

Rob, however, graduated second in the class and moved to Connecticut to complete the final leg of the program: running a real nuclear reactor. With only six months to complete the operator certification, Rob had to go about the Herculean task of learning the entire reactor and understanding every particular system of the reactor. This meant that Rob would work twelve-hour day and night shifts with very few breaks in between to recuperate. In the end, it all paid off as Rob became certified within just four months and graduated first in his class. He then stayed as an instructor, where he taught about the operational nuclear reactor for three years.

Waves: Difficult times and lessons learned

When I asked Rob about his biggest challenge, he without hesitation pointed to his time in a submarine. "This is where I finally grew up and learned how to be a leader," he said, reopening the mental box containing this difficult part of his life.

He explained how he had volunteered himself to work in a submarine during boot camp, specifically in Portsmouth, New Hampshire. Little did Rob know what was to come as he was tasked to work 460 hours over four weeks at a shipyard. He and his other fellow Navy brothers first spent weeks working tirelessly on land to repair the submarine and refuel the reactor, only to reach the most formidable part of their journey: going underwater. Rob then explained how the depths of the ocean were a true test of strength and resilience as he saw three men leave in straitjackets, doctors inject people with morphine to calm them down, and alcohol be the one place of solace as all forms of communication with family members were cut off.

Here, Rob's tone changed from introspective to melancholic as he described the pain of not seeing his family for 182 days, including missing the birth of his youngest son. With his only family being his Navy brothers, Rob described in detail some of the tasks and skills learned from underwater missions, including burning both hands to stop a steam leak, identifying Russian and American torpedoes, and escaping both fires and floods.

After his time in the Navy, Rob finally moved to Boston where he traversed the world of office politics. Although he may no longer be in the Navy, Rob continues to use the acquired technical skills and couple them with the courage and strength gained from his experiences to help others. By working at a start-up, Rob is able to pass along his knowledge and echo his life story to prove that greatness can come from even the smallest of beginnings.

PHOTOS BY FLICKR AND PXHERE

SCIENTISTS STUDY THE NORD STREAM METHANE LEAK IN THE RUSSIA-UKRAINE WAR

BY DARREN EASLER, CHEMICAL ENGINEERING & PHYSICS, 2026

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

War brings environmental concerns. Examples that typically come to mind include Agent Orange, nuclear weapons, deforestation — and now, energy. In February 2022, Russian President Vladimir Putin initiated a military invasion of Ukraine that has since put the European Union in a tailspin of major decisions concerning their future relations with Russia, with energy being one of them. Today, 16 European countries get over 50% of their natural gas from Russia. Finland, Moldova, and Estonia import 100% of their natural gases from Russia. So, it is no fabrication to say that Europe has a not-so-small energy dependence on Russia.

Then, on Sept. 26, 2022, the Nord Stream 2 pipeline, a gas transport line from Russia to Germany that has yet to operate since February's invasion, suddenly sprung multiple leaks. By Sept. 30, it had released an estimated 115,000 tons of methane gas into our atmosphere. What do climate experts say about the pipeline burst? How can we fix this problem?

Environmental scientists use carbon dioxide equivalents, to give the proportionate effects of greenhouse gases on the environment. For example, 1 kilogram of methane gas has the same effect on the atmosphere as 25 kilograms of carbon dioxide. As of Sept. 30, 2022, the amount of methane that escaped from the pipeline was equivalent to 2.875 million tons of carbon dioxide. The pipeline had not been operating and was simply holding natural gas. Methane greatly affects the temperature and climate of our planet, like all greenhouse gases, and has a lifetime of approximately a decade. Carbon dioxide has a much smaller warming potential but remains in the atmosphere for much longer than methane gas, upwards of 200 years.

The exact amount of methane released by the pipeline has yet to be quantified. No doubt significant, but without an actual number, environmental scientists can only guess the impact of the effusion of methane into our atmosphere. The most reasonable approach to fixing the problem? Light it up. Yes, as wild as it sounds, burning methane gas will create carbon dioxide and water vapor, and the effects of carbon dioxide are much less significant than methane.

The pipeline began construction in the spring of 2021, connecting Europe to energy resources in Russia. The construction raised immediate environmental and safety concerns due to the remnants of World War II violence near the site of the pipeline, most specifically, the chemical munitions dumped in the Baltic Sea by the USSR and the Nazis. With chemical uncertainties in the Baltic Sea, combined with a cautious approach to becoming more reliant on natural gas from Russia, the EU and the general population were hesitant about the construction of the pipeline. Amidst the initial attacks on Ukraine, the construction of the pipeline was stopped. What had been so controversial was nearly forgotten, until the leak in the Baltic Sea was spotted shortly after a sudden pressure drop in the pipeline.

How did it happen? Unsure of what caused the immediate hole in the pipeline, a team of seismologists led by Björn Lund, a professor at Uppsala University in Sweden, used his expertise to look toward the potential causes for a pipeline filled with 90% methane to drop from 105 bar, 103.6 times the atmospheric pressure, to just 7 bar, nearly immediately. Lund's team believes that the bust was caused by TNT, as the result of the seismic data changes is similar to previous naval explosions but has no definite evidence that this was the case.

Now, as the methane leak slows, two major questions remain. Who, if anyone, is behind the rupture of the Nord Stream 2 pipeline? And what will the European energy dependence on Russia look like in the future?

Environmental Science and Ecotechnology (2022). DOI:10.1016/j.ese.2022.100210
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PHOTO BY SHUTTERSTOCK

A STRUGGLE TO FIND PREY

How climate change is affecting bat echolocation

BY SOPHIE DONNER, ENVIRONMENTAL & SUSTAINABILITY SCIENCES, 2025

DESIGN BY ANANYA JAIN, BEHAVIORAL NEUROSCIENCE, 2025

Imagine you lost your AirPods. Multiple "pings" are emitted from the case for you to track down. Now imagine attempting to locate the source of these pings but with noise-canceling headphones on. It would be much harder to find the AirPods with something blocking the sound from reaching you, right? Bats that use echolocation may suffer from effects similar to those of noise-canceling headphones.

As climate change intensifies, the prey detection abilities of bats are wavering, which could impact population dynamics and competition among echolocating bats. Bats produce high-frequency sound waves, called ultrasound waves, and compare the sounds they emit with the returning echoes. Echolocation has a crucial role in allowing bats to locate and forage for prey, navigate their environment and the obstacles within it, and — in some cases — communicate with other bats. Over half of all bat species rely on echolocation for survival.

How do rising temperatures have the potential to hinder echolocation? As sound waves travel through the atmosphere, the amplitude, or how loud the sound is, decreases. This process is known as sound attenuation. Echolocation depends on how far the emitted sound waves travel, which is controlled by sound attenuation. Both air temperature and humidity influence the attenuation of sound. As air temperatures rise and humidity increases, ultrasound waves emitted by bats could lose clarity and effectiveness. If increases in humidity and air temperature do increase sound attenuation, then prey detection, navigation, and communication will indeed suffer from the impacts of climate change.

PHOTOS BY SHUTTERSTOCK

Scientists at the Max Planck Institute for Ornithology in Germany have studied the effect of shifted temperature distribution, due to the rise of air temperature from climate change, on prey detection. In a particular study, these researchers modeled changes in prey detection with increasing temperature using two different species, perch hunting bats and aerial hawking bats. The prey detection ability of each bat was measured as "prey detection volume," which is the total amount of air space in which a bat can hear echoes off of prey.

All models from the study showed that higher temperatures lead to better prey detection for low-frequency calls, and worsened prey detection for high-frequency calls. The frequency of a sound wave is the number of waves that pass a certain point in a fixed amount of time, which is similar to how high-pitched or low-pitched the sound is. The impacts on prey detection volume were more extreme at a 4 degrees Celsius increase than at a 2 degrees increase. Additionally, the research team found that these effects are stronger in temperate regions than in tropical regions, meaning that a temperature increase in temperate biomes has a more intense effect than in tropical biomes.

Bats with low call frequencies will likely have improved prey detection, and therefore could outcompete species with high call frequencies. This increased competition between bats with different call frequencies could lead to new foraging patterns and other ecological changes. Changes in reproductive success could occur, possibly leading to the genetic selection of bats with lower frequency calls that will have advantageous prey detection abilities under elevated temperatures.

While these changes in sound attenuation pose a threat to bats, there remains a possibility for bats to compensate with the frequency of ultrasound emitted. The team at the Max Planck Institute suggests that bats could adapt to increasing temperatures by decreasing call frequency, or by increasing the intensity of their calls. However, these potential adaptive frequencies do not exist without costs. Increasing call amplitude could lead to increased energy expenditure or vocal fatigue, especially in stationary bats. Reducing call frequencies could also reduce the maximum distance at which bats can detect prey. Despite compensating calls to increase detection ability, advantageous bat species could still outcompete.

Bats are not the only species that could be affected by climate change. Many other organisms on Earth including dolphins and whales utilize echolocation and depend upon this ability. It is key to recognize and study how future temperature changes can influence echolocation, to better understand how climate change will negatively affect these organisms.

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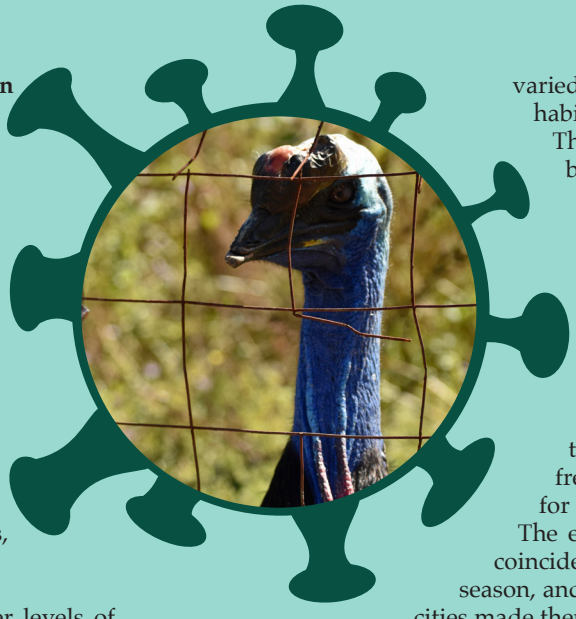
WITH PEOPLE AT HOME, MORE SPACE TÓ ROAM

HOW COVID AFFECTED BIRD BEHAVIOR

BY DESSY DUSICHKA, COMPUTER SCIENCE & BIOLOGY, 2025

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING & DESIGN, 2024



While people tend to focus on COVID-19's disruption to our daily routines, there was a separate world of consequences for wildlife. Animals have always had to adapt to the changing behaviors of human civilization by moving their habitats and adjusting their usage of resources like food, water, and shelter to maximize survival. The COVID-19 pandemic changed human behavior by forcing a stay-at-home culture, which reduced transportation and activity in many public spaces like schools, offices, retail spaces, and restaurants.

Less human travel resulted in lower levels of vehicle traffic, noise, and air pollution. Additionally, vehicle accidents involving animals were reduced, an often-overlooked aspect of decreased human travel. People had a lesser influence on the natural landscape and the results of human scarcity rippled into the animal kingdom, especially the bird world.

To analyze changes in bird populations and behavior, researchers have been using eBird, a website where anyone can report bird observations to a large database representing bird abundance and diversity. Data gathered in 2020 from March to July showed that the populations of 80% of major bird species in North America and the United Kingdom increased. This result highlights how the pandemic was beneficial for bird communities; however, not all bird species experienced the same success. Effects varied widely based on each species' habitat and resource needs. This demonstrates the delicate balance of ecological systems — environmental changes can shake up communities and cause varied responses based on species' unique niches.

Decreased human automotive activity resulted in more available safe space for birds. This is evidenced by the fact that urban areas were more frequently used as stopover sites for birds to rest during migration. The early months of the pandemic coincided with the spring migration season, and decreased traffic and noise in cities made them attractive spots for traveling birds. Avian populations generally grew near formerly busy roads and airports during peak COVID-19 years.

In addition to population increases, some species demonstrated altered birdsongs. When traffic is present at its usual levels, noise pollution is high and there is an abundance of low-frequency sounds from vehicles. This causes birds to sing at higher frequencies so they can be heard in this cluttered soundscape. However, during COVID-19, traffic and noise pollution lowered to levels last seen around 1950. A study by Elizabeth Derryberry and a team of researchers at the University of Tennessee showed that white-crowned sparrows in the Bay Area responded by singing more softly (at lower frequencies) since they no longer had to compete with vehicle noise. Communication

distance doubled, meaning birds could reduce territorial conflict by spreading out, but male birds could still have high mating potential since their songs could be heard by more females.

Bird activity was also altered in public parks as a result of people spending more time outdoors. Birds that typically live in these public spaces grew in population size, largely since more human-sourced food was available. Long term, some species decreased in population, presumably due to human disturbances in their habitats. Bird activity in backyards and gardens decreased since humans were more present to maintain their outdoor spaces, which presented a disturbance to birds seeking to nibble on homegrown produce.

Some pandemic results that we generally view as positive, including decreased noise pollution and less roadkill, ended up producing unexpected negative results for bird communities. Some species were actually harmed by the decrease in noise since anthropogenic noise can lower competition among species and reduce predation rates by displacing certain species that are less able to adapt. Additionally, the reduction of vehicle accidents involving wildlife intuitively seems like a good result for animals; however, it actually limited food availability for scavenger species like crows that consume decaying flesh.

While the pandemic certainly had devastating impacts on human economic and social systems that should not be overlooked, vital information about bird behavior in the face of anthropogenic change was collected. Researchers were able to pinpoint specific effects of human patterns on wildlife communities and analyze how different bird species responded. These responses included shifts in population size and changes in bird diet and behavior, including song patterns. Hopefully, this sneak peek of a society with reduced pollution inspires some long-term compromises that allow humans to continue enjoying their daily lives while still allowing wildlife to thrive.

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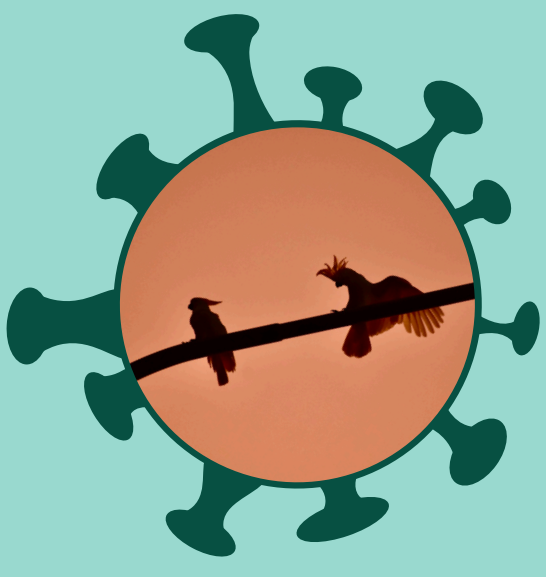
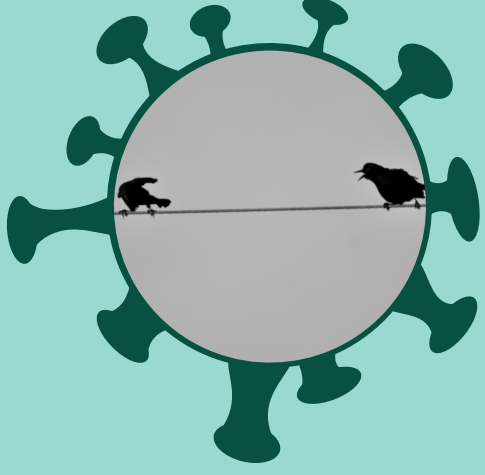
PHOTOS BY JIAJIA FU, BIOENGINEERING, 2026





A SILENT THREAT

HOW NORTHEASTERN RESEARCHERS ARE STOPPING THE SPREAD OF DANGEROUS INDUSTRIAL CHEMICALS

BY JEFFREY PAN, ENVIRONMENTAL & SUSTAINABILITY SCIENCES & DATA SCIENCE, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Many of us have the privilege of being able to use convenient and efficient items in all aspects of our lives. We use non-stick cookware to avoid having to viciously scrub their stainless steel counterparts after a long day of work. We use stain-resistant clothes that have the added benefit of being water-repellant. This privilege of convenience comes at a price, however. Many of these items are manufactured using perfluoroalkyl and polyfluoroalkyl substances (PFAS), which are human-made chemicals that are industrially used for consumer products.

The worrying aspect about these chemicals is that they do not break down naturally and remain in the environment. According to a study by Fatihah Suja from the National University of Malaysia, they can be "released into the water environment through both point source (industrial and sewage treatment plant) and non-point source (surface runoff and atmospheric) discharges." This is especially worrisome for aquatic ecosystems, where these chemicals may bioaccumulate within fish, which can later be consumed by birds or humans, further distributing them throughout the food chain.

A more direct path of human consumption is the contamination of tap water designated for drinking. Water treatment plants have been deemed inadequate for the treatment and removal of PFAS, allowing them to infiltrate drinking water reserves. This direct consumption of PFAS can pose serious health risks. A 2020 study led by Suzanne Fenton of the National Toxicology Program determined that multiple PFAS chemicals have various health effects that were considered toxic to humans. These health effects include altered immune and thyroid function, liver disease, kidney disease, and cancer.

Using their knowledge of wetland environments, these students selected *Juncus effusus*, a native, fast-growing wetland plant known for its remediation capabilities of metals such as lead. The fibrous roots of this plant and its ability to grow while suspended in water make it a prime candidate for chemical cleanup and mitigation efforts. Lanava and his peers want to observe the possibility of PFAS translocation, the absorption of the chemicals by the plant through its roots. If this is possible, *J. effusus* may very well be a top choice for large-scale PFAS remediation in water bodies such as reservoirs, lakes, and rivers.

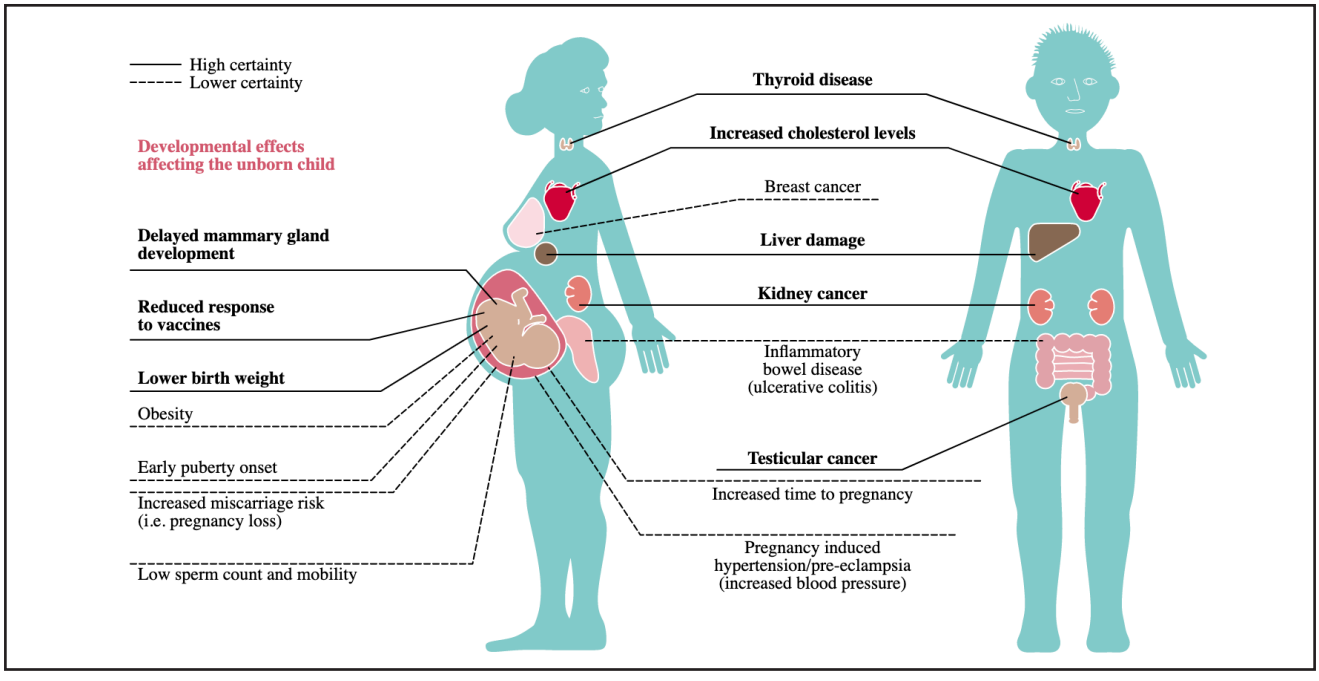
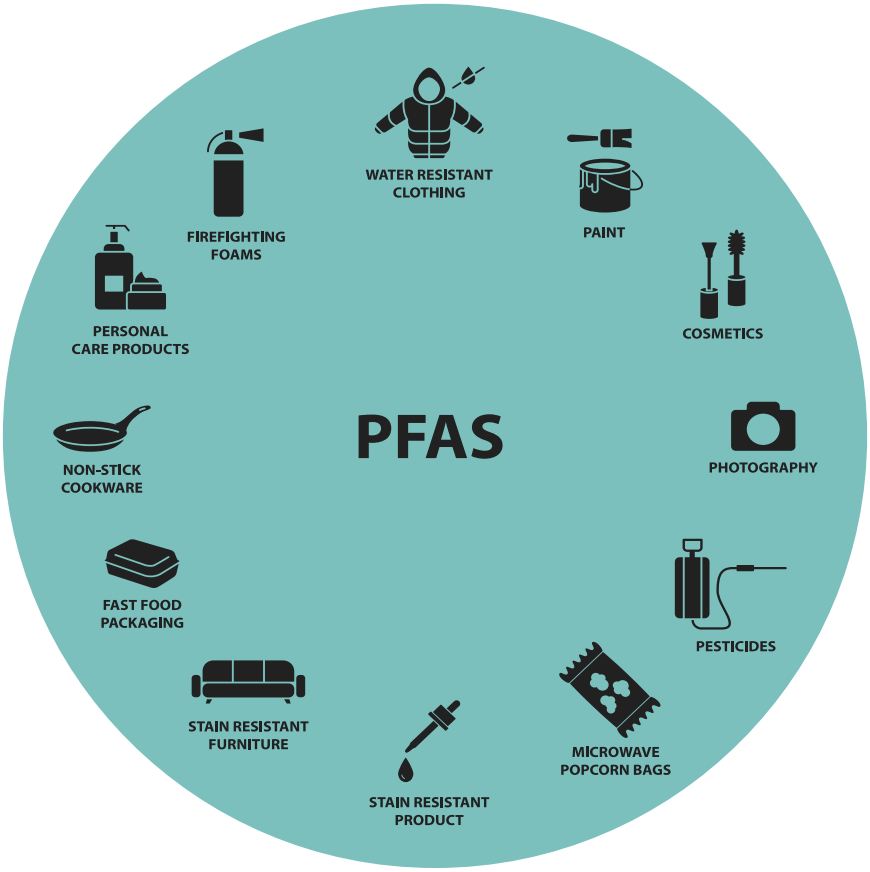


PHOTO BY EUROPEAN ENVIRONMENT AGENCY AND MRMW



To proceed with their experiment, the Northeastern students have set up industrial-grade plastic containers, with and without *J. effusus*, suspended in PFAS-contaminated water. The containers without plants act as the control group used to compare against the experimental group to see if the chemicals attach themselves to the lining of the container.

After a set period of time, water samples from the containers are collected and heated to a point where condensation causes water to separate from the dissolved chemicals. This results in a super-concentrated solution of any chemical and substance within the sample. Plant samples are also extracted and ground up, with the resulting powder being dissolved in a separate vial of water. The same condensation process is applied to the plant samples to separate the water and the chemicals from one another. Components of the sample are then individually separated for mass spectrometry testing, revealing the proportions of each substance within it. Depending on the results of the experiment, *J. effusus* may be an effective prevention and clean-up method for PFAS chemicals within water bodies.

Lanava has optimistic views of his project. The "implications of this research could potentially provide a biological treatment method for the remediation of PFAS from water to not only save thousands in operating costs for water treatment plants but hopefully thousands of lives as well," he said.

While students such as Lanava have been working hard on the frontlines of scientific research, consumers around the world can be more cautious of the products they are buying. Being conscious of the materials and chemicals used to create waterproof coatings and non-stick applications can reduce the risk of consumption and contamination. Careful consideration of the things we use can help preserve our good health and increase our vigilance against toxic substances.

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PHOTOS BY SHUTTERSTOCK

The industrial biorecycling complex

Beating PET pollution with plastic-degrading enzymes

BY JIAJIA FU, BIOENGINEERING, 2026

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

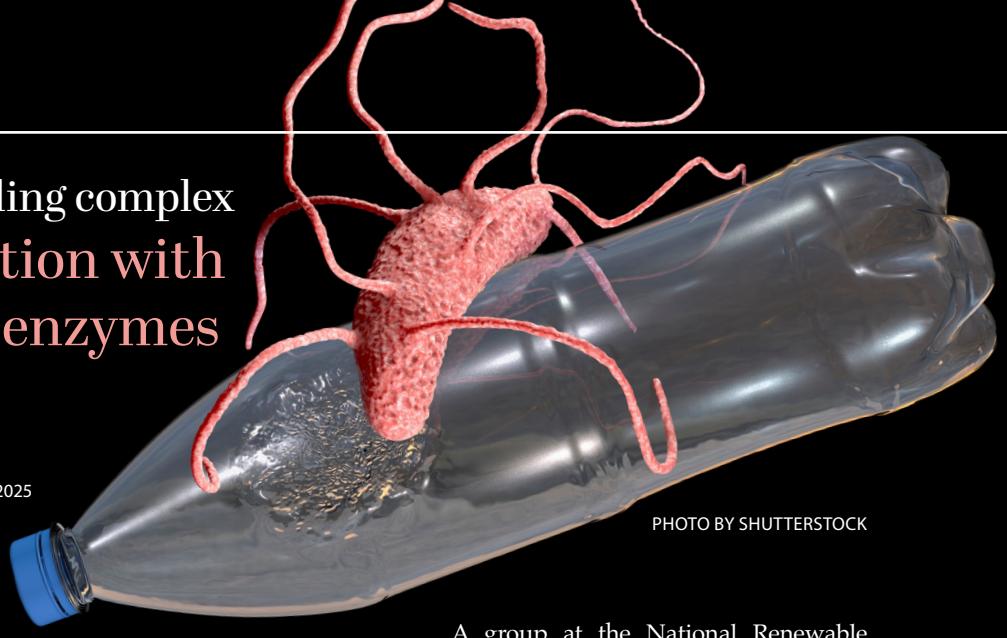

PHOTO BY SHUTTERSTOCK

As of 2021, 367 million tons of plastics were produced globally, with over 22% composed of single-use items. Thanks to its durability, versatility, and ease of production, polyethylene terephthalate (PET) has become the most common form of plastic in disposable products like water bottles and grocery bags. Despite some successes in reducing single-use plastics in daily life, there is a fundamental caveat with the current strategy.

Plastic resists chemical breakdown due to its unique structure. Its synthetic, tightly ester-bonded hydrocarbon chains cannot be produced in nature. As such, common decomposers cannot break the linkages. Recycling is the primary tool to address plastic waste, however, only 9% of all plastic waste is recycled as it is a prohibitively costly and energy-intensive process. It is simply cheaper to manufacture more plastic. This has spurred researchers to search for alternative management tools.

In 2016, researchers from the Kyoto Institute of Technology discovered *Ideonella sakaiensis*, a bacteria that produces the enzymes PETase and MHETase to break down PET into its monomers MHET, terephthalic acid (TPA), and ethylene glycol (EG), which it subsequently consumes. Although other plastic-eating organisms were isolated, wild-type PETase and MHETase have 5.5- to 120-fold greater degradative abilities than other homologous enzymes and can function at a range of temperatures from room temperature to 65 degrees Celsius. This organism, which evolved to thrive on a completely foreign material in less than half a century, provides a promising mechanism for biochemical recycling.

Despite its intrinsic specificity to PET, without modification, the enzymes cannot break PET down fast enough to be applied in an industrial context. A colony of *I. sakaiensis* would need six weeks to completely degrade a low-grade plastic water bottle. However, researchers have employed a multitude of bioengineering techniques to enhance their catalytic activity and structural specificity to PET.

How do they function, and can they be improved? PETase's region known as the binding pocket latches on to a long PET chain and cleaves the bond between MHET monomers, where MHETase then binds and cleaves into TPA and EG, which are non-toxic and can be reprocessed into new plastics. The physical shape of the enzyme determines the efficiency and speed of such a reaction — the more tightly the binding pocket can wrap around and bind to PET, the faster the enzyme can degrade its substrate.

Researchers have applied two types of protein engineering to this problem — directed evolution and rational design. The first relies on accelerating the evolutionary process with random enzyme mutations and screening the most successful conformations. Rational design refers to directly altering amino acids at critical sites to change the final configuration. These techniques have produced significant improvements: One group's directed protein evolution mutant PETase had a 14-fold increase in PET degradation activity at 40 degrees Celsius. Another group applied machine learning and rational design to produce a variant with 31 degrees increase in melting temperature and over 300-fold activity increase under mild conditions.

Nature, enhanced with bioengineering, has produced a remarkable new system, but can enzyme-driven biorecycling be scaled to a commercially viable solution? A group at the National Renewable Energy Lab proposed a model for such a bioreactor network — a facility processing at a scale of 150 metric tons of treated PET would enter the enzymatic "bioreactor," and be distilled into TPA and EG to be conventionally recycled. Various studies with the most recent PETase variants have projected 90% PET degradation extent at a purity of greater than 98%, less cost, and greenhouse gas emissions of virgin TPA. Despite such a promising theoretical yield, the initial cost of such a plant would be over seven times that of a conventional plant.

At such an experimental stage with a similarly high cost and no proof of concept, large-scale enzyme bioreactors may not start chewing up plastics in the next few years. However, more long-term models indicate that over 5 to 10 years (a typical recycling plant's breaking even point), the high-quality materials, and sustainability may compensate in the long run. Overdependence on plastics and fossil-fuel consumption has had drastic consequences. Biorecycling may not be a silver bullet solution, however, with more investment at the intersection of protein engineering research and society-wide policy, the world has a platform for a promising bioeconomy and plastic-less future to strive towards.

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CRAWLING CURES: THE POTENTIAL VALUE OF INSECTS IN MEDICINE

BY ELLA MESSNER, BIOLOGY & MATHEMATICS, 2023
DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

For thousands of years, humans have looked to nature for ways to cure disease. Ancient civilizations around the world relied on plants, animals, and fungi to treat every malady from headaches to heart disease. Even as our ability to develop synthetic drugs has increased, natural products remain crucial in the field of medicine. Between 1981 and 2019, nearly one-third of drugs approved globally were derived from natural sources. Scientists have discovered biologically active compounds in a diverse range of organisms, but most research has focused on plants, leaving many other life forms unexplored. In particular, insects are a promising yet underutilized source of biologically active molecules. Despite being relatively under-researched, insect-derived molecules have shown promise in a wide range of applications in medicine.

One insect-derived molecule of interest comes from the pesky bite of the mosquito. Mosquitoes employ anticoagulants to prevent clotting when feeding on their victims' blood for long periods of time. When mosquitoes bite, they puncture their victims' blood vessels with their proboscis, or feeding organ, and excrete a small amount of saliva, which is chock-full of molecules that prevent blood clotting. One of these molecules is anopheline antiplatelet protein, or AAPP, which comes from the mosquito *Anopheles stephensi*. Typically when a blood vessel is damaged, platelets aggregate on the blood vessel wall, creating a plug that prevents blood from escaping. AAPP binds to collagen, a protein that makes up much of the blood vessel wall and prevents platelets from adhering to it. This stops the damaged blood vessel from being sealed and allows the mosquito to continue feeding. Mosquito-derived anticoagulants like AAPP could potentially be utilized to treat dangerous blood clots like those that cause heart attacks and strokes. These molecules may also have applications in the field of medical devices. When devices are implanted in the body, they can trigger blood clotting, which increases the chance of the body rejecting the device and can damage cells. Coating devices with anticoagulant proteins derived from mosquito saliva may prevent this clotting and could be an alternative to currently used anticoagulants such as heparin, which can cause negative immune responses.

Scientists have identified another biomolecule with disease-treating potential in bees. The protein melittin, the primary component of honey bee venom, demonstrates antiviral, antibacterial, and, perhaps most intriguingly, anti-tumor activity. Melittin is able to kill more than 15 different types of cancer cells, largely due to its ability to disrupt the membrane of these cells, as demonstrated in a study at the Free University of Berlin. Positively charged melittin binds to cell membranes, which are negatively charged, and creates pores within them. This causes molecules to leak out of the cell, eventually leading to cell death. Healthy cells are more likely to be resistant to pore formation, so melittin primarily harms the more vulnerable tumor cells. However, some damage to healthy cells still occurs, which can cause severe negative reactions. To reduce the toxicity of melittin, researchers are working to combine the molecule with delivery methods that are able to more specifically target tumor cells.

Insect-derived molecules have also shown promise as stabilizers. Vaccines that are made from weakened or killed viruses must be stored at very low temperatures. In order to infect cells, proteins on the surface of viruses must bind to cell receptor proteins. When not kept cold, the viral proteins denature, or unfold, making them unable to bind to the proper receptors and preventing effective vaccination. This phenomenon makes the distribution and storage of vaccines difficult, especially in developing nations, as constant refrigeration is required. However, proteins found in silkworm silk may provide a solution to this challenge. In 2014, researchers in Japan and Australia found that at elevated temperatures, the fibrous proteins in the silk of *Bombyx mori*, the domesticated silk moth, stabilize viruses. This may be because the silk proteins hydrogen bond to the proteins on the viral surface, making them more compact and harder to unfold. Scientists hope to harness this property to reduce the need for vaccine refrigeration, thus making vaccines more accessible to those in areas that lack the infrastructure to maintain the cold temperatures currently required.

Evolution is a fantastic problem-solver. Despite the sophisticated techniques of modern science and the ability to create synthetic molecules, scientists continue to turn to natural molecules, honed by millions of years of evolution, to cure disease. In insects, we may find life-saving treatments for blood clots, cures for cancer, and strategies to bring vaccines to more people than ever before. The wealth of knowledge contained in insects, and all other organisms, underscores the importance of conservation. When species are lost, a plethora of potential solutions to human problems is lost with them.

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PHOTO BY SHUTTERSTOCK

CAN YOUR BRAIN HANDLE THE BEAT?

BY DORTHEA GEROULAKOS, CHEMICAL ENGINEERING, 2025
DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

If you come home from concerts with disheveled hair, a leather jacket, and neck pain, chances are you are a headbanging metalhead. Whether you listen to Led Zeppelin or obscure Turkish death metal, headbanging is a form of musical appreciation common for artists and fans. Can rocking too hard cause brain injury?

Crowds are connected through this wild and unruly motion that aims to match the intensity and fast tempo of the metal and rock genres. Despite what the name suggests, headbanging does not involve direct collision to the head and is a full-body motion: moving your body side to side, up and down, or all around. While traumatic brain injuries impact 69 million people a year, headbanging at concerts is not usually what comes to mind as a culprit.

A review published this year sought to assess concert-goers' risk. Researchers evaluated 13 cases of moderate-to-severe brain injury in which doctors declared music-associated headbanging as the main cause. None of these cases involved direct collisions to the head. Victims connected by a shared calling from the beat and subsequent trauma included a 15-year-old drummer in a rock band, a 50-year-old Motörhead concert-goer, and a woman who had been headbanging for hours at a religious dancing ritual.

The vigorous back-and-forth motion of headbanging may have been responsible for the tearing of bridging veins in the brain. As a result, hemorrhaging followed in more than half of the cases. In two cases, the repetitive force led to basilar artery thrombosis, or blood clotting. Headbanging also worsened previous conditions. An 11-year-old boy's colloid cyst ruptured after an intense disco party. While some were able to recover in weeks or even days, others were not as lucky. The study focused on extreme cases but it warns that unrecognized mild traumatic brain injuries might be much more frequent and go unreported. Mild brain injury has the potential to be dangerous when compounded with frequent headbanging.

Another group of researchers used biomechanical theorization to model the effects of the range of motion in the cervical spine, between the head and neck, and song tempo (beats per minute). Researchers estimated the probability of head injury from these variables using the existing head injury criterion (HIC) in the field. Athletes and car crash victims frequently use HIC to calculate head injury risk based on the acceleration and duration of their collisions. The study recognized the limitations of their model due to the debated relevancy of these criteria for headbanging. Unlike a single acceleration peak caused by a collision, headbanging involves regular sinusoidal peaks without a direct impact. Much remains unknown about these effects.

The study found that as range of motion over 45 degrees and song tempo increased, the theoretical chances of injury also did. The total range of motion of the cervical spine between your neck and head is about 160 degrees up and down. Using their model, the researchers theorized that headbanging 146 beats per minute at more than 75 degrees of cervical motion could cause a mild traumatic brain injury. Popular songs at tempos as fast as 180 beats per minute like "Kickstart My Heart" by Mötley Crüe in conjunction with a 120 degrees range of motion could have severe consequences that could be avoided by keeping head and neck motion below 45 degrees. This means more of a bobbing motion than banging unless you intend to dance to the slower but still punchy tempos of Celine Dione or Adele. Of course, this model is based on the imperfect HIC model and also calls into question the likelihood of fans' heads hitting these beats at those angles. However, no true metalhead is yet to be overcome by a zealous crowd of flying hair at these angles.

There is still so much uncertainty on the topic of headbanging, especially in an environment where there is frequent illicit substance use and moshing. One thing is clear, however, traumatic brain injury cases directly linked to music-associated headbanging appear to be rare in medical literature compared to the millions of headbanging fans around the world.

Further research is needed to learn more about the potential for brain trauma from intense, repetitive motion instead of direct impact to the head. Headbangers deserve to know the answer to the question, "Can you rock too hard?" once and for all. Knowing the limits of our brains could help lead to more precautionary dancing forms. Who knows what could be the next staple of rock? Jazz hands are waiting for their comeback.

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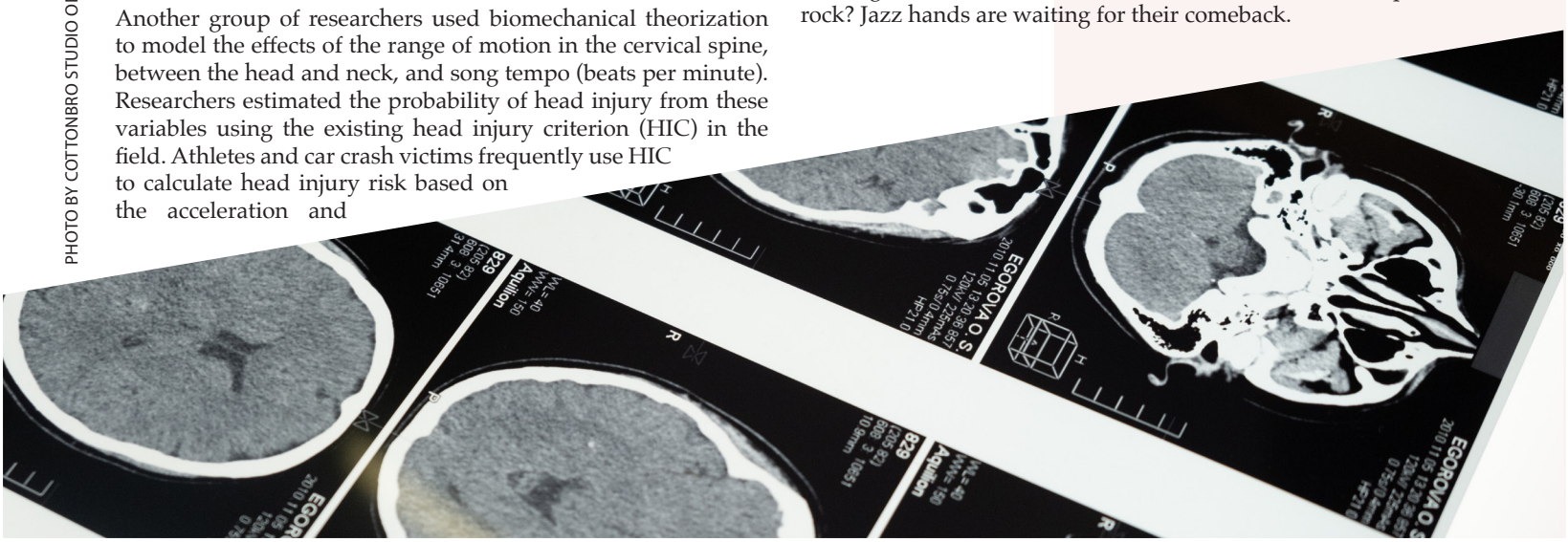

PHOTO BY COTTONBRO STUDIO ON PEXELS

Human neurons in rat brains

Researchers demonstrate a new way to study the human brain in the lab

BY LYRIC WESTLUND, BIOCHEMISTRY, 2025

DESIGN BY EVELYN MILAVSKY, CELL & MOLECULAR BIOLOGY, 2025

Modern scientists rely heavily on cell culture in laboratories to understand how cells work in order to provide possible cures for diseases. Brain cells are some of the most difficult cells to study simply because there's a lack of access. Scientists have been able to grow brain cells previously by use of induced pluripotent stem cells (iPSCs). iPSCs are cells created in a laboratory that take skin or blood cells and use human transcription factors to turn the cell into an embryonic-like stem cell. An embryonic-like stem cell can differentiate into any type of cell in the human body, including neurons. This is one way that scientists have been able to grow neurons in culture without needing human tissue samples.

The only problem is that cells in a culture do not always act in the same way as cells in a human body. Cells in the human body receive different nutrients via the bloodstream and cell-to-cell interactions that cells in culture cannot receive. Cells in culture tend to have trouble maturing in the same way. These cells also cannot integrate into a system to generate behavioral outputs. This creates a limitation when looking at neuropsychiatric diseases because scientists cannot yet understand those processes in a laboratory. As of this year, however, scientists may have found a solution to overcome these limitations.

Recently, scientists have successfully implanted human neurons in newborn rat brains. According to Omer Revah, a scientist in the Department of Psychiatry and Behavioral Sciences at Stanford University, and his colleagues, not only has the implantation of these neurons been successful, there is evidence that these new cell types "integrate into sensory and motivation-related circuits." These cells display much more complex properties than neurons grown in culture.

In order to test whether this rat model could be an option for studying disease phenotypes, the scientists implanted cells from patients with Timothy syndrome (TS). TS is a rare, life-threatening genetic condition that affects the brain as well as the heart, the immune system, and the phalanges of a child. The mutation, found in the *Cacna1c* gene that builds a protein associated with calcium ion transport, can affect a child's brain development tremendously. In this study, not only did these cells mature in the rat brain, the rats implanted with TS cells showed defects in neurons just as they would in a human. This finding could possibly open the door for in-depth studies of brain development and brain disorders through rat brain modeling. If scientists can continue to implant cells of different brain disorders into rat brains and continue to see the correct phenotype, this can lead to a whole new aspect of study in the fields of both neurology and psychiatry.

In addition, these scientists studied whether the rats with human neurons could drive reward-seeking behavior. In order to do this, they first implanted human neuron cells that expressed a light-sensitive cation channel, channelrhodopsin-2, which made the rats more reactive to blue light. Then they trained the rats by rewarding them with water if they licked during a blue light rather than during a red light. After a little over two weeks of this practice, the rats were beginning to show increased licking during the blue light rather than the red light. This behavior change was not observed in rat brains that were implanted with neurons that did not express the channelrhodopsin-2. This demonstrated that the human cells implanted in rat brains can communicate with rat neurons in order to drive reward-seeking behavior.

Overall, this study shows that neurons can mature in rat brains and integrate themselves into the phenotype. By demonstrating the rat's ability to seek rewards for certain behaviors, it shows the ability of the human neurons to connect and influence rat neuron activity. In addition, the prospect of being able to produce disease phenotypes such as TS in rat models could provide amazing new disease research in the coming years. This study is the beginning of a very promising new laboratory technique and could possibly open up studies for diseases that before were quite limited.

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PHOTO BY SHUTTERSTOCK

THE SPIRIT MOLECULE
OUR BODY'S NATURAL PSYCHEDELIC

BY KHOSHNA ANDE, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

DMT earned its nickname as the "spirit molecule" in the 1990s when over half of Dr. Rick Strassman's research subjects vocalized experiencing something extraordinary. His experimentation had initially concerned the physiological effects of the molecule, but he couldn't ignore its inherent psychoactive influences after about 200 of his participants reported undergoing a "religious" transformation with "non-human beings." These collective hallucinations are not unique to Dr. Strassman's study. In fact, many anecdotal accounts report similar experiences.

In 2020 and 2021, the University of Greenwich conducted an experiment where 36 experienced DMT users were administered between 40- and 75-milligram doses of DMT. Results conveyed that 34 out of the 36 participants had encountered "sentient entities ... beyond the self" who had enhanced their trip. The appearances of these entities varied, with the majority allegedly seeing "Otherly Creatures" — any non-Earthly manifestation, including but not limited to, silhouettes and "humanoids." In another study, Dr. David Lawrence qualitatively analyzed over 3,000 DMT experiences posted on the r/DMT subreddit from the past 10 years. He found that at least 1700 of those posts included "entity encounters" with many entities possessing a religious or divine influence.

> "His experimentation had initially concerned the physiological effects of the molecule, but he couldn't ignore its inherent psychoactive influences after about 200 of his participants reported undergoing a 'religious' transformation with 'nonhuman beings.'"

Recreational psychedelic usage, though illegal, has existed for decades now and is sought after for the vivid sensory distortions that accompany its euphoric effect. Raves, concerts, or any covert college environment are likely to boast a variety of hallucinogens, ranging from lysergic acid (LSD) to psilocybin (magic mushrooms) to MDMA (ecstasy). However, DMT has yet to gain mainstream popularity.

DMT affects individuals in a slightly different manner than most conventional psychedelics. For one, DMT "trips" are brief, only lasting about 10 to 30 minutes, rather than the standard several hours experienced with other drugs. Second, its effects are felt almost immediately upon ingestion and include intense hallucinations. Steven Barker, a researcher at Louisiana State University, describes it as the "feeling of transcending one's body and entering an alternative realm ..." But what is it about the spirit molecule that neurologically differentiates it from LSD, magic mushrooms, and other psychedelics? It is produced endogenously, within the body.

Perhaps surprisingly, this Schedule 1 Class A, unbelievably potent hallucinogen, is an actively metabolized neurotransmitter in the body much like serotonin, and it can even sometimes be traced in blood, urine, and spinal fluid. There are several conjectures theorizing the role of DMT in daily life, but as of right now, there is still no concrete proof delineating its physiological function.

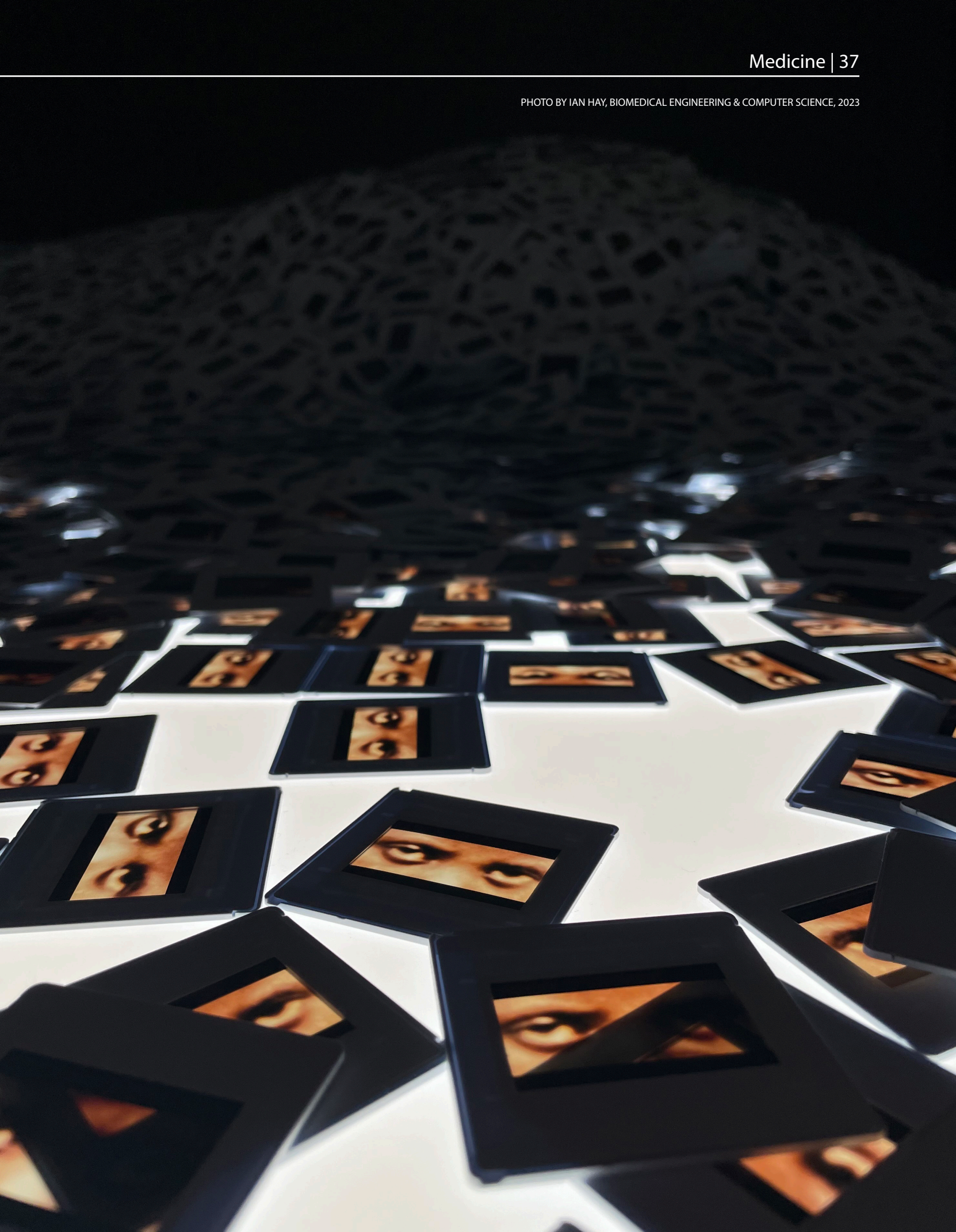
Structurally, DMT is analogous to the major mood regulator, serotonin. Both are derived from the amino acid tryptophan, which is decarboxylated to form the tryptamine compound. The major variation in the synthesis of DMT is a final methyl group (CH_3) from an adjacent compound that is transferred to the tryptamine into DMT, which doesn't occur during serotonin production. This conversion is the pivotal step in the biosynthesis of DMT and is only possible in the presence of the enzyme INMT. Thus, the 1961 discovery of natural INMT in rodent brains was groundbreaking and suggested the possibility of endogenous DMT. Shortly after that breakthrough, INMT activity was uncovered in several regions of the human brain, most notably the sensory cortexes and the emotion control center. Unfortunately, the implications of these discoveries are still in their infancy; however, they might explain the hallucinatory similarities experienced by those under the influence.

The significance behind Dr. Strassman, Dr. Lawrence, and the University of Greenwich researcher's findings lies in how most other psychedelic trips are highly individualized and do not induce such large-scale, paralleled hallucinations. The prevalence of these recurrent themes has given rise to numerous psychological and metaphysical questions, including: Who are these entities? Why are they found in so many different recounts? What does their existence tell us about the brain?

Evidently, DMT is a puzzling molecule for neuroscientists and users alike. The psychotropic state it induces is more intense than most other recreational hallucinogens, yet it is one of the least understood endogenous compounds. There are many avenues for future research to proceed in to clarify the countless theories postulating its significance. One such theory includes the idea that DMT is released in high volumes during birth and death, and can explain the "dream-like" states perceived in Near-Death Experiences. If this is true, then we are one step closer to understanding where we go when we die, and it is all connected to that tiny, 12-carbon spirit molecule coursing through our bloodstream right now.

Frontiers in Neuroscience (2018). DOI: 10.3389/fnins.2018.00536
Frontiers in Psychology (2021). DOI: 10.3389/fpsyg.2021.720717
Scientific Reports (2022). DOI: 10.1038/s41598-022-11999-8

PHOTO BY IAN HAY, BIOMEDICAL ENGINEERING & COMPUTER SCIENCE, 2023



Patisiran to Treat Hereditary Transthyretin-Mediated Amyloidosis (hATTR)

BY JASON DENONCOURT, CHEMICAL ENGINEERING & BIOCHEMISTRY, 2023

DESIGN BY CARINA HALCOMB, EXPERIENCE DESIGN, 2024

The advent of RNA therapeutics has generated several novel drug platforms and accelerated research in rare diseases, targeting formerly "undruggable" proteins. Unlike small molecules, these therapeutics mimic the natural machinery directly involved in protein expression within cells, either knocking up or down genes via mRNA and siRNA, respectively. Given the tremendous specificity of the constructs, the greatest challenge remains with drug delivery, as RNA is relatively unstable and unamendable to traditional administration methods without modification.

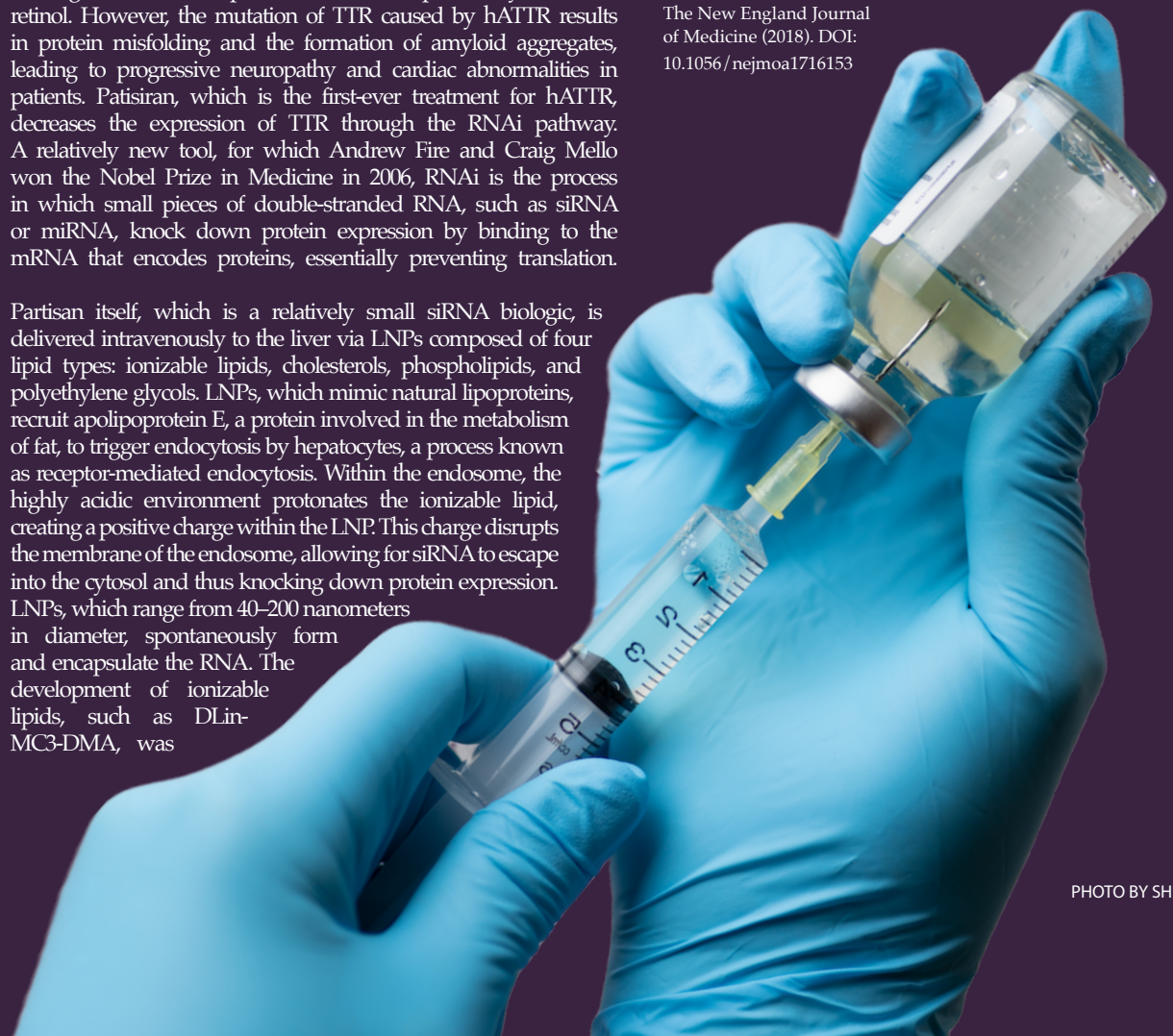
In 2018, the FDA approval of Onpattro, commonly known as Patisiran, to treat hereditary transthyretin-mediated amyloidosis (hATTR) marked the first siRNA drug to reach the market and the first to employ lipid nanoparticles (LNPs) for drug delivery. Though hATTR is a rare disease with only about 50,000 patients worldwide, Patisiran established RNA interference (RNAi) and LNPs as viable platforms for modulating protein expression and delivering RNA to cells, respectively. The approval also foreshadowed several more siRNA drug approvals by Alnylam Pharmaceuticals, the maker of Patisiran and leader in RNAi therapeutics.

hATTR is a genetic disease caused by a mutation in the transthyretin (TTR) gene, which is responsible for the transport of thyroxine and retinol. However, the mutation of TTR caused by hATTR results in protein misfolding and the formation of amyloid aggregates, leading to progressive neuropathy and cardiac abnormalities in patients. Patisiran, which is the first-ever treatment for hATTR, decreases the expression of TTR through the RNAi pathway. A relatively new tool, for which Andrew Fire and Craig Mello won the Nobel Prize in Medicine in 2006, RNAi is the process in which small pieces of double-stranded RNA, such as siRNA or miRNA, knock down protein expression by binding to the mRNA that encodes proteins, essentially preventing translation.

Partisan itself, which is a relatively small siRNA biologic, is delivered intravenously to the liver via LNPs composed of four lipid types: ionizable lipids, cholesterols, phospholipids, and polyethylene glycols. LNPs, which mimic natural lipoproteins, recruit apolipoprotein E, a protein involved in the metabolism of fat, to trigger endocytosis by hepatocytes, a process known as receptor-mediated endocytosis. Within the endosome, the highly acidic environment protonates the ionizable lipid, creating a positive charge within the LNP. This charge disrupts the membrane of the endosome, allowing for siRNA to escape into the cytosol and thus knocking down protein expression. LNPs, which range from 40–200 nanometers in diameter, spontaneously form and encapsulate the RNA. The development of ionizable lipids, such as DLin-MC3-DMA, was integral to the success of Patisiran and LNP delivery. While a charge is required for endosomal escape, the cytotoxic effects of a cationic lipid make it unamendable for drug delivery. Thus, by including a lipid that is electrostatically neutral at physiological pH and positively charged in acidic environments, LNPs are stable in circulation while facilitating endosomal escape once within cells.

While Alnylam's Patisiran was the first LNP-delivered drug approved by the FDA, several companies have since designed and developed proprietary ionizable lipids that mimic the behavior of DLin-MC3-DMA. In fact, the early research of Alnylam and other research institutes enabled, in part, the rapid development of both the Pfizer/BioNTech and Moderna COVID-19 vaccines, as both use LNPs for local intramuscular delivery. Recently, Alnylam has filed lawsuits against Pfizer and Moderna for patent infringement, seeking royalties for unauthorized use of the ionizable lipids crucial to successful LNP delivery. Pfizer and Moderna have faced similar lawsuits from other small biotech companies, raising the important question of who should profit off of the billions in vaccine revenue. While the ionizable lipids of Pfizer and Moderna may be proprietary and beyond the scope of Alnylam's patent, Patisiran certainly laid the groundwork for future RNAi and LNP-delivered therapeutics.

The New England Journal of Medicine (2018). DOI: 10.1056/nejmoa1716153



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Fraudulence in science

Vital research for Alzheimer's was potentially fabricated

BY MACKENZIE HEIDKAMP, BIOENGINEERING, 2026
DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

Science is a field of building upon mistakes, failures, and incorrect theories. Without thousands of flawed ideas from scientists over generations, we would not have developed the foundation necessary for the discovery of the tried-and-true methods we have today. A great example of this is Bohr's model for the atom. His model was revolutionary at the time and expanded the scientific community's understanding of electrons' connection to the atom, but it ultimately was discovered to be inaccurate due to the fact that the electron was being viewed as a particle and not as a wave. Scientists today understand that Bohr was incorrect in his construction of the model due to his lack of understanding of quantum physics, but they also acknowledge how vital he was in the progression of chemical theory. No one faults Bohr for not being 100% accurate and predicting every facet of atomic theory, but the scientific community might not have been so forgiving if he had been fraudulent in his work.

In 2006, neurology postdoc Sylvain Lesné from the University of Minnesota published his research in *Nature*, which was viewed as vital to our understanding of Alzheimer's disease. More specifically, he claimed to have discovered that Aβ*56, an amyloid-beta oligomer, was the cause of cognitive decline in patients with Alzheimer's. If his work was truthful, his discovery could have opened the door for numerous potential treatments and expanded projects for Alzheimer's. After the height of the new discovery, however, red flags started to appear when many scientists tried to replicate his work and failed to succeed.

The realization that his work was fabricated came fully into view when a group of image analysts and Alzheimer's researchers came together and conducted an in-depth six-month-long dive into determining the validity of Lesné's work. One of the forensic image consultants, Elisabeth Bik, told *Science* that she could conclude that the individuals behind the Aβ*56 research "appeared to have composed figures by piecing together parts of photos from different experiments." Altogether, the investigative group determined that the photos and conclusions from Lesné's work were very clearly altered. Some speculate that his team must have wanted to be correct in their original hypothesis, prompting them to fabricate new data themselves.

As expected, the scientific community was alarmed to learn that an established researcher would fabricate a seemingly important discovery. Not only is it harmful to the credibility of the community, but the event had a direct impact financially and intellectually. This is because many researchers invested money and their own time into starting new projects rooted in Lesné's discovery. Stanford University's Thomas Südhof, the winner of the 2013 Nobel Prize for Physiology or Medicine with his work in presynaptic neuron transmission, told *Science* "the immediate, obvious damage is wasted NIH funding and wasted thinking in the field because people are using these results as a starting point for their own experiments."

Shockingly, the NIH also wasted money in a similar situation that occurred recently at Harvard Medical School, where Dr. Piero Anversa falsified images of cells in 2001 to make it appear like stem cells could have the ability to potentially cure heart disease completely. According to *Reuters*, "the U.S. National Institutes of Health spent at least $588 million on such heart research" after the claimed discovery.

The direct impact of both instances of fraudulence strongly emphasizes the importance of the scientific method. People should not start feeling untrusting toward scientific research. While there are a few instances of researchers being deceitful such as Lesné or Dr. Anversa, a majority of researchers use research as a way to learn more about the world and go through the proper steps to ensure validity in their results.

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