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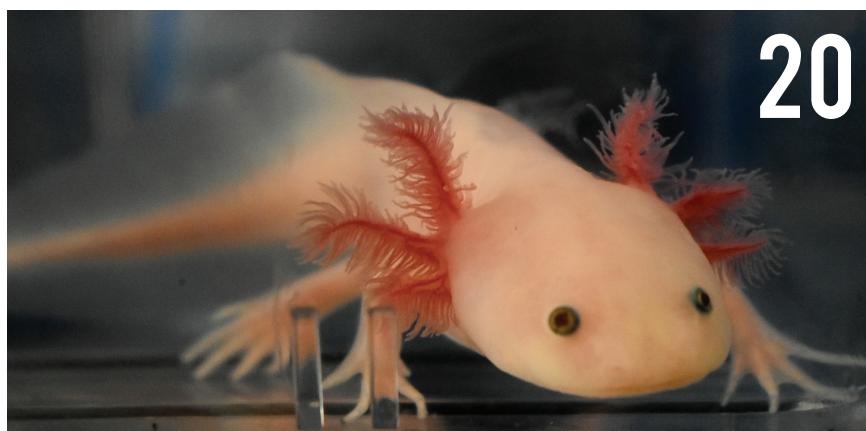
# NU SCI



# RESILIENCE

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# LETTER FROM THE EDITOR

# STAFF

We're still here. That's what resilience is all about. While the world goes on, unflinchingly, we marvel at its persistence in spite of everything that stands in its way. It's a very human tendency to think of resilience as an admirable quality, yet resilience is such a natural part of the Universe, quietly triumphing against the odds every day. For yet another issue, our writers have captured moments of resilience — the need to be more resilient in the face of climate change, the resilience of people against psychological and physical hardship, and the resilience of the nature surrounding us.

From our humble beginnings of black-and-white pages and Comic Sans font, NU Sci has stood the test of time to become the publication that it is today. I'm privileged and honored to be here to celebrate our 50th issue. It took the hard work and dedication of so many before us to reach this point today, and I hope our efforts will help reach another 50 issues — and many more to come after that.

Every year it astounds me how many people are interested in science and writing, design, or photography — sometimes even some or all of those things. To some of our members, NU Sci is a place to combine their creative passions with science; to others, it's a place to learn and to improve on their writing. There are countless reasons why people decide to join the magazine, and there are even more reasons why they stay. And, as long as those reasons exist, I think NU Sci will be here to stay too.

So, without further ado, please enjoy your stay in these pages, as we present NU Sci's 50th issue: "Resilience."



A handwritten signature of Binh Dang in cursive script.

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# Moo-ving about: The transitional lives of dairy cows

BY RACHEL LINES, BEHAVIORAL NEUROSCIENCE, 2022

DESIGN BY SOPHIE PATE, BEHAVIORAL NEUROSCIENCE, 2024

**F**rom cow-print phone cases and jackets to “drink milk” posters to paintings illustrating herd-speckled landscapes, dairy cows are among people’s favorite creatures. Affection toward these docile animals is clear, but what do their lives really look like? It’s not all scenic red barns and grazing.

Dairy cows go through several major life transitions, and cattle are bred to have traits making them healthier, more comfortable, and better milk producers. A dairy cow’s capacity to stay healthy and return to a calm state during and after challenging transitions is known as dairy cow resilience. For cows, moving between barns, integration into a new social group, or even a change in diet can signify transition.

One major transition that all dairy cows experience is calving. Like any mammal, cows must first give birth to produce milk. Birth induces changes in hormone production: prolactin induces milk production, and oxytocin production causes milk to flow into the teat. Transitioning to be a milking cow is also a sensitive time for the animal since infectious diseases occur more often in the weeks following calving. Amongst physiological and hormonal changes, this event also often accompanies transition in where the animal lives on the farm.

Before giving birth, cows may live in group housing. Multiple cows can live together in free-stall housing or large cubicle-like stalls. Additional space can accommodate more animals, and conventional bedded-packed barns allow cows to roam without separation into stalls. Some farms also have pasture systems or dry-dirt lots depending on the climate. Housing styles vary in hygiene, floor space, and climate control. If insufficient, these factors can cause stress. Furthermore, when an animal gives birth, housing transitions can occur. New milking cows can be moved from group housing to an enclosure that aids in milk collection. This transition could mean moving to new group housing or tie-stall housing with a single stall for each animal.

Methods of milk collection depend on how cows are housed. In tie-stall barns, farmers can bring a milking unit, or small robotic milker, to the cow. The animal stays in one place while a pipeline carries milk from the animal to a collection tank. For group housing, milking parlors are typically used; cows go to be milked with robotic milkers throughout the day. A new version of collection for group housing is

complete robotic milking, which allows cows to have the freedom to determine when to be milked. Animals frequent this robotic milking enclosure at their leisure, choosing when and how often they want to be milked. Each animal wears a transponder collar carrying information such as udder size, teat location, and even how much milk the cow produces. As farms adapt their technology to introduce new systems like robotic milking, housing changes during this limbo period can stress the animals.

Beyond their physical environment, social interactions and group changes can strain cows as well. Dairy cows are gregarious, and their social interactions lead to the establishment of dominance hierarchies and bonding with other conspecifics. When a new group is introduced, animals fight to establish dominant and submissive roles. Submissive animals often have less access to food, water, and comfortable places to lay, which decreases their resilience to additional social group change. Decreased food access can cause metabolic disorders, triggering a negative cycle of further health problems. In contrast, establishing bonds with other cows, according to research from the Laboratory of Herbivore Adaptation in France, leads to stress reduction.

Farmers and researchers have studied how cows respond to environmental and individual changes. Researchers at the Wageningen Livestock Research Institute found poor animal welfare can lead to decreased milk production and loss of life due to illness. For this reason, farmers breed more resilient animals. Behavioral traits such as time spent eating and maintaining a daily routine reflect dominant and more resilient animals. Consistent patterns of variation in ear temperature is a useful measure of animals able to maintain homeostatic balance during the transition. These traits indicating resilience improve the welfare of the animal and help maintain milk production.

A single dairy product can derive from so many lives. Creameries combine milk from a multitude of farms and cows, meaning each product contains milk potentially produced by thousands of animals. The next time you’re enjoying a cheesy treat, take a moment to appreciate these gentle giants, each who has experienced transition and conveyed resilience as they become dairy cows, bond with others in their group, and produce calves for the next generation of cows.

PHOTO BY SHUTTERSTOCK

# Inspiration from one who lives in a pineapple under the sea

BY ANNABELLE MATHERS, CIVIL ENGINEERING, 2022

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

**N**eck craning, you gaze up at an impossibly tall building, its windows shimmery and surreal against the bright sky. You spin around, eyes focused upward, and realize that all the buildings around you are taller than ever before achieved by structural engineers. What you perceive as a curious weightlessness to the building contrasts the sturdiness promised by a towering network of beams and columns. Funny enough, the inspiration for these ultra-efficient skyscrapers, imagined by engineers and architects around the world, comes not from the terrestrial nor the aerial realm that the buildings occupy, but from the dark depths of the ocean floor. As experts seek inspiration for stronger, more efficient structural designs, they often turn to nature, and newly realized qualities of glass sea sponges have inspired a re-envisioning of structural potential.

“Lattices and an array of criss-crossing support systems form this skeleton and are startlingly comparable to man-made structures.”

Known as Venus' Flower Basket (*Euplectella aspergillum*), this particular species of deep sea sponge belongs to the hexactinellid group of sponges, characterized by a silica-based, glass skeleton. The skeleton is composed of lattices and an array of criss-crossing support systems, which are startlingly comparable to man-made structures. In order to withstand the immense pressures experienced on the ocean floor, the skeleton has evolved over millions of years to have a high strength-to-weight ratio and efficient force distribution through skeletal symmetry.

Experts across universities continue to collaboratively analyze the structural strength of glass sponges, with a significant portion of the research centering around the Wyss Institute for Biologically Inspired Engineering and John A. Paulson School of Engineering and Applied Sciences (SEAS) at Harvard University. Among many others, Joanna Aizenberg, PhD, James Weaver, PhD, and Matheus Fernandes, PhD have tested how the skeletal configurations behave under loading conditions, particularly evaluating buckle and fracture.

Such tests focus on the main load-bearing members of the skeleton, which are column-like and beam-like connectors known as spicules. Diagonal spicules interlace between vertical and horizontal

spicules, creating a square lattice or multilayered checkerboard of skeletal

members. This lattice forms the contours of the often tubular or rounded sponges. As chronicled in *Nature Materials*, researchers modeled and compared the diagonally reinforced sponge lattice to traditional lattices (both diagonally reinforced and non-reinforced) used in man-made structures. The models had identical total mass and, as such, the experts discovered that the lattice of spicules was 20 percent stronger without the addition of extra material. Additional bracing, connection material, and stronger but heavier member material might increase the overall strength of a system, but they may also increase the weight and cost. The strength-to-weight ratio of the sponges is higher than conventional structural systems, requiring the greatest force to buckle the lattice but remaining remarkably light and theoretically cost-effective.

Not only does the configuration of the spicules increase the efficiency of the structural design, but the actual composition and internal structure of spicules increases the strength of each member. Concentric layers of silica and silica cement form individual spicules and become progressively thinner toward the outer radius of each spicule. The thinner outer layers are more breakable and experience cracking first and more easily than inner layers, thus taking the brunt of any damage and limiting cracks from advancing to the core of the spicule. In this way, the expendable nature of the outer layers increases the strength of the spicule. Although today's conventional steel and concrete beams and columns may not yet be able to mimic this exact internal structure, extrapolated lessons on forces, cracking, and increased resilience still intrigue experts.

It is important to note that the overall and internal structures of glass sponges' spicules do not only apply to the construction of buildings, but to those of bridges, consumer products, aerospace apparatuses, and many more. Engineers, designers, and architects, among many others, are often seeking something lighter, stronger, and sleeker but still long-lasting and durable. Sea sponges may not seem like the most glamorous inspiration, but their quiet efficiency and resilience through countless millennia and environmental factors demonstrate structural proficiency we have yet to quite achieve.

*Journal of the Royal Society Interface* (2021). DOI: 10.1098/rsif.2021.0559  
*Life Sciences* (2016). DOI: 10.1016/B978-0-12-800049-6.00270-5  
*Nature Materials* (2020). DOI: 10.1038/s41563-020-0798-1

PHOTO BY SHUTTERSTOCK



# OPINION: WHY NORTHEASTERN SHOULD BECOME CLIMATE RESILIENT

**A**ccording to the United Nations Intergovernmental Panel on Climate Change, “without ... a sharp decline in greenhouse gas emissions by 2030, global warming will surpass 1.5 [degrees Celsius] in the following decades, leading to irreversible loss of the most fragile ecosystems, and crisis after crisis for the most vulnerable people and societies.” As 2030 fast approaches with a lack of adequate action by many top polluters, humans are faced with the increasing likelihood of the dire effects of a warming planet. In order to sufficiently prepare for those effects, countries, businesses, and institutions like Northeastern will have to act now to become climate resilient.

Climate resilience involves planning to minimize the impact of increased temperatures, rising sea levels, and higher intensity storms that are expected to occur as a result of climate change. In practice, climate resilience is highly dependent on the needs of the specific community. In California, where increased wildfire intensity is a major threat because of climate change, energy companies are outlining wildfire mitigation plans to reduce the risk of wildfires ignited by their infrastructure. Cities such as Baltimore and Minneapolis have implemented “Resilience Hubs,” which provide resources such as food and shelter to residents during and after hazard events as well as act as community centers during non-crisis times.

What does climate resilience mean for institutions like Northeastern? A 2018 study from the *International Journal of Sustainability in Higher Education* found that, while many universities have plans in place for reducing their emissions, very few have plans to prepare for the effects of the warming that is already inevitable. The study found that the reasons behind the lack of climate resilience planning from universities primarily stemmed from the uncertainty around climate scenarios and the complexity of potential climate impacts.

However, since the 2018 study, more universities have taken steps to prepare

BY MAYA KRAUSE, ENVIRONMENTAL SCIENCE, 2022

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

their campuses and surrounding communities for the effects of climate change. Harvard University, for example, is in the process of constructing a storm drain in Allston to help prepare for increased flooding in the neighborhood. Many institutions that have taken steps to be more climate resilient have recognized that, in addition to the social good, preparing their campuses for climate change is in their best interests to reduce damage to university property and ensure safety for their students. These actions can also demonstrate the intent of the university to act as a role model by demonstrating a forward-thinking approach and taking concrete actions to address potential harms.

“While many universities have plans in place for reducing their emissions, very few have plans to prepare for the effects of the warming that is already inevitable.”

Northeastern has committed to reducing emissions by 80 percent by 2050, according to the university’s most recent climate action plan from 2010. But the 2010 plan lacks steps towards climate resilience. Northeastern’s Facilities department has taken some actions towards preparing campus buildings for increased temperatures, such as increasing the plant cover on campus and creating reflective roofs on 39 percent of buildings. However,

Northeastern can go much further to adequately prepare the campus and surrounding communities for other risks such as sea level rise and worsening storms.

This year, Northeastern’s Facilities department is leading a community-driven initiative to produce a recommendation to the administration for a new climate plan. While the expressed intention of the plan is to make Northeastern carbon free, in order for the plan to truly benefit the Northeastern community, it should conduct a risk assessment and incorporate climate resilience methods to prepare the campus and surrounding neighborhoods for the impending effects of climate change.

*International Journal of Sustainability in Higher Education* (2018). DOI: 10.1108/IJSHE-02-2018-0028

PHOTO BY SHUTTERSTOCK



# The materialism of climate change:

## Exploring ancient philosophy's impact on climate change

BY ABIGAIL POTTER, PHYSICS &amp; PHILOSOPHY, 2023

**C**limate change is one of the biggest health crises humanity faces, according to the World Health Organization. It is all-consuming, impacting almost every aspect of our daily lives. However, we very rarely look beyond greenhouse gas burning to the root cause of how climate change became what we know it as today: philosophy. Similar to how if you continuously click the first link on any Wikipedia page, 97 percent of the time (as of 2016), you will end up on the "Philosophy" page, the root cause of climate change can be traced back to ancient greek philosophy.

In ancient times, people commonly believed that everything was sacred. Everything in the world, plants, people, rivers, had a perceived life force; there was no divide between the spiritual and the material. However, once the philosophy "atomism" was introduced, everything began to change.

The philosopher Leucippus proposed the idea that matter is made up of atoms. Very little of his written work remains, however, his idea of "atoms" was carried on and launched into widespread recognition by his student, Democritus. The theory he popularized was called "atomism," based on the Greek word for indivisible, "atomos." Atomism declared that everything in the world was made up of very small, invisible, indestructible particles known as "atoms." Every type of object has its own atoms, varying by their size, shape, speed, and rotation, and — because the atoms are indestructible — their atoms would either temporarily hook together to form objects or bounce off each other into an infinite void. Centuries later, scientists such as Rutherford and Bohr would go on to make their own models of atoms, supporting the theory. People then adopted the term "atom" to refer to the basic unit of matter. However, this had one key consequence: it created the idea that the world is purely matter.

Atomism introduced the idea that there was a divide. It rejected the idea of spirituality or a divine plan. With atomism in place, things were temporal and there were no gods or spirits to anger by destroying the land.

As time went on, this idea became embedded into Western thought. With the new ideology in place and at the root of morality, humanity began exploiting the planet. As the idea proved more and more true as scientists continued to improve their theories on atoms, humans became more focused on other material things. We made mass advancements, improving our ideas in the Renaissance and our technology in the Industrial Revolution, with little regard for possible consequences.

The consequences of materialism are becoming more intrusive. Climate change is already known to have massive effects on the weather: increasing flood risks, intensifying drought, exasperating heat waves. Recent research has revealed that these changes are contributing to a decline in human health. The heat is becoming more deadly, increasing extreme heat mortality rates, causing pregnancy complications, and impacting our soil. Being pregnant during heat waves increases the likelihood of going into preterm labor and having a stillbirth. Drier soil can cause malnutrition and crops withering. Changing temperatures and humidity levels can create better habitats for disease-carrying insects, such as mosquitos and ticks.

In a world focused on fast fashion and buying the newest piece of technology, the effects of materialism appear to be set in stone. However, while philosophy seeks to answer questions about the world we live in, it also seeks to answer questions about the lives we lead. Every philosopher, ancient to modern, has had at least one of two questions at the root of every theory: "What is the world?" and "What is a good person?" Atomism is a fast answer to the question of the world, but it has overshadowed the question of a good person. Perhaps a solution to climate change begins with that. After all, small individual beliefs can quickly extend to societal or cultural beliefs, changing the way humans function as a collective.

DESIGN BY PARKER HITT, BIOLOGY, 2024  
PHOTO BY SHUTTERSTOCK



# An exploration of crop diversity

## The importance of biodiverse agriculture

BY TENZING BRIGGS, ENGLISH, 2022

DESIGN BY KAI GRAVEL-PUCILLO, PSYCHOLOGY, 2022

**H**umans have made many lasting, devastating changes to the world in which we live, but biodiversity loss has been one of the main changes we have wrought upon the planet. In the world of agriculture, there has also been a loss of biodiversity in the specific species of crops grown to feed a rapidly growing world population. However, this loss of diversity has an extra layer of complexity, because, unlike most ecosystems, the agricultural one is mired in arguably one of the most powerful forces across modern human societies: capitalism.



In the 1960s, the global market was developing for cash crops with universal market demand, such as wheat, maize, rice, and other grains. Agricultural initiatives focused on “high yield variety” seeds, which increase crop yields, but require large amounts of fertilizer and irrigation. Combined with trends towards which are now considered modern methods of planting and harvesting, such as industrial harvesting equipment and pesticide use, the agricultural world developed more and more monoculture, which is the cultivation of a single species of crop for a given area. This was compounded by increasingly competitive economic markets, which favored large grain companies that could run huge operations over small-time, multi-crop farmers.



Monocultures are a problem created by the market as well as a potential problem for the market itself. With a decrease in crop biodiversity, the agroecological system is weakened to the possibility of disease; all it would take is the advent of a disease especially effective against the primary, or in some cases only, species of a certain crop, and it could all be devastated. On top of this, because monoculture crops often rely upon large amounts of pesticides and fertilizer, if one seeks to achieve a circular economy (where all products are consumed and cycled around for as long as possible so as to save costs and resources), these crops are, ultimately, not environmentally nor economically sustainable.

What might be the positives of crop diversity beyond avoiding disease wiping out a whole crop? A 2008 *Ecosystems* study by Smith et al. researched how corn, soybean, and winter wheat crops of diverse species fared compared to monocultures. They also varied the number of “cover crops”—legumes or small grain species planted in tandem with the corn, soybean, or wheat fields. They found that, in contrast to research focusing on industrial monoculture yields, all three crops had *more* yield than monocultures, even more notable for the fact that they used no fertilizers or pesticides for the three-year study time so that diversity was the only variable. Measuring the amount of inorganic nitrogen at harvest, levels were greater with the most diverse primary and cover crops, likely because legumes cause an increase of nitrogen in the soil.



This study shows a few things about the benefits of genetic diversity in an agricultural crop. First, in the absence of modern pesticides or fertilizers, agriculture benefits from a complete ecosystem, not isolated monocultures. Second, with more research into unappreciated agricultural practices like crop rotations or usage of cover crops, humans might better understand the ecosystems in which they live, so as to create a safer, more effective environment with which to coexist.



As humans are rapidly discovering, we must begin to question the norms of the market economy because many things which are beneficial to the economy are toxic to the environment. Such might be the case with our reliance on only a few species of crops. If we want a sustainable agricultural industry, it is important that, with research, we find those farming practices that are *actually* stable, and it appears likely that a diverse agro-ecological system is one of them.



*Ecosystems* (2018). DOI: 10.1007/s10021-008-9124-5  
*Global Change Biology* (2020). DOI: 10.1111/gcb.15396  
*Journal of Hunger & Environmental Nutrition* (2006). DOI: 10.1300/J477v01n02\_07  
*Scientific Reports* (2021). DOI: 10.1038/s41598-021-99728-5

# FOLIAGE OF THE FUTURE

How Harvard's new tech aims to prevent a global food shortage

ARTICLE AND DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

**W**hat if humans created a leaf better at utilizing sunlight than plants? And what if that leaf was engineered with such efficiency that it could feed the future world? Researchers at Harvard University have created and improved their "bionic leaf" to do just that and are now ready to bring this new technology into the world.

The planet is experiencing an exponential change in its population as time goes on. With population growth, the sustainability of available resources is decreasing. Specifically, experts anticipate a drastic food shortage approaching within the next 100 years. Unfortunately, current efforts to combat this food shortage are not increasing the world's supply at a sufficient rate. Further, current methods rely heavily on unsustainable resources, such as fossil fuels, and interconnected transport networks for supply distribution, leaving many places expected to experience large food shortages isolated.

The scientists at Harvard have redefined how the global community shows resilience against a changing planet Earth. By creating the bionic leaf to combat food shortage and sustainability issues, they have effectively used nature as a blueprint for creation, a method that may be the key to protecting our future.

Plants are incredibly sustainable in that they can harness energy from the sun through a process known as photosynthesis. Unfortunately, the multistep nature of this process decreases the net amount of energy produced by the plant. The original

bionic leaf was created to mimic this process, but with a higher yield. The technology, developed by Daniel Nocera, Pamela Silver, and others, produced hydrogen through the splitting of water molecules. The hydrogen would be consumed by bacteria that leads to the production of isopropanol fuel; however, the catalyst used to make hydrogen also produced an oxygen species that attacked and destroyed the bacteria's DNA unless the system was run at a very high voltage. This contradicted the original purpose of higher energy production.

“

Using self-enriching soil, plants can produce flowers in larger sizes and frequencies, which then produce the fruits and vegetables that feed the population.”

The newest bionic leaf developed by the researchers, bionic leaf 2.0, uses a new cobalt-phosphorus alloy catalyst designed by the lab. The new catalyst has two components — the alloy and the anode — that drive two different reactions. Together, these reactions split water to produce hydrogen without damaging the bacteria, allowing the reaction to occur at a significantly lower voltage. The bionic leaf can now transform solar energy with 10 times the efficiency of the fastest-growing plants.

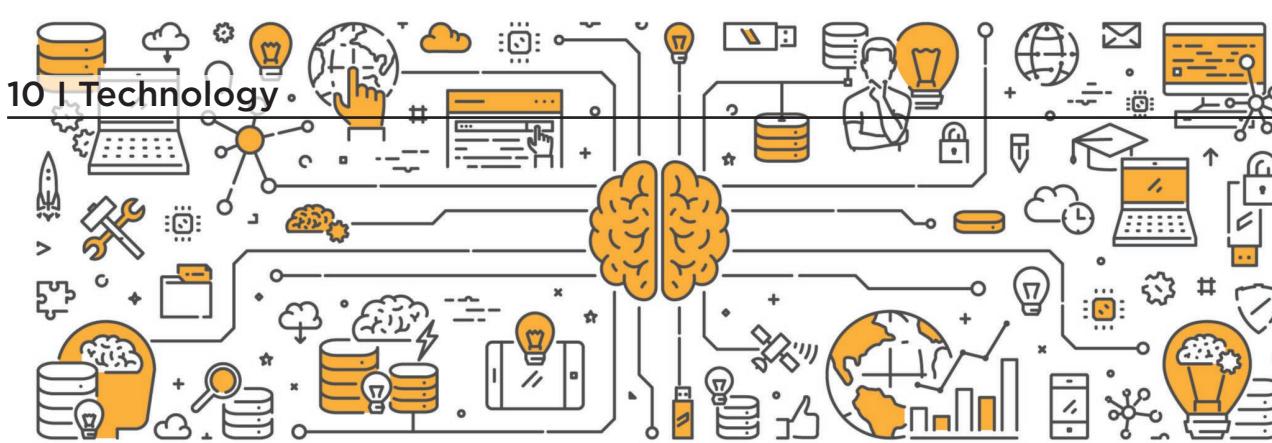
Innovation of the new bionic leaf did not stop there. Scientists combined this technology with a new, reengineered bacteria, creating a hybrid system. The scientists observed that the hybrid system was able to store over half of the original energy as products of CO<sub>2</sub> fixation. Further, it was able to produce multiple different types of liquid fuel. The production of ammonia and phosphorus by the bacteria also increases the efficiency of the system. Ammonia and phosphorus improve fertilizer and promote plant growth. Using self-enriching soil, plants can produce flowers in larger sizes and frequencies, which then produce the fruits and vegetables that feed the population.

Postdoctoral fellow Kelsey Sakimoto of the Harvard University Center for the Environment is working with Nocera to create new methods of fertilizer distribution to farmers and farms beyond the reach of industrial agriculture networks. His goal is that when this technology does become readily available it can have a greater reach. He believes scientists could implement the bionic leaf by either letting the bacteria reproduce naturally and using the liquid byproduct as a spray fertilizer or by reengineering the leaf with a new compound to use it as a normal ammonium chemical fertilizer.

Currently, Sakimoto is collecting grants and collaborating with engineers in India to upscale the production of his technology and use it in small rural and remote farms that feed their surrounding communities.

*Science* (2016). DOI: 10.1126/science.aaf5039

PHOTO BY PIXABAY



# Spatio-temporal information and applications of spiking neural networks

BY DINA ZEMLYANKER, DATA SCIENCE & BIOCHEMISTRY, 2024  
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

The goal of artificial intelligence (AI) is to teach a computer how to think. So, it's unsurprising that many of the strides made in AI and specifically machine learning — a subset of AI focused on using large collections of data to teach a computer rules through discovering patterns — have been based on biological knowledge. Artificial neural networks (ANN), a type of machine learning model, are designed around how neurons communicate. However, they are only loosely based on the brain and stray from biological truth. There is another type of neural network called Spiking Neural Networks (SNNs) that follow the architecture of the brain much more closely, making them superior.

In the brain, information is conveyed through neuron-to-neuron communication in the form of discrete action potentials or electrical spikes (distinct voltage changes in either direction). The signals pass through synapses — tiny spaces between the axons and dendrites of adjacent neurons. The spikes encode information from external and internal stimuli. The type of stimuli and area of the brain determines the type of temporal patterns of spikes, which can be regular, irregular, or even intricate.

In an ANN, the modeled neurons do not account for how signals are passed in discrete events and do not usually consider proximity when determining connectedness between neurons. SNNs differ because they do pass information through the modeled neurons with discrete signals and only nearby neurons are connected.

SNNs offer two main advantages: increased efficiency and a greater ability to utilize spatio-temporal data, information about space and time. Because of the structure of SNNs, the network processes separate chunks of

input independently. Even though the chunks are processed independently, the order that they come in and their relation to each other timewise is not lost because the processing occurs over time, resulting in a significant gain in temporal information. The network can account for the potential temporal patterns of spikes. ANNs do not account for temporal patterns because information is inputted continuously, so they disregard the patterns of when the information appears. Networks such as recurrent neural networks account for time dependency; however, information from

Spiking Neural Networks [follow] the architecture of the brain much more closely, making them superior."

previous inputs or times must be saved and used multiple times, increasing complexity. In an SNN, time is accounted for automatically, effectively saving a lot of complexity and processing power. Additionally, SNNs severely decrease the amount of redundant information processed. The discretized spike sequences and less connected networks prevent redundant updates as new information is only passed to modeled neurons when there is a distinct change rather than a continuous one.

The advanced use of spatio-temporal data extends to using SNNs as accurate models of brain activity. In a study from a researcher from University of Moratuwa, Kumarasinghe, a Brain-Inspired SNN (BI-SNN) was shown to successfully predict continuous muscle activity and kinematics of upper-limbs. They recorded muscle activity of the

right arm with sensors that accounted for x, y, and z positions; azimuth; elevation; and roll angles. Additionally, they used an electroencephalography (EEG) to detect electrical activity in the brain while each person picked up and put down a small object.

Both the muscle activity and EEG information were then passed through spike sequence encoding algorithms based on thresholds. The EEG information served as the input as it is the electrical information of neuronal communication, and the muscle activity served as the expected output as this is the result of the neuronal communication. The BI-SNN clustered the spike activity based on anatomical location and learned the spike-time rules to create spatio-temporal associations with distinct brain regions. This was achieved through building the BI-SNN with Spike Pattern Association Neurons (SPAN), which are neuron models that emit spikes at desired times. The goal of the BI-SNN was to predict the onset and trajectory of movements, given EEG signals. The results of the BI-SNN were evaluated based on the similarities between predicted and actual values of 29 different motor signals, such as elevation of thumb and wrist and roll of index finger. The majority of these signals had similarity scores of around 0.6, meaning that the signals predicted by the BI-SNN were similar to true motor signals.

The ability to more closely recreate the true architecture of the brain gives SNNs an increased efficiency that has the potential to vastly impact the abilities of artificial intelligence. These are vast advantages over ANNs and other previously widely used neural networks. Although they still have their drawbacks, mostly in training complexity, they open the doors to solving much more complex problems.

PHOTO BY SHUTTERSTOCK

# How to fix debris from taking up too much space—in space

BY KYLE KIRSHEN, CHEMISTRY, 2025

DESIGN BY KAI GRAVEL-PUCILLO, PSYCHOLOGY, 2022

**H**umans produce a lot of trash. The Great Pacific Garbage Patch, for example, has accumulated plastic and other kinds of waste from all over the world's oceans. While the problem of polluting the seas is fairly well known, another territory is also feeling the effects of human interference: space. It is estimated that there are over 27,000 large pieces of debris floating close to the Earth, posing a threat to functioning satellites and government spacecraft. It can not be solved as simply as the problems that exist on Earth though, and the debris, both small and large, pose a deadly hazard.

According to NASA, debris in the Earth's low orbit can reach speeds of approximately 15,700 mph, making space travel at any capacity a large risk. In 2019, there was an incident in which India blew up a dead satellite and created thousands of large pieces of debris and shrapnel that threatened the International Space Station. So what exactly is being done to combat these issues and prevent the waste problem that is happening on Earth?

Right now, scientists are implementing new technologies to help limit the amount of space junk. The recently-developed End-of-Life Services by Astroscale is a spacecraft addition that attaches to compatible docking plates and pushes dead satellites towards the Earth's atmosphere to burn up. The only issue with this new technology is that it can only be attached to satellites before they are launched; it does not solve the current problem. Thankfully, scientists thought of the simplest way to solve the problem of debris, through the use of magnets. The only blatant complication is that space debris, with the majority consisting of aluminum, contains little magnetic material.

However, in an innovative new study, Lan N. Pham and collaborators discovered that the physics concept of magnetic induction may hold the key. In this phenomenon, a strong enough magnetic field can turn any conductive material, like aluminum, into a magnet by inducing electrical current loops through the metal

from proximity. These loops, or eddy currents, can then generate a temporary magnetic field that opposes the original, thereby decreasing the speed of the object. Referred to as a "non-contact manipulation method," the induction acts similarly to a science-fiction movie's depiction of a UFO tractor beam. While this 3D manipulation is normally limited to a single direction, the fields of the electromagnets can be purposefully arranged on any axis. This breakthrough has major implications: the speed and orientation of debris can be controlled, limiting the hazards of these objects. On top of that, this magnetic manipulation technology promises to safely disintegrate debris in the Earth's atmosphere.

However, this breakthrough is not without its problems. Scientists cannot easily test the use of electromagnets in this capacity without simulating the effects of space. Because weight is certainly an aspect of life on Earth, it makes the minimal force of attraction much more difficult to accurately measure without being in orbit. So until that is tested further and studied, this method of electromagnetic inductions is only theoretical — but scientifically likely very possible. Additionally, the strength and distance of the magnetic attraction are still factors that scientists are trying to solve. The study found that as of right now, the induction of non-magnetic objects currently can only be done within the minimal range of 5 to 10 centimeters before losing strength. The functional hope, however, is that the magnets will be used from large distances without having to be in any danger of any harmful collision.

So, while this new type of technology is likely plausible, more testing is needed to ensure that it can be applied without risk and with minimal error. When completed, it could pave the way for a new type of thinking and design into how human waste is properly disposed of and ultimately removed before causing more harm to the environment and ourselves.

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PHOTOS BY SHUTTERSTOCK

# Language death and the decline of minority cultures

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

DESIGN BY CARINA HALCOMB, DESIGN, 2024

**W**ith 574 recognized tribes in the United States alone, the Indigenous people of North America have a diverse population, diverse culture, and a diversity of languages. At the turn of the twenty-first century, there were approximately 210 Native American languages still spoken in North America, according to linguist Michael Krauss in his paper "Status of Native American Language Endangerment." With such a large swath of languages, one may expect to have met at least a few speakers in their lifetime, but this is seldom the case.

This raises the question — why are Native American languages so rare when they are so numerous? The obvious answer is the fact that the U.S. Indigenous population is tiny, making up approximately one percent of the general population, due in no small part to colonization and genocide, but the truth stretches yet further.

Indeed, following Christopher Columbus' landing in the Caribbean, the local Arawak people perished under subjugation and disease, taking with them their languages. In many other cases, an imperialist regime would attempt to "civilize" native people by forcing them to learn the ruling class' language.

In the United States, this philosophy took the form of the infamous American Indian residential schools. Under the onus that "no unity or community of feeling can be established among different peoples unless they are brought to speak the same language," the Department of the Interior Bureau of Indian Affairs forced Native American children from their homes and into boarding schools, where they were brutally assimilated into "American" civilization.

Indigenous children who attempted to hold on to their tribal languages were abused and publicly humiliated; children

found speaking their native tongue were beaten by teachers and ostracized by peers to avoid the same fate, forcing these children to hide their true cultural identities. As bilingualism scholar and educator James Crawford points out, due to this systematic torture, many victims of these schools became reluctant to teach their children their languages, remembering the horrors and shame of the boarding schools, even decades after they were closed.

This loss of learning has had cascading effects, members of the Arikara Language Project explain. While larger tribes like the Navajo Nation retained a stable population of speakers, ones like the

Category E languages are "moribund," facing imminent extinction. Today, over 70 percent of North American Indigenous languages are Category C or D, with that number growing larger by the decade.

Today, the number of spoken Native American languages hovers around 150, lessening by the decade, clinging to a dedicated speaker base of tribal elders keeping the flame of their culture alive. In response, several tribes have started revitalization programs, bringing these elders to schools in an attempt to propagate their local languages. However, as these elders become unable to continue teaching due to advancing age, qualified educators become increasingly difficult to find. Written records, no matter how well-made, can never supplant the traditional methods of oral teaching. Thus, the loss of these elders would spell the end of the language.

What is more, this fate is not unique to Native Americans — over half the world's 6000 languages are Category B or higher. As English, Spanish, Chinese, and the few dozen other major world languages grow more dominant, Indigenous peoples all over the world lose their languages. Without drastic action, these languages will be lost by the century's end.

After surviving 15,000 years on the continent of North America and enduring 500 years of cultural imperialism, nearly 150 languages now face extinction due to the crimes of generations long since passed. The diverse languages that once populated the continent may fall permanently silent.



Arikara of the Three Affiliated Tribes and the Dakota lost generations of learners, with younger generations moving away from the reservations without learning languages from their elders.

To describe this phenomenon, Krauss, in that same paper, devised a scale to describe the "viability" of Indigenous languages. Category A languages, such as Navajo and Central Yupik, are those languages still taught to the current generation of children in the traditional manner for the area. Category B and C languages are those only known and utilized by the parents and grandparents of the current generation, respectively. Category D languages are those spoken only by the advanced elderly, and

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# BUSINESSES AND RESEARCH RESILIENCE DURING COVID-19

BY KYLE JONES, BIOCHEMISTRY, 2024

**F**rom social distancing guidelines to stay-at-home orders to government-mandated shutdowns, the way people partake in society has changed dramatically during the COVID-19 pandemic. To stay afloat, businesses have adapted responses to these changes and have greatly benefitted themselves and society.

During pandemics, it is expected that people will hold onto their assets rather than spend, and this situation has been no different for COVID-19. With stay-at-home mandates and business closures, the economy saw a deserted market void of eager shoppers. The tourism industry shattered and saw major losses on income, and it is likely that some of these areas will never recover to the same level they were before the pandemic. According to the *Journal of Business Research*, the majority of 2020 saw 80 percent of hotel rooms empty, and airlines had to lay off 90 percent of their employees to compensate for such losses. Closer to home, businesses concerned with nonessential services were forced to close or go to an online format. According to an article by the Century Foundation's *Journal of Economy & Jobs*, one in four American workers had to resort to unemployment checks to maintain income. Even the large conglomerates like J. Crew, JCPenny, and Sears were placed under suffocating financial pressure due to closures and lack of demand. On a larger scale, countries that were supported by larger economies for trading goods may also slip back into poverty-stricken states due to decreases in trade with outside countries and customer demand for goods.

To compensate for the decrease in demand and shutdowns, businesses and organizations had to shift their models. Most commonly switching to an online format, this was the basis of online learning for educational institutions around the world. The endeavor often involved the implementation of Zoom Video Communications, which saw a 600 percent increase in stock shares and a 355 percent increase in revenue from just July to September of 2020. Without online video, Zoom could be seen as the critical tool in maintaining a normal life. Outside of going digital, companies switched to "grab-and-go"-based models of operating. Although rising in popularity before, online ordering increased dramatically with the demand for social distancing, and most restaurants limited their services to takeout only. Delivery services saw large gains, including DoorDash tripling its revenue in the first quarter of 2021 compared to the same time

in 2020. Therapy, which became even more vital with increased isolation, went online and helped maintain people's mental health. For example, Olivia, a Spanish startup, switched to an online format to provide its personalized healthcare and therapy to its customers.

Outside of changing their delivery methods, many companies altered their technology to make health products to help society. Dyson innovated their own ventilator to compensate for the shortages in hospitals. The U.K. government ordered 10,000 of these ventilators, and the company pledged to donate 5,000 to international organizations. Absolut Vodka, Tito's Vodka, and Jameson Whiskey used their distilleries to make hand sanitizer. Brooks Brothers and Hanes had some factories stop producing clothing in favor of gowns and masks, and Canada Goose started producing scrubs and gowns for hospitals in Canada. Even Louis Vuitton used its perfume lines to make (some very fancy) hand sanitizer for French health officials.

In science, essentially any research lab that could study SARS-CoV-2 switched its focus to understanding the virus. According to virologist Julie Pfeiffer and virologist-physician Terence Dermody, there were 1,400 results in an online archive for a search of "SARS-CoV-2" and the surface protein "ACE2." They found considerable overlap between the research topics, such as how hundreds of papers delved into the inhibition of viral entry into cells. They also point to concerns of not exposing new researchers to other research areas, as the emphasis on COVID-19 caused labs to lose focus of their original projects. Although the combined effort helped quicken the creation of vaccines, there are drawbacks, and our progress in other areas of science has diminished. Future efforts may create formats for labs to more easily work together to obtain effective data and limit repetition amongst groups.

Almost two years old, the COVID-19 pandemic has had unmistakable effects on the way society operates. These effects have led to broad changes in the way businesses and consumers operate, and it is likely that some of these changes are here to last for years to come.

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PHOTO BY SHUTTERSTOCK

# Snapping back

## The power of resilience in children

BY HIBA HUSSAIN, BIOLOGY, 2024

**S**pider webs are known for their amazing tensile strength and have been calculated to be five times stronger than steel. Despite this strength, they also have an incredible amount of elasticity: the web strands snap back like a rubber band, even after a seemingly long stretch. Surprisingly, the brains of children work similarly. After experiencing challenges or traumatic experiences, children become resilient over time and can lead productive lives in the future.

In neuroscience, resilience is defined as one's ability to achieve a successful outcome in the face of adversity. The development of resilience in children is especially important to study, as their plastic psychological growth puts them in a unique position to learn and adapt to challenges faced early on in their lives.

For years, scientists have searched for specific markers of resilience in children but have failed to come across a catch-all that directly leads to the development of this trait. Instead, studies have found that a combination of polygenic and environmental conditions is responsible for helping children overcome challenging situations.

**"In neuroscience, resilience is defined as one's ability to achieve a successful outcome in the face of adversity."**

These changes can first be noted at the physiological level. A study of MRI images was conducted by Rajendra Morey and his team at Duke University. These images were collected from victims of child maltreatment — children who have experienced emotional or physical abuse — and separated into two groups: victims with mental health disorders (due to maltreatment) and those without mental health disorders.

Upon observing these images, scientists noted differences in the volumes of the prefrontal cortex (PFC), a region of the brain responsible for the regulation of emotions and the severity of stress responses. The group of children without mental health disorders displayed larger PFC volumes, which was correlated with better performance in school, supportive friendships, and emotional health. On the other hand, the group with mental health disorders had smaller PFCs, which was associated with delays in the formation of the superior frontal gyrus. This structure is responsible for high-cognition abilities and short-term memory storage. Due to the delay, children exhibited decreased functioning and were less likely to complete middle and high school on time.

Children who have experienced challenges also have better-adapted stress responses. In a study by Dr. Johannes Dahmen at University College London, MRI images of maltreatment victims were analyzed. Astoundingly, these individuals had smaller areas of the hippocampus that were sensitive to stress in comparison to their age-matched, normal counterparts. As a result of their smaller hippocampi, the victims produced smaller amounts of baseline cortisol, leading to less intense stress responses when faced with new challenges.

Social factors are also vital for the formation of resilience in children. Firstly, children who have a support system (via strong relationships with family and friends) tend to be less afraid to take on new experiences and develop grit, according to a 2006 article published in *Urban Education*. Since they are aware they have a support system, they are allowed and encouraged to make mistakes without consequences of rejection.

Social status and integration are also fundamental to the development of resilience. A study led by Keely Muscatell and published in *Social Cognitive and Affective Neuroscience* found that children of a higher social status — defined as those who had an easier time making friends — had better-adapted stress responses in their PFC after being exposed to a simulation of peer rejection. In comparison, those of a lower perceived social status — or had a harder time making friends — had higher stress levels after experiencing rejection. There was significantly more activity in the PFC and higher levels of cortisol and pro-inflammatory cytokines in the children's blood samples. Children willing to reach out tended to be more resilient to such rejection, while those who kept to themselves were less resilient; these studies on social factors help reveal important connections between resilience and social integration when peer rejection was involved.

Children who can develop resilience early on are likely more apt to handle the challenges of adulthood. As college students facing assignments, exams, and extracurriculars every semester, we need to remember our resilience. We are expected to balance our work and perform well, but without our ability to take on challenging times, it is easy to burn out and lose motivation.

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# The Ethotest: A new screening process for service dogs

BY MICHELLE WILFRED, COMPUTER SCIENCE & BIOLOGY, 2021

DESIGN BY SOPHIE PATE, BEHAVIORAL NEUROSCIENCE, 2024



**T**he saying goes, “a dog is a man’s best friend.” This has been proven true; they were the first domesticated animals and have been by our side for thousands of years. Today, service dogs, in particular, are carefully selected and trained in highly specialized areas to assist people emotionally and physically. Many of these dogs were chosen and trained as puppies to work in complex environments. However, many shelter dogs don’t have those opportunities. These dogs are overlooked because they have unidentifiable backgrounds or haven’t been bred to do a specific job. That begs the question: what qualities make a dog fit for training as a service animal, and how can we screen for such qualities in shelter dogs?

To answer this question, Pia Lucidi, a professor of domestic animal physiology and behavior, has created a model that translates a shelter dog’s traits into those of a talented service dog or pet. This model, called the Ethotest, is beneficial for shelter dogs who are unknown breeds and have unknown backgrounds. According to her research paper in *Applied Animal Behavior Science*, this test “is able to select dogs capable of creating a special bond with humans and able to work anywhere and with any human partner or team.” She set up an experiment with 23 dogs—many of them mixed-breeds—and tested them in a three-step evaluation process.

Test A, the first step, checks for aggressiveness and dominant temperament. It tests a dog’s aggression toward both people and other dogs. The test administrator pulls ears, raises hind legs, and turns the dogs onto their back. If the dogs react aggressively, they score a zero on that section. Those who pass this test are more friendly and docile.

Test B, the second step, filters for the traits of initiation, sociability, and fear. The test administrator goes near

a dog enclosed behind a fence. The dogs earn points if they don’t jump and only go near the fence. If the dog does nothing or jumps on their hind legs, they score a negative one or zero, respectively. To test sociability, the test administrator stands silently, calls the dog’s name, invites the dog with open arms, and brings in a new dog. During each step of these actions, the first dog is observed for a wagging tail and an easy demeanor. The final part checks for fear: dropping an object noisily on the ground. If the dog shows fear, runs away, or barks, it loses points. If the dog is quiet but alert, it earns points.

Test C is the final part of the test and measures the dog’s learning capability. Only if the dog passed the cutoff for test B will it be tested for this part. The dog is taught new, basic skills, such as walking on a leash, climbing stairs, or sitting. The dog earns points by consistently learning these skills and performing them without hesitation, nervousness, or disobedience.

The results were confirmed by the Delta Society standards, which is involved in many assisted animal therapy programs. When comparing the results of the Ethotest to the Delta Society method, they were almost the same. However, the Delta Society focuses on the relationship between the handler and the dog, while the Ethotest focuses on the dog. This emphasizes the dog’s ability to be a service animal in a variety of job placements and not just in singular roles. This test model also allows dogs with unknown backgrounds and who don’t meet the age requirement to be part of the service industry. The Ethotest can also provide shelter dogs with higher chances of being adopted, tending to be more appealing to families if they pass the test. Training shelter dogs as service animals allows dogs to have a chance at a life with purpose, compassion, and security.

# WAR! WHAT IS IT GOOD FOR? DESTROYING THE ENVIRONMENT

BY KAELEN ENCARNACION, BIOLOGY &amp; ENGLISH, 2022

PHOTO BY PIXABAY



**F**ields once green and lush, pockmarked and rife with forgotten land mines. Two cities, hundreds of thousands of lives, gone in an instant. Shrapnel in trees, poisoned air, scorched earth.

These are the devastating effects of war. Like carbon emissions, oil spills, and deforestation, most of the environmental disasters we face today are man-made. War is no exception. As our technology has significantly advanced within the past two centuries, military weaponry has also evolved and become more destructive. In World War I, we saw the creation of flamethrowers, tanks, and poison gases, such as chlorine and mustard gas. World War II led to the infamous creation of the atomic bomb. During the Vietnam War, the U.S. military used a powerful herbicide mixture called Agent Orange to destroy crops and forest cover, which later proved to cause severe health issues. While war is typically associated with a long list of casualties, the decimated land and plant and animal life often go uncounted.

The mere existence of military power damages the environment. Building and maintaining military forces consumes a vast amount of resources, ranging from common metals for production to oil for fuel. Military training disrupts landscapes and natural habitats. The use of weapons, vehicles, and aircraft can damage sensitive landscapes and biodiversity as well as create chemical and noise pollution. Detonation of explosive weapons creates large amounts of debris and rubble, contributing to soil and air pollution. Destruction of environmentally-sensitive structures such as water treatment plants or power stations can also lead to repercussions in energy loss. In militaries all around the world, surplus ammunition is disposed

of through open burning, detonation, or — historically — dumping it into the sea. On top of polluting the environment, military activities generate massive carbon emissions, worsening the climate change crisis.

Military strategies themselves often purposefully aim to destroy the environment to gain the upper hand in battle. Scorched earth policy, which involves setting fire to anything that might be used by an invading enemy

**“**Like carbon emissions, oil spills, and deforestation, most of the environmental disasters we face today are man-made. War is no exception.”

force, has roots back to the ancient Romans. A similar strategy called flooding involves destroying dams to stop enemies from advancing. Trench warfare in World War I involved digging up long systems of ditches throughout open fields on the front lines that are still evident to this day. Some troops even filled their trenches with booby-traps as they retreated for incoming enemies to find, disrupting the landscape further and allowing chemicals to seep into the soil and groundwater. During the 1991 Gulf War, the retreating Iraqi army intentionally destroyed over 600 oil wells in Kuwait, releasing a devastating, toxic mix of crude oil, noxious gas, and metals into the air and land.

After all of this destruction, how could nature possibly heal? Luckily, there have been efforts made to restore damaged landscapes and ecosystems. Since 2003, the Environmental Protection Agency and U.S. Agency for International Development have been working with the Vietnamese government to clean up remnants of Agent Orange by identifying “hot spots” of contamination, setting up containment measures such as filtration systems and sediment traps, and cleaning up the soil by superheating it. Police forces all over Europe continually monitor for any undetonated explosives left over from World War II via metal detectors and analysis of old aerial reconnaissance photos.

Even without human intervention, nature typically finds a way to heal itself over time. It has been well-documented that forested areas will gradually begin to grow back after fires as long as there are still seeds, roots, and soil. The half-life of the radiation created by an atomic bomb is incredibly short compared to the nuclear disasters of Chernobyl and Fukushima. This allowed Hiroshima and Nagasaki to rebuild and become repopulated within two years of the atomic bombings, with both of them returning to their original sizes by the mid-1950s.

Grass grows and softens the harsh lines of the trenches. People move back into cratered cities once the radiation leaves, building new homes from the rubble. The trees grow back. The air clears. The earth is green again.

This could be our future. If we learn how to take care of each other instead of resorting to armed conflict and destruction, we could still have a planet left to share.

# You have heard of forest fires, but how about forest frosts?

BY LAUREN CHRISTENSON, BEHAVIORAL NEUROSCIENCE, 2023

**F**orest fires have taken over the news. The past year has seen major wildfires on multiple continents. Climate change stands at the center of this crisis, especially in light of the United Nation's COP26 Climate Summit taking place at the end of October. Unfortunately, forest fires are not the only thing we should be worrying about. Forest freezing has also become a significant obstacle that forest ecosystems have had to overcome.

As the climate warms, freeze-thaw cycles increase. A freeze-thaw cycle occurs when the soil repeatedly undergoes periods of melting and subsequent freezing. Frequent freeze-thaw cycles damage root systems and affect the growth of trees and plants as well as microbial organisms. As the global climate temperature rises, these freeze-thaw cycles become more and more frequent.

In many places, the early arrival of spring has led to longer growing periods and seemingly great benefits for plants and forest life. However, the warmer temperatures early on mean budding plants may be exposed to temperature drops later on in the season. These unpredictable temperature fluctuations are causing harmful effects on plants in general.

“Frequent freeze-thaw cycles damage root systems and affect the growth of trees and plants as well as microbial organisms.”

A case study from the Hubbard Brook Experimental Forest in New Hampshire showcases these issues first hand. Researchers observed this northern forest ecosystem over two years to observe the effects of colder winters and warmer summers on nitrogen uptake by plants. These researchers found that freeze-thaw cycles have damaged the root systems of trees. Not only that, but the trees also had significant decreases in nitrogen uptake. Nitrogen is a necessary nutrient for these trees, and the displacement of nitrogen into the soil can have negative impacts on tree growth during the growing season.

Snowpack is a natural protector of trees in these northern forests. Snowpack occurs when layers

DESIGN BY IAN PROULX, BIOENGINEERING, 2022

of snow accumulate and remain as covering for extended periods of time. A group of researchers conducted a five-year experiment where they removed snowpack from trees in the first weeks of winter. They observed that reducing the snowpack increased soil freezing and harmed tree growth within that five-year period. The implications of this study show how the projected decreases in snowpack due to global warming may significantly impact tree growth.

Importantly, trees have their own methods for combating these harsh temperatures. A study conducted by Charrier et. al. in 2017 observed freezing dynamics in the alpine timberline, which is the highest elevation that trees can grow and withstand the cold temperatures. Upon freezing and thawing, quite complex water hydraulic changes occur within the trees. The researchers discovered that the trees exhibit physiological decreases in their stem diameters, potentially to protect themselves from greater amounts of ice buildup. The diameters went back to normal after thawing. Additionally, they noticed that bubble formation occurred following ice formation, which may be related to gas exchange. These changes are just some of the ways trees and other woody plants protect themselves from harmful drops in temperature.

To protect trees from suffering root damage, budding too early, and tissue damage, many things can be done. In personal gardens or trees around your homes, you can add excess mulch to keep the soil from freezing at fast rates and conserve soil moisture. Additionally, you can wrap small trees with burlap during the winter season to keep the moisture in the leaves. Proper winter pruning and shaking trees after heavy snow can protect smaller trees from the weight of winter precipitation.

As strides are made to combat global warming, the future protection of trees from forest freezing is looking up. For now, it is important to learn about how climate change impacts winter climate events that are often overlooked.

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PHOTO BY GUS MUELLER, MECHANICAL ENGINEERING, 2023



# FROZEN FROGS

Nature's not-so-tasty popsicles

BY LIAM O'MALLEY, BIOCHEMISTRY, 2023

**C**ardiac arrest. For most of us, it spells the end. For wood frogs, however, it's just their annual hibernation through the winter. Hibernation is usually a similar process among most species — eat as much as possible, find shelter, and live off those energy stores until the snow begins to melt. Usually, the animal spends the long months in a decreased metabolic state in which their heart rate and consumption of nutrients slow down. This is often as extreme as it gets for mammals. For frogs, however, it's a different story.

The wood frog spends its winters completely frozen still — literally. While mammals and other animals often experience varying levels of activity during winter — from experiencing basic hypothermia to gestating and giving birth while asleep — wood frogs cease to act altogether. Most remarkably, the amphibians suffer no lasting consequences come spring.

Normally, other frog species either dig deep underneath the soil frost line or find an oxygen-rich water source and remain at the surface of the mud, according to Rick Emmer, the lead keeper of The RainForest at Cleveland Metroparks Zoo, to *Scientific American*. The wood frog isn't the best digger, nor is it aquatic, which narrows its options. As temperatures begin to drop, wood frogs don't make lifestyle changes like mammals or birds. Instead, they sustain a few physiological changes. The evolutionary solution is simply to survive sitting out the cold under a few layers of leaf matter.

After winter sets in, the first major change in the frog's body occurs in the heart. A study in the *American Journal of Physiology* found that the frog's heart rate roughly doubles at the onset of freezing. Then, after about an hour of freezing temperatures, the heart rate slows continuously to a complete stop. Only after the frog has thawed for an hour does the heart resume beating. And the frog regains full physical activity after thawing.

But why does the heart rate initially increase? Normally, a heart rate increase serves to deliver more oxygen to vital organs. In this case, it is less about oxygen and more about glucose. The liver quickly converts most of its glycogen store into glucose, which is then pumped into the cells of all of the vital organs. One 2021 study published in *Cryobiology* found that in a wood frog, blood glucose levels quickly rose at least three-fold compared to control when subjected to freezing temperatures.

Glucose is important to keep in these cells, not for energy use, but rather to serve as a cryoprotectant. Glucose protects cells via two mechanisms: increasing colligative effects and water retention. The colligative property is a chemical phenomenon in which increasing the concentration of a solute (i.e. glucose) decreases the freezing point of a liquid. In this case, this helps the cells prevent the formation of ice crystals within major organs. In addition, the high concentration of solutes encourages more water to remain within the cells, again preventing them from death, according to a study published in *Comparative Biochemistry and Physiology*.

A study published in the *Journal of Experimental Biology* also found that high retention of urea within these frogs also promotes survival through freezing temperatures both by exerting colligative effects and by preventing loss of glucose from vulnerable cells. In another study published in the same journal, the researchers found that frogs also beef up their cold tolerance by producing special "antifreeze lipids," molecules that help prevent the cell membrane from solidifying at low temperatures.

"The frogs have 'solved' not only the single-organ problem but also the 'entire organ-systems' problem."

All of these physiological tools are expertly employed in concert, allowing the frogs to survive even the harshest winters. Their ability is now a field of study within cryomedicine, especially with ramifications in prolonging organ transplant windows. Historically, the issue has lain not with the survival of individual cells, but rather with the preservation of an organ as a whole. It's exceedingly hard to preserve a single organ for an extended time, let alone single or multiple organ systems. Researchers at the University of Miami claim that the frogs have "solved" not only the single-organ problem but also the "entire organ-systems" problem. Their simple evolutionary solution may bode well for medicine, allowing us to preserve tissues and organs well beyond our current capabilities.

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# TARDIGRADES:

## Earth's most resilient animals

BY SOPHIA RUGGIER, BIOCHEMISTRY, 2024

**E**xreme temperature, extreme pressure, dehydration, starvation, air deprivation, radiation, and exposure to outer space. Microscopic, moss-inhabiting animals called tardigrades can withstand all of these conditions, making them one of the most resilient animal species on the planet. They can be found in any of Earth's ecosystems, though most commonly live in damp environments like moss and lichens. Despite their preference for moisture, tardigrades are well-adapted enough to survive virtually anything that nature has to offer — and beyond.

It's almost inconceivable to think about how much tardigrades have endured. These microorganisms have survived all five mass extinctions and have been on Earth for an estimated 600 million years. What aspect of their biology makes them so resilient? How is it possible that tardigrades have evolved to withstand high levels of radiation that surpass anything found in a natural environment?

To address these questions, researchers in a 2016 *Nature* study examined the genome sequence of *Ramazzottius varieornatus*, a highly stress-tolerant tardigrade species. This species is particularly well-adapted to withstand dehydrated conditions, often referred to as desiccation. In the study, geneticists sequenced the tardigrade genome and transplanted some of the tardigrades' proteins, genes, and enzymes into mammalian cells to determine which biological mechanism creates this tolerance for extremes. One of the major findings of this experiment is the role of a protein called Dsup that is unique to tardigrades. Dsup, short for "damage suppressor," prevents the DNA breakage that usually occurs when an organism is faced with radiation or desiccation. This protein helps protect the tardigrades from X-ray radiation, while other enzymes encoded in their genome repair damaged DNA. With the knowledge that tardigrades harbor all of these biological safeguards, it becomes much less surprising that they are such resilient animals.

One may still wonder how tardigrades evolved to synthesize proteins that protect them from radiation if they haven't been exposed to radiation in any of their natural environments. The

results of the aforementioned study involving *R. varieornatus* support the hypothesis that tardigrades have not adapted to unnatural conditions like radiation or the vacuum of outer space. They have primarily evolved to withstand desiccation due to their affinity for damp environments like wet moss. If these normally aqueous habitats experience long periods of dryness or a lack of precipitation, the tardigrades have historically needed to adapt to the dehydration. It is simply a beneficial side effect that the genes and proteins encoded in their genome for protection against desiccation also function to protect them from radiation and other extreme conditions.

Going forward, geneticists hope to apply the resilience and high tolerance of the tardigrade to other animal cells and utilize it to protect human DNA in extreme

conditions. They see the potential of the tardigrade genome in several different industries.

The study involving *R. varieornatus* found that the protein Dsup suppresses single-stranded breaks in DNA when exposed to radiation. This leads to the belief that enhancing Dsup in human cells would make them easier to preserve and better able to resist damage to DNA. Furthermore, people would be more tolerant of medical therapies involving radiation. In terms of agriculture, farmers could work in more extreme conditions and grow crops in environments that are hotter, colder, wetter, or drier than usual. There are also major implications for advances in space exploration if humans could become more adaptable to outer space.

These possibilities may seem far-fetched now, but the recent discoveries surrounding tardigrades open many doors for researchers in the future. Adaptability to extreme conditions is especially relevant as we feel the growing impact of climate change. A seemingly insignificant, microscopic creature could provide humans with the tools we need to advance even further. It would be wise to learn as much as we can from tardigrades if we hope to keep on enduring as they do.

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PHOTO BY SHUTTERSTOCK





# HOW A SALAMANDER CAN TRANSFORM THE WAY WE HEAL

BY DOMIKA PETRASOVA, BIOCHEMISTRY, 2023

**O**ne look at an axolotl is enough to explain how such an animal entranced pet owners and scientists alike. Native to the Xochimilco Lake near Mexico City, these salamanders are recognized by their crown-like gills, slight smiles, and uniquely adorable appearances. The axolotl is currently endangered in the wild; however, enthusiasts breed the animal in captivity to live as exotic pets.

This salamander species captivates scientists, and not because of its unique physique. According to studies at the Broad Institute, axolotls have one of the largest and most complex genomes of all living creatures, containing a whopping 32 billion base pairs compared to the 2 billion base pairs in the human genome. They also stand out from other salamanders because of their uncanny ability to regenerate body parts, including their liver, spinal cord, and brain tissue. The magic does not stop there — understanding genetic and molecular mechanisms underlying this healing process can translate to new and efficient treatments for human illnesses and injuries as well.

Before jumping into the applications of regeneration, it is important to understand the process itself. The axolotl first loses tissue, usually a limb, to kick-start regeneration. A thin layer of skin known as the wound epithelium quickly covers the open injury, and the damaged space is innervated. The wound epithelium then communicates with budding nerves to form a signaling center, where signals cause surrounding tissues to de-specialize and form a blastema, or group of cells that take the shape and function of damaged tissue. Therefore, if an injury does not kill them, they can grow the affected area back.

Axolotl regeneration is significantly different from the way mammals heal. Rather than growing an arm or leg back within a couple of weeks, mammals experience fibrosis, which is when scar tissue replaces cells at the original site of injury. This form of healing is faster and more protective in the short term. However, in many cases, the original tissue types do not replace scar tissue and function cannot be fully restored. Understanding regeneration by identifying genes, pathways, and molecules involved in regeneration can improve healing for all mammals, including humans.





Northeastern's Monaghan Lab is dedicated to decoding regeneration. In 2018, the lab confirmed that axolotls can, in fact, regenerate injured lung tissue. Researchers cut off one-third of axolotls' lungs and compared genetic and molecular changes to uninjured axolotls. *ErbB2* and *ErbB4* mRNA was upregulated when the lung was injured, meaning that the resulting receptors are likely involved in lung regeneration. Inhibiting *ErbB2:ErbB4* receptors causes the lung to heal up to four times slower than in axolotls with functioning receptors. The Neuregulin-1 $\beta$  (NGR1) molecule, which binds to *ErbB2:ErbB4*, also plays a significant role in regenerating lung tissue. Injecting NGR1 doubled lung proliferation in uninjured axolotls, while inhibiting the molecule in injured axolotls prevented regeneration and stunted cell development throughout the body. The molecule was therefore hypothesized to be highly involved in cell growth throughout the whole axolotl.

The Monaghan Lab found that lung regeneration does not occur like limb regeneration. Instead of forming a lung shaped like the uninjured lungs, lung tissue grew back in different sizes and shapes, only restoring function. The entire lung is also involved in regenerating tissue, called

compensatory regeneration, whereas limb regeneration only happens at the blastema during epimorphic regeneration.

Although researchers stress the need for mammalian studies, this is a step forward in regenerating human lung tissue. The *ErbB2:ErbB4* receptor is found in humans, and increased NGR1 levels cause lung cell proliferation in human lung cells *in vitro*. Humans are also capable of compensatory regeneration, a feat widely studied in the liver.

The Monaghan Lab's research does not stop there. Currently, researchers are looking at different factors that could impact regeneration, including nerve dependency, hyper transcription of a variety of genes in regeneration, and retinal regeneration in axolotls. Labs beyond Northeastern's are also researching regeneration to mitigate aging diseases, apply epigenetics, and understand the chemical impact on regeneration. Humans will not live forever or regrow limbs anytime soon; however, more research into this peculiar salamander may turn life-altering diseases and injuries into routine doctor's appointments sooner than we think.

PHOTOS BY ANNA TORTEN RABINOWITZ, BIOLOGY, 2024  
DESIGN BY KATIE GREEN, BIOENGINEERING, 2022



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# MASS EXTINCTION?

## THEY WERE BORN READY

BY NETHRA IYER, CHEMICAL ENGINEERING, 2024

PHOTO BY UNSPLASH

**S**ixty-five million years ago — a time popularized by shows and movies like “The Land Before Time” and “Jurassic Park.” With that being said, we often think of dinosaurs through their remains: fossils, fragments of bone, and skeletons encapsulated in rocks and dust, providing a glimpse into the past. However, what if we could view the past through something alive? Crocodiles — living fossils — can provide that lens, having survived the mass extinction to remain one of planet Earth’s top predators.

But what adaptations allowed this remarkable species to persist when so many did not? First, it is important to understand what took place during the mass extinction at the end of the Cretaceous. Scientists believe that an asteroid, coupled with volcanic eruptions and climate change, led to the sudden disappearance of dinosaurs, ammonites, pterosaurs, and many other species. Essentially, the environment changed so quickly that the dinosaurs could not adapt and survive. Notably, and perplexingly, crocodiles did not need to adapt quickly to such a catastrophe — they were already prepared from the get-go.

Researchers at the University of Bristol were surprised to find that crocodiles follow what is known as “punctuated equilibrium.” Essentially, evolutionary change for crocodiles is extremely slow, but any environmental or abiotic forces, from gradual climate change to an asteroid, will rapidly speed up the process. Specifically, in the case of crocodiles, they were able to increase their body size as the Earth’s temperature increased.

In his doctoral thesis, Maximilian Stockdale from the University of Bristol found a strong correlation between time, temperature, and body size of crocodylomorphs — or the general group of reptiles that includes crocodiles and their relatives. Stockdale used a machine learning algorithm and counted the lineages to create phylogenetic, or evolutionary, trees. He divided these diagrams into intervals of one million years, placing each crocodile species

at times it was extant. For each time interval, extinct species were removed, and Stockdale noted when species first and last appeared. Through calculations and graphical analysis, Stockdale found the evolutionary rate, or the speed of genetic change in a lineage, for crocodiles as a whole. He then compared body size, a good indicator of growth, and population size to the environmental factor of temperature.

The results showed that diversity increased throughout the Mesozoic Era slowly, peaked in the late Cretaceous, and then dipped during the mass extinction. These results made sense as the temperature was higher during the Mesozoic Era, allowing for more diversity and ergo larger species of crocodiles. Furthermore, the results supported the idea of punctuated equilibrium in crocodiles — the mass extinction was large enough to promote sudden decreases in diversity. Unlike many dinosaurs, this decrease in diversity did not result in the complete extinction of the species. While some crocodylomorphs, especially the larger ones that depended on warmer climates, did die out, smaller crocodiles that evolved more slowly did not increase in size during the warm Eras preceding the mass extinction. These crocodiles were able to survive in the cooler aftermath of this event through a slower evolution.

Incredibly, crocodiles have survived millions and millions of years, through many global temperature changes and mass extinctions. They have adapted to their new environments, only to become threatened and endangered at the hands of humans. Habitat loss, hunting, and other human interventions have caused seven out of 24 species of crocodiles to be critically endangered. Even an asteroid 65 million years ago could not cause this devastation. The evolution of crocodiles has provided a window into Earth’s past, but the rate at which humans are destroying the planet means there might not be any living fossils left to teach us about the past or provide insight into our future. Hopefully, conservation efforts can support these spectacular creatures, helping to slowly but surely foster their return to resiliency.

# Stay in with mom or go out with friends?

A new study on spotted hyenas teaches us that early life social experiences could have effects into adulthood

BY CATRIN ZHARYY, BEHAVIORAL NEUROSCIENCE, 2023

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

**I**n the next decade or two, when adults unpack the lasting impact of their childhood experiences, research on these facetious creatures could be the reason why therapists have such astute insights into the topic.

A 2021 study published in *Nature Communications* used 28 years of data on wild spotted hyenas' social habits, genetic composition, and stress hormone concentration. The researchers tested if early-life social experience (encompassing maternal care and interaction with peers) altered genetic material or influenced stress in adulthood. The data was collected by the Maasai Mara Hyena Project in Mara National Reserve in Kenya.

Research on the effect of early social experience on later life stress has been increasing since the 1950s and, thus far, has been supportive of the hypothesis that greater maternal care and increased interaction with peers while young lowers — or is protective against — stress in adulthood.

Besides targeting a new species, what differentiated this study from previous ones was its focus on wild animals instead of those raised or behaviorally manipulated in a lab setting. Hyenas may seem like a random choice of subject, but the species is a near perfect wild analog to humans. Hyenas live in communities, offspring receive maternal care for the hyena equivalent of "childhood" and "teenage" years, they exhibit a diverse range of social behaviors, and have a strict social hierarchy.

This study measured spotted hyena offsprings' social experiences during two sensitive periods of development: the communal den (CD) period, when cubs live in the communal den, and the den-independent (DI) period when they leave to explore the clan's territory. Hyena offspring interact with other members of their clan and receive nutrition and social support from their mothers during both periods.

For each hyena, researchers mapped out a social network during these periods. They quantified the individual's degree of centrality (social circle), relationship strength (based on how much time they spend with others), and betweenness centrality (based on how often they were present for interactions between others). Additionally, researchers recorded how much time mothers spent with, nursed, and groomed their cubs. To sense how much stress the hyenas experienced in adulthood, the

**II** Hyenas may seem like a random choice of subject, but the species is a near perfect wild analog to humans."

researchers measured the concentration of fecal glucocorticoid metabolites (fGCMs), a byproduct of the breakdown of the stress hormone corticosterone.

Though the authors' main hypothesis was that less or worse social experiences in childhood would correspond with greater stress in adulthood, they were also curious if epigenetics mediated this relationship. Investigating the connection between nature and nurture, the increasingly popular subfield of epigenetics explores how chemical or structural changes to the genome — *except* for changes to the DNA sequence itself — affect cell function, and consequently, the function of entire systems in the body. The researchers quantified global DNA methylation, an epigenetic characterization that is associated with positive health outcomes.

The study showed some results that corroborated those of previous investigations as well as some that did not support the authors' hypotheses. In alignment with extant research on rodents, humans, and non-human primates, the study found that greater time spent with their mother in the first year of a cub's life and a larger social circle during the DI period were associated

with higher global DNA methylation. Another expected result was that a greater degree of centrality and relationship strength during the DI period was associated with a lower concentration of fGCMs in adulthood. Surprisingly, maternal care and social connectedness during the CD period were not associated with adult stress in any way, and there was no evidence for global DNA methylation mediating the relationship between social experience and stress phenotype in adulthood.

The unforeseen results of this study could have been because of the abundance of possible confounding variables like age, sex, maternal social rank, human disturbance, and local prey presence. Although the researchers did try to control for these factors in their data analysis, it is impossible to remove all influence of a confounding variable in the wild. On the other hand, it's possible spotted hyenas simply react differently to early social experience than rodents and primates. As is often the case, this study might have created more questions than answers.

Perhaps the most striking aspect of this study was its robust data source — the Maasai Mara Hyena Project — which has opened an exciting door to safer and more efficient biosampling and naturalistic observation. Hopefully, this will lead to discoveries about organisms being simultaneously products and architects of our social environments.

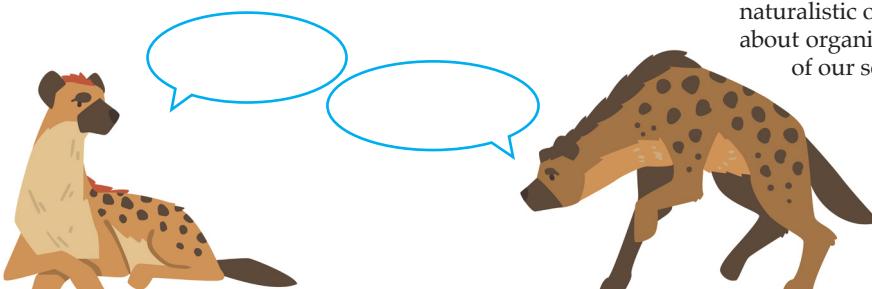


PHOTO BY SHUTTERSTOCK

# DIAMETRIC DISASTERS

Effects of climate change on monsoons in the southwest U.S.

BY CARA PESCIOTTA, PHYSICS, 2022

DESIGN BY DIVYA RAVIKUMAR, BIOENGINEERING, 2025

**M**orning glories bloom in a new year, and riparian trees paint canyon walls green. Sonoran green toads screech as they start their breeding season just as hummingbirds migrate to follow the nectar in new blossoms. Soon, prickly pear cactus fruit will ripen into their famous bright-red flowers. These are just some of the beautiful sights to see at the beginning of monsoon season in the southwest U.S.

Monsoons are storms that accompany the rainy season in many parts of the world, accounting for over 50 percent of rainfall in the Southwest. The few months of monsoon season from July to September offer a break from unrelenting dry spells and deliver much-needed rains. These extreme conditions kindle a unique assemblage of vegetation and wildlife that capitalizes on a few months of rainfall. Monsoon season sparks breeding season, migration to the area, and excess water intake to store for the remainder of the year. Humans await this deluge also to resupply water, and cooler temperatures compounded by the active ecosystem draw tourists to the area, accounting for almost 200 thousand jobs in Arizona in 2019 according to the Arizona Office of Tourism. In a normal year, the benefits of these waterworks ameliorate any infrastructure damage from intense storms.

Recent years have set rainfall history, though, with 2020 having record low and 2021 record high precipitation, according to the National Weather Service. In 2020, Arizona had 6.63 inches of rain to make it the driest year since 1956. This caused a record high average temperature in August of 99.1 degrees Fahrenheit. Just a year later, the end of monsoon season in September 2021 left Arizona with a record-high 12.79 inches of rain.

In addition to temperature, the flux of precipitation also influences the amount and intensity of wildfires. Fires are typical in this region and come in shocking numbers, even for a relatively average year in rain and temperature. For example, 2019 saw 1,869 fires and 380 thousand acres of damage. Drought in 2020 produced 2,524 fires covering a whopping 980 thousand acres, while 2021 thus far has over 1,100 fires. It is difficult to correlate this data to rainfall since factors like preparedness affect wildfire spread, but what is especially interesting is the time of year these disasters occur. Of the 63 most notable fires in 2020, 36 began during monsoon season. Contrarily, four of 35 major wildfires in 2021

occurred during monsoon season. This shows that no matter the wildfire statistics before monsoon season, monsoons are good at mitigating these blazes. Unfortunately, this advantage to increased rainfall is met with adverse effects that make years like 2021 disastrous.

Monsoons can overwhelm dry environments to result in a different type of natural disaster — flash floods. Flash flooding occurs when dry soil cannot absorb water fast enough to accommodate torrential rain, causing flooding with powerful and dangerous currents. Canyons and dry stream beds called arroyos make the Southwest particularly prone to flooding and related hazards like mudslides. When thunderstorm conditions are present with lesser rains, hurricane-strength winds and lightning also threaten the land. Dust storms reduce visibility and air quality, and lightning-based fires spark and spread rapidly. Monsoons present enough risk themselves to seriously question their aid in relieving wildfires.

With extreme consequences from both excessively wet and dry monsoon seasons, the Southwest should covet an average year. Climate change, however, is making average years less common. A 2019 Princeton study found that Southwestern atmosphere thermodynamics are trending toward extreme rain patterns as Earth warms, meaning monsoons will decrease in number and increase in intensity. Warming will also make droughts drier and rainwater deplete such that more fuel is available for wildfires.

Monsoons are one in a long list of weather patterns expected to fluctuate due to climate change. Heat waves, heavy rain, cyclones, and droughts can strike anywhere in the world and have been shown to hit less often but more severely. These extraordinary natural disasters can wreak havoc on infrastructure, disrupt communication and transportation services, and disproportionately affect vulnerable populations. In moderation, weather phenomena keep order in local ecosystems, with their human inhabitants able to prepare for these events. Climate change is disrupting this order, and without action, there will be dire consequences. This will require large-scale reformation among companies and governments. You can do your part by voting, spending responsibly, and educating yourself and others on how to be more responsible global citizens.

PHOTO BY SHUTTERSTOCK

# THE MOST RESILIENT (AND WIDEST) CORAL, MUGA DHAMBI

BY EVAN DOGUS, BUSINESS ADMINISTRATION, 2024

DESIGN BY EVELYN MILAVSKY, CELL &amp; MOLECULAR BIOLOGY, 2025

In the summer of 2021, a group of snorkelers accidentally discovered one of the oldest and largest coral colonies in the world. Located off the coast of Golboodi, one of many Palm Islands in Queensland, Australia, this coral was named Muga dhambi, which means “big coral” in the language of the indigenous Manbarra people. This carousel-sized coral stands over seventeen feet tall and thirty-four feet wide, making it the sixth-tallest known coral in the Great Barrier Reef system. According to Australian biologists, this coral colony is estimated to be 421 to 438 years old, making it older than the United States. This age indicates that the colony was able to survive centuries of coral bleaching events, natural disasters, invasive species, and erosion.

Coral belongs to the kingdom Animalia and the phylum Cnidaria, meaning that they are closely related to jellyfish and sea anemones. They are colonial animals that connect themselves by building a calcium carbonate skeleton made from elements in surrounding seawater. Coral polyps are small, soft-bodied parts of the animal and bring in ion-rich seawater. They absorb the calcium ions in the seawater and then apply them to the surface of their existing skeletons. The corals then pump hydrogen ions from the water out of the calcifying space between their cells, which produce more carbonate ions that bond with the calcium ions to form calcium carbonate. This process continuously repeats itself as long as the coral is healthy enough to survive. Massive coral colonies, such as Muga dhambi, tend to prioritize width over height to sustain greater stability in the water.

Given that Muga dhambi isn’t even the largest known *Porites* (a coral genus) in the world, there is a possibility that even larger *Porites* colonies can exist elsewhere on the Great Barrier Reef. This discovery gives us hope for the future of our marine ecosystems.

If our oceans are still able to sustain

coral colonies of this size, that means that the planet has not hit the tipping point of extinction and still has time to make a recovery. However, coral are some of the most vulnerable species to the effects of climate change, as the chemical reactions that take place in the calcium carbonate building blocks of the skeleton partially depend on the acidity of ocean water. The average pH of seawater is 8.1, but as atmospheric levels of carbon dioxide continue to increase, more carbon is sequestered into oceans in the form of carbonic acid, thus lowering the pH level. For every one pH unit decrease, there is a tenfold increase in acidity. This carbon absorption causes chemical reactions in the water that produce more bicarbonate ions and less essential carbonate ions for corals. This change in pH prevents the coral colony from building and repairing its skeleton, leaving it vulnerable to erosion and natural disasters.

The rise in ocean temperatures is another impact of climate change that threatens the health of coral and their associated ecosystems. The average global ocean temperature has increased by about 1.5 degrees Fahrenheit since 1901 and has been consistently higher during the last thirty years than at any other recorded time period. To obtain energy, corals have formed a symbiotic relationship with a species of photosynthetic algae called Zooxanthellae. This alga grows in the tissues of the coral, but once the water temperature gets too warm, it gets expelled, causing the coral to turn white. The bleached coral is not dead — it is just under more stress and is more susceptible to death, which usually comes about if conditions do not return to equilibrium. Furthermore, Nathan Cook, a marine scientist at Reef Ecologic, reports “a decline of 50 percent of coral cover on the Great Barrier Reef over the past thirty years” in a post on The Australian Institute of Marine Science’s website. This change is proceeding at an alarming rate, but there are still resilient coral colonies — such as the Muga dhambi — that could survive in the future. There is still time to turn things around for the rest of the corals, given that there is sometimes a 20-year recovery period after initial bleaching. Human sustainability and conservation efforts must continue to be enforced and employed for years to come, and, hopefully, we can foster a world filled with countless massive coral colonies.



PHOTO BY SHUTTERSTOCK

# Staghorn coral studies show promise for global warming-resistant reefs

BY CAILEY DENONCOURT, BIOENGINEERING & BIOCHEMISTRY, 2022

**C**oral reefs are not only beautiful scapes of nature but also home to the most diverse ecosystems in the marine world. Being the home of thousands of fish, hundreds of corals, and many other various organisms, scientists have been investigating ways to combat the dangers to the reefs caused by global climate change.

A currently endangered coral, staghorn corals, used to be one of the most abundant species in the Caribbean reefs. These corals have been present in wide expanses of the Caribbean for over 5,000 years and are known for their antler-like branches that stem up and outward from their bases. Because of the staghorn's dense growth pattern, the reef was the home of many sea animals. However, in the 1980s, a severe disease wiped out nearly 97 percent of the staghorn coral population. According to the National Oceanic and Atmospheric Administration (NOAA), this disease was called the white band disease, which caused the corals' tissues to degrade. Previously, staghorn corals lived in vast stretches along the coasts of the Caribbean, but now, they only exist in small colonies and isolated tufts. After already suffering a sharp decline in its population, the staghorn coral, along with other reef organisms, continue to suffer from the effects of global warming.

With climate change come increases in atmospheric temperature and carbon dioxide levels. The atmospheric temperature also causes an increase in ocean temperatures.

This increase in temperature causes staghorns to release the algae that typically serve as their food source, resulting in their deaths. Additionally, the increase in atmospheric carbon dioxide makes the ocean more acidic. The higher acidity of the ocean dissolves the corals' skeletons, which also results in death because of their fragility.

These negative impacts on an already endangered species leave scientists and marine biologists with the challenge of trying to rebuild these precious ecosystems. To try to prevent further coral reef death or possibly reverse the effects of human activities, scientists are performing multiple different types of restoration projects. One of which is propagation and outplanting; this approach requires scientists to grow coral seedlings in well-regulated nurseries and, once

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

strong enough, replant the new coral fragments into the diminishing reefs.

Most recently, in a study done at the Shedd Aquarium and the University of Miami Rosenstiel School of Marine and Atmospheric Science, scientists explored the idea of artificially selecting and replanting staghorn corals in an environment that is most compatible with their genetic and phenotypic ability to resist heat. Throughout 2020, the team took up small fragments of coral and had them undergo a heat resistance test in a series of stress tanks to determine each strain's ability to withstand warmer ocean temperatures. Additionally, the DNA from the various coral fragments were analyzed to look for possible genetic influences on heat resistance.

From the 229 corals taken from six different coral nurseries off the coast of Florida, the results showed a wide variation within nurseries, rather than between them. From this, it can be deduced that there is likely a genetic influence on the

heat tolerance of the staghorn corals. However, by gaining the ability to determine which strains within the nurseries are more heat resistant than others, scientists optimize restoration through propagation and outplanting. Higher heat-resistant corals can be planted in the shallow, warmer reef sections, while the lower heat-resistant corals could be planted in the deep reef sections where the ocean temperature is more resistant to temperature changes.

Through this research, along with more studies to analyze the effects of climate change on coral reefs around the globe, scientists optimize the different restoration methods that could be revolutionary for saving the reefs. Although this study was only performed off the coast of Florida, further monitoring of the optimized propagation must be analyzed to assess the method's effectiveness and applicability to reefs in other parts of the world. However, if research continues along this trend, a multitude of fish and coral species will be able to flourish despite the harsh environmental effects humans continue to have on the Earth.

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PHOTOS BY SHUTTERSTOCK AND RUTH BEKALU, BIOLOGY, 2025

# WHAT DOESN'T KILL YOU MAKES YOU STRONGER

The interplay between trauma and resilience

BY LILY WEBER, BIOLOGY & ENGLISH, 2023  
DESIGN BY CARINA HALCOMB, DESIGN, 2024

**T**rauma is a near universal experience. According to the National Council for Behavioral Health, 70 percent of U.S. adults have experienced a traumatic event in their lifetime. In accordance with this statistic, one would expect PTSD to have a similar prevalence. However, the National Institute of Mental Health places lifetime prevalence of post-traumatic stress disorder around 6.8 percent. So what are the reasons for such a significant disparity?

Put simply, not everyone who goes through a traumatic event will necessarily develop PTSD. This is in part due to what is known as resilience factors. As defined by an article published in the Harvard Review of Psychiatry, resilience factors are “the dynamic ability to adapt successfully in the face of adversity, trauma, or significant threat.”

According to Harvard University’s Center on the Developing Child, the most commonly observed factor in children who develop resilience is having a stable and supportive relationship with a caregiver. Relationships such as these are vital in providing a buffer against developmental disruption. Stable parental relationships are also key in allowing children to develop the skills to monitor and regulate their own behavior. Such capabilities enable children to be adaptive rather than hindered in the face of adversity. In essence, the foundation of resilience relies on supportive relationships and adaptiveness. Importantly, as discussed by Masten et al in 2018, research has demonstrated that resilience is highly dependent on a child’s relationships as opposed to any of their inherent qualities. Other environmental factors that are tied to resilience include low family stress, stable parental health, a lack of alcohol or drug abuse present in the family, and an overall sense of safety and security

in the family (Kumpfer et al., 2002). While these factors may seem obvious, they form the vital backdrop which allows children to develop strong coping skills despite the traumatic experiences they may encounter. Beyond the scope of the family, community factors play a significant role in developing resilience. These can include a supportive mentor figure, safe neighborhood, extracurricular activities, or even involvement in a religious or faith based community. The underlying truth here seems to be that what is going on around a person when they experience trauma can be just as significant as what is going on inside them.

“ Put simply, not everyone who goes through a traumatic event will necessarily develop PTSD. This is in part due to what is known as resilience factors.”

These concepts also translate to real life studies conducted on subjects with post traumatic stress disorder. A study conducted by Marshall et al in 2006 examined a subset of 88 male Vietnam veterans who presented with war-related PTSD. The study found that of the soldiers who experienced potentially traumatic experiences while in combat, approximately 31.6 percent ended up developing PTSD. Furthermore, when the researchers narrowed their analysis to focus on those that had the most severely traumatizing exposures, there was still a significant proportion that did not develop the syndrome, around 30 percent. This seems to suggest that there are other factors at play which

influence whether or not someone will ultimately develop PTSD. In the aforementioned study, factors such as abuse during childhood and pre-existing psychiatric disorders contributed to the likelihood that veterans developed post traumatic stress. In other words, while the severity of trauma logically plays a role in the development of PTSD, outside factors from early childhood development have their own, significant role to play.

So what can one do to bolster their resilience in the face of trauma? Our ability to be resilient is not set in stone. While we cannot always change the circumstances in which we grew up, we can choose how to deal with the aftermath. According to the Mayo Clinic, there are many things that can improve resilience. For example, one can work on getting connected with loved ones, remaining hopeful, learning from experience, practicing self-care, and being proactive when facing problems. By learning from how you dealt with issues in the past, one can analyze what helped and what did not. Self care can involve leaving time for hobbies and interests, or practicing stress management techniques such as meditation and yoga. PTSD can be a chronic and debilitating condition, but by bolstering resilience it can be managed or potentially even avoided altogether. As such, there is hope for those who suffer with traumatic experiences. While trauma may not be avoidable throughout the course of one’s life, those who experience it do have the potential to both process it and even flourish.

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# ADHD in dogs:

How studying the condition in dogs may help us learn more about humans

BY MADELINE SCHANEN, BIOLOGY & MATH, 2025  
DESIGN BY PARKER HITT, BIOLOGY, 2024



**A**bout five percent of people are affected with ADHD, according to a study published in *The Lancet Psychiatry* in 2018. Beyond that five percent, even more do not meet the full criteria, but still have difficulties with focusing and impulse control. Many kids with ADHD tend to struggle more in school. According to the study, if left undiagnosed, ADHD can lead to an unsuccessful adult life both socially and financially. However, some of the specific causes of ADHD are still a mystery — particularly in girls — which contributed to the prevalence of people who are undiagnosed or misdiagnosed.

It was originally thought that ADHD was just a human condition, but a recent study published in *Translational Psychiatry* in 2021 found that “canine hyperactivity, impulsivity, and inattention share similar demographic risk factors and behavioral comorbidities with human ADHD.” This suggests that this condition appears in dogs as well. Observing how ADHD affects dogs has useful applications for studying humans. Results showed that high levels of hyperactivity inattention were more common in young male dogs. This is notable considering that ADHD is also often noticed in young, male humans, suggesting that dogs might be a good model for studying ADHD. There was also a correlation shown with being aggressive or shy, something that is also documented in humans with ADHD. Given that dogs have many similar traits to humans, this doesn’t come as much of a surprise. The study also found that many of the neurological pathways that play a role in ADHD in humans are similarly affected in dogs, further solidifying that dogs may be a good model for ADHD research. ADHD and impulsive behavior can come from disruptions in the frontostriatal circuit and activation of the prefrontal cortex (PFC). The anterior cingulate cortex (ACC) and striatum are also involved in human ADHD as well as in dogs. Neurological pathways involved in aggressiveness also connect to PFC and striatum, and fear and anxiety are also associated with activity in PFC and ACC in both humans and dogs.

The study also found that dogs who spend more time alone and lack exercise and socialization are more prone to developing ADHD. Some can get stressed when they are alone, which leads to increased levels of fear and anxiety. The pathways in the brain relating to the PFC can be overactivated and contribute to impulsive behaviors and ADHD traits. While all dogs can exhibit ADHD symptoms, some breeds may be more vulnerable than others. For working breeds such as the border collie and German shepherd, ADHD characteristics were more common. In contrast, dogs kept usually as pets like poodles and chihuahuas were calmer but also displayed inattention. Dogs kept as pets were shown to not display ADHD traits at all or in the same capacity that work-bred dogs did. The study notes that this could be because these dogs don’t have to concentrate in the same capacity that dogs bred for work have to.

Research in humans shows an ADHD brain differs from a neurotypical one, but how do increased levels of hyperactivity and inattention affect dogs’ brains? Do parts of a dog’s brain also mature at slower rates, similar to humans with ADHD? Future research should investigate these kinds of questions. According to the article “The ADHD vs. Non-ADHD Brain” published in *Very Well Mind*, the amygdala and hippocampus — responsible for emotional processing — are smaller in the brains of those with ADHD. Dopamine regulation is also different. Evidence also showed that ADHD may be related to dysfunctional brain connectivity. Research using resting-state MRIs suggests that individuals with ADHD may have “increased functional connectivity in certain regions of the brain” which is interesting when comparing it to a neurotypical brain, and raises questions for how and why ADHD increases the functionality of only some parts of the brain. One might wonder if these neurological differences are similar in dogs, and if they are, what could work in dogs to regulate traits of ADHD that could work in humans.



*Translational Psychiatry* (2021). DOI: 10.1038/s41398-021-01626-x  
*The Lancet Psychiatry* (2018). DOI: 10.1016/S2215-0366(17)30167-0

PHOTO BY SHUTTERSTOCK

# The toughest jobs in the world:

## Do you have what it takes to be a nurse?

ARTICLE AND DESIGN BY VIANNA QUACH, PHARMACEUTICAL SCIENCE, 2025

**C**an you handle a job where your mental resilience is tested every minute? Tens of millions of people do it worldwide, and their contributions help keep humanity on its feet. Nurses, physicians, therapists, healthcare workers, and more make up one of the most vital sections of society. Unfortunately, they also make up the part of the population most vulnerable to compassion fatigue.

Compassion fatigue is the mental and physical exhaustion developed from exposure to the trauma of individuals in their care. Its symptoms align with those of burnout and secondary traumatic stress: exhaustion, anger, irritability, negative coping behaviors (alcohol and drug abuse, etc.), decreased ability to sympathize or empathize with others, decreased job satisfaction, job evasion — and in extreme cases, the development of psychological disorders such as depression, anxiety, and post-traumatic stress disorder.

Unsurprisingly, those that work in healthcare and community services are some of the most susceptible to these symptoms, according to numerous studies. Caregiving heavily relies on interactions with their patients; as such, these workers must be able to feel and convey empathy with those individuals to successfully complete their tasks. Over time, these abilities eventually become strained and exhausted. This is particularly significant for those working with life-threatening cases, such as in the emergency department.

Not only does compassion fatigue impact caregivers; there are also occupational consequences. Patient care standards lower considerably due to stressed caregivers' decreased decision-making abilities and job turnover rates (because of job dissatisfaction) increase the workload on the remaining workers — which shortens the amount of attention and effort they can partition to each patient. Some also become fearful that they cannot provide satisfactory care, leading to evasion and ultimately impairing patient care. Coworker relationships become strained as well, decreasing organization and the efficiency of the healthcare system to treat patients.

Furthermore, recent years have proven especially stressful to healthcare workers due to the COVID-19 pandemic. Physicians have been forced to make tougher ethical decisions due to limited resources, like having to decide which cases to prioritize. They face an overwhelmed and disorganized healthcare system on one side and patients suffering on the other. The uncertainty of the disease and fear for their safety, along with their unpreparedness to handle a pandemic, led to many caregivers reporting compassion fatigue (including emotional and psychological distress) in separate studies conducted in Spain and China.

There is hope for prevention and recovery from this condition. Although not enough research has been conducted on compassion fatigue, some studies have shown that programs that focus on promoting resilience, such as the Accelerated Program for Compassion Fatigue, help decrease symptoms of burnout and stress in healthcare workers. These trainings include teaching workers how to identify compassion fatigue and take control of their emotions, particularly their stress reactions. As they learn to shift their perceptions more optimistically and develop self-compassion, some have reported feeling more empowered and energetic.

Studies have also found that compassion satisfaction — the positive feeling that healthcare workers develop when they feel competent and socially valued — can protect them from compassion fatigue. A study conducted in Spain found that more nurses than physicians feel compassion satisfaction, which researchers speculate comes from the fulfillment they experience from the closer contact and direct care for their patients along with the recent upsurge in social recognition that nurses have been receiving.

Additionally, support and encouragement from management may not only improve a worker's feelings of competence and importance but increase job satisfaction. Some engage in self-care activities, which not only bolster compassion satisfaction but also improve self-control over their emotions and allow their minds a mental break to process their feelings.

Compassion satisfaction can also be improved from positive relationships with one's coworkers. Some institutions implement group discussions after difficult cases to get workers to confide in one another and process their emotions. The connection and support among coworkers have been speculated to protect pediatric palliative care providers from the emotional toll of compassion fatigue in certain studies.

With their mental fortitude, nurses, physicians, and therapists should be considered some of the most resilient people in society. Healthcare workers constantly manage the challenge of handling multiple sets of emotions at once, not to mention their own. Without their strength and compassion, we would not be here today.

*Palliative & Supportive Care* (2019). DOI: 10.1017/S1478951517001237

*Journal of Clinical Nursing* (2020). DOI: 10.1111/jocn.15469

*International Journal of Environmental Research and Public Health* (2016). DOI: 10.3390/ijerph13060618

PHOTO BY GUS MUELLER, MECHANICAL ENGINEERING, 2023

# WHAT DOESN'T KILL YOU MAKES YOU STRONGER...

HOW TRAUMA CAN LEAD TO PSYCHOLOGICAL RESILIENCE

BY ANANYA INYEGAR, BIOLOGY, 2023

DESIGN BY RESHIKA SAI DEVARAJAN, HEALTH SCIENCE, 2025

**F**or thousands of years, philosophers and religions have tried to find hidden meaning in the trials and tribulations of human life. From Greek antiquity and early Hindu texts to Nietzsche and Schopenhauer, we have striven to answer this question: does our suffering have meaning? Many religions and schools of thought hold that hardships are necessary for personal development or that "everything happens for a reason." Although these ideas may sound like banal platitudes, more recently, a body of scientific literature has emerged focusing on the concept of post-traumatic growth (PTG), a phenomenon of psychological resilience experienced by some survivors of trauma.

Most of us are familiar with post-traumatic stress disorder (PTSD). It has been documented in military veterans, natural disaster survivors, victims of violence, and even women who suffered traumatic childbirths. Exposure to the stressful event may cause an acute adrenaline response, commonly known as "fight or flight," that can trigger the formation of neural pathways in the brain that persist after the threat has passed. The firing of this stress-response circuitry then is triggered causing heightened responses to non-threatening situations and thoughts. Neural imaging paradigms conducted on PTSD patients have shown changes in activity in the frontal lobe, anterior cingulate cortex, and thalamic regions, which collectively play key roles in executive function, attention, cognition, memory, and integration. Dysfunction in these areas leads to the behavioral and psychological disruptions experienced by PTSD patients. Psychotherapeutic and pharmacological treatments exist for PTSD, but the condition cannot always be effectively resolved. However, not all trauma survivors experience PTSD, and most experience no long-term negative psychological effects. Some survivors, however, can positively accommodate the stressful experience and integrate it with their prior beliefs in a manner that fosters psychological development in the aftermath of trauma. This phenomenon, in stark contrast to PTSD, is known as post-traumatic growth.

Research in the last few decades has elucidated the idea that trauma need not be exclusively pathogenic — appropriate interventions could contribute to the development of its salutogenic effects and give rise to post-traumatic growth in trauma-exposed individuals. PTG is a product of the individual's struggle to come to terms with their traumatic experience, and it is not mutually exclusive with post-traumatic stress. An individual may constructively process



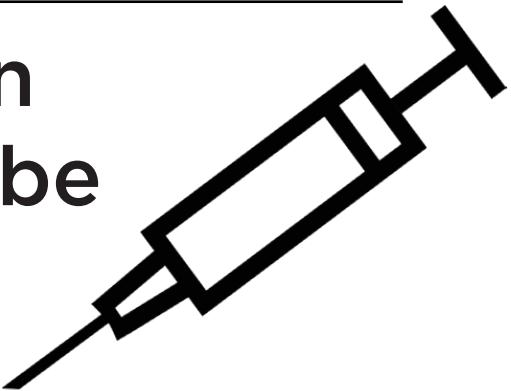
their trauma while still exhibiting symptoms of stress; however, over time, the positive assimilation of the stressful information with existing core beliefs drives the patient to a sort of homeostasis in their perception of their new reality. The five key domains that help identify PTG are personal strength, interpersonal relationships, life possibilities, appreciation for life, and spiritual/philosophical changes. These factors are measured by the patient's endorsement in the Posttraumatic Growth Inventory assessment, commonly used by psychologists to evaluate whether positive adaptation is observed in a survivor of trauma.

PTG has been documented in survivors of a range of traumatic experiences. Research conducted on frontline nurses in China during the COVID-19 pandemic measured moderate to high levels of PTG in these health professionals, who faced extremely high stress working environments. The factors correlated with increased psychological growth were level of experience, self-confidence, psychological interventions, risk awareness, and deliberate rumination on the stressors. Rumination, or the turning over of information in one's mind, has been identified as a key facet of recovery and growth following trauma. For an individual to come to terms with and accommodate their experiences positively, they must be able to mentally immerse themselves in the recollection of the trauma and subsequent emotions. Consequently, the opposite, avoidance, is a key indicator of PTSD in trauma survivors. Another recent study published by a team at Massachusetts General Hospital found that most women studied endorsed psychological growth — with the highest ratings of appreciation for life occurring in those who experienced a stressful birth — supporting the idea that serious adversity can bolster psychological strength and wellbeing.

Perhaps what doesn't kill you does make you stronger psychologically at least. The two diverging trajectories of psychological wellness in the aftermath of trauma begs the question, what differences lead one trauma survivor down the road to recovery and resilience and another down a path to psychological pathology? As research into this dichotomous area of human psychology progresses, researchers hope to develop interventions and supports that help more trauma survivors achieve psychological resilience and growth. So, to answer the age-old question, it seems suffering can hold meaning. We just have to help people find it and turn tragedy into psychological triumph.

# With new technology, an HIV vaccine may finally be within reach

BY NOAH HAGGERTY, APPLIED PHYSICS, 2024



**J**une 5, 1981, the United States CDC published a report describing five cases of pneumonia in young gay men. The same day, the CDC received a call warning about a cluster of unusually aggressive cancers in New York. After the Associated Press picked up the story of these strange cases, the CDC received dozens of similar reports of pneumonia, cancers, and severe infection. An epidemic has been born.

It wasn't until over a year later, on September 24, 1982, that the CDC defined the term Acquired Immune Deficiency Syndrome, or AIDS. Over 240 people had already died.

Fenway Health, a Boston-based LGBTQ community health center, was one of eight sites selected to conduct the first vaccine trials in 1994, 12 years later. Dr. Kenneth Mayer was working with the organization on STI prevention at the time. He is now the Medical Research Director and Co-Chair of The Fenway Institute, serving as the education and community activism arm of the organization.

"We realized that Fenway might be in the epicenter of ... an emerging epidemic," Mayer said. "So I helped Fenway develop some initial studies to understand what were the factors associated with being sick or not being sick. And when the source of the epidemic was identified, we did some of the first studies looking at [correlates] of having antibodies against HIV."

Early HIV vaccines selected specific characteristic proteins from the virus, copied the DNA that creates these proteins, and inserted them into a weakened virus — typically a flu or common cold strain. Once injected, the encoded proteins are produced by the weakened carrier virus, triggering the immune system's B cells to produce specific antibodies designed to fight the HIV virus.

But the ultimate failure of early trials quickly began to reveal the lethal strength of HIV: a fast mutation process that creates incredible genetic diversity. One study found antibodies in unvaccinated HIV patients to be six months behind the quickly mutating viral infection.

"It's very frustrating," Mayer said. "To get to that point, you're putting in a lot of effort, and then the review board says, 'There have been enough infections compared to the placebo, we don't think this is going to work.' You have to stop the trial. That's always very disappointing."

In 2007, Merck researchers attempted to implement a new technique, aiming to stimulate T cells instead. The sibling of the B cell, T cells attack the virus themselves instead of producing antibodies to attack the virus.

The trial ended in devastation. Enlisting over 3,000 participants, the study found that the experimental vaccine had increased the odds of infection. Leaving a permanent scar on the already battered HIV community, no other research group has attempted to create another T cell HIV vaccine.

Persevering, the National Health Institute (NIH) and Johnson & Johnson spearheaded a new "mosaic" approach, attempting to elicit a response from a large number of specific B cells. While still limited in scope, this method attacks much more of the HIV mutations than earlier vaccines.

Nearly three decades after the first documented case of HIV, the NIH, with its Thai partners, announced the first successful results of an HIV vaccine trial. With an efficacy of 31.2 percent after 42 months, the 2009 trial marked the first statistically significant efficacy for an HIV vaccine but did not meet the 50 percent threshold for vaccine approval. Both the NIH and Johnson & Johnson tried and failed to improve upon these results, in 2020 and 2021 studies respectively.

In February 2021, Scripps, a California- and Florida-based vaccine research company, announced they had successfully produced preliminary results in a new technique dubbed the "holy grail" of HIV vaccine research. Instead of targeting specific B cells, they sought out to precisely target a rare type of B cell that produces a wide range of highly adaptable antibodies, beating out the virus's mutations.

In the same press release, Scripps announced a partnership with Moderna. Instead of using a weaker virus to produce the viral target proteins from DNA, Moderna encodes the proteins into messenger RNA, which uses the existing machinery of the human body's own cells to create the targeted proteins. With easier manufacturing processes, mRNA technology provides greater freedom and flexibility to vaccine developers. Mayer is hopeful for the new technology.

# THE SUPER COLD

BY LILLY SCHAR, BIOLOGY & ENGLISH, 2025

**O**n a college campus populated by a fully vaccinated and COVID-cautious student body, having a coughing fit in the middle of a lecture feels like a crime against humanity. Such a fit is often followed by whispers of “it’s not COVID, I promise! I was just tested!” and attempts to reassure surrounding students that they are safe. But after only a few weeks with 13,000 students on campus, the resounding question became *why does it feel like everyone is sick?* The answer might not come as a surprise, but it will surely feel frustrating. Simply put, while we spent two years isolating ourselves to evade COVID-19, our innate immunity was weakened through drastic lifestyle changes and irregular exposure to common viruses and bacteria.

Humans harbor two different kinds of immune systems: innate and adaptive. The adaptive immune system has a delayed activation after a pathogen enters a host. Conversely, the innate immune system activates immediately after a pathogen is detected and helps facilitate the work of the adaptive immune system, making it a necessary and fundamental factor in a host’s defense. In a healthy person, the two immune systems work in harmony to successfully protect and defend the host from harmful pathogens. Sometimes, exposure to pathogens aids in strengthening the immunological response, or the ability for both immune systems to recognize a pathogen from previous infections and destroy it more efficiently.

Beginning in March 2020, most of the world entered a mandated lockdown, and for the next 18 months, no one was able to socialize in conventional ways. While these



lockdowns and self-imposed quarantines were effective in flattening the COVID-19 curve, there is now evidence of adverse consequences. Without a regular winter of crowded public transportation, holiday travel, and the general mixing of people in public spaces, individuals across the world have suffered from a lack of exposure to seasonal respiratory illnesses. This has contributed to weakened innate and adaptive immune responses. Now, with universities, public transportation, clubs, concerts, offices, and more reopening at nearly full capacity, the human population has transitioned from virtually no exposure to extensive exposure. In addition, the average college student’s lifestyle has further suppressed immunity through irregular sleep patterns, unhealthy diets, anxiety, and excessive drinking — all factors that weaken the immune system. Not only has the level of exposure to pathogens increased significantly, but due to missing out on the cold and flu season last year, immune systems have to work extra hard to rid the body of common respiratory illnesses. Thus, this year’s common cold feels especially grueling. This year, the onset of fatigue is a particularly notable symptom that is causing people to stay home from school and work. Such fatigue is the result of the immune system working overtime to kill pathogens.

So, what can be done? After eliminating the possibility of a COVID-19 infection, how does one treat the “worst cold ever?” Unfortunately, the common cold must go away on its own. Over-the-counter decongestants and anti-inflammatories can help alleviate symptoms, but curing the common cold this year is no different than curing a cold two years ago. Lifestyle changes such as going outside, exercising, and maintaining a healthy diet can certainly promote a stronger immune system. But the bottom line is this: if you have a cold, know that you are not alone and take extra care of your body and mind. Go forth with the knowledge that next year’s cold and flu season may be less extreme because our immune systems will be better adjusted.

# THE TINY ORGANISMS POSING A GIANT THREAT

BY ELANA VON DER HEYDEN, BEHAVIORAL NEUROSCIENCE, 2024

DESIGN BY PARKER HITT, BIOLOGY, 2024

**A**mong the many increasingly complex medical developments made since the start of the twentieth century, one discovery stands out among all the rest: antibiotics. Today, antibiotics may not seem to be such a wonder, yet their discovery — beginning with the isolation of penicillin in 1928 — has been revolutionary to medicine and global health. In the United States, antibiotics single-handedly changed the leading cause of death from communicable, infectious diseases to non-communicable diseases, including cardiovascular disease, stroke, and cancer. However, despite the overwhelmingly positive clinical outcomes, antibiotics may lose efficacy due to an emerging threat: antibiotic resistance (AMR). The antibiotics that have been successfully prescribed for decades are becoming increasingly less effective due to genetic mutation and the inheritance of resistant genes vertically and horizontally through species. Not only does this pose a serious public health threat, but due to the evolving nature of the problem, current solutions are scarce and mostly unsustainable.

At a microscopic level, numerous factors influence a strain's ability to become resistant to antibiotics. While some strains of bacteria are naturally resistant to specific antibiotics, others gain resistance through genetic mutation or horizontal gene transfer. Genetic mutations include drug inactivation and alteration of the target binding site. Bacteria, like all organisms, evolve to promote the long-term survival of the species. By inactivating the bacterium's intracellular enzyme that is targeted by antibiotics, the bacteria lose susceptibility.

Similarly, bacteria can change the target binding site to which the antibiotic binds on the bacterium cell body. Mutations such as these are then passed onto offspring, making progenies equally as impervious. Moreover, bacteria can horizontally transfer genetic information, a process in which they convey genes to other bacteria that are not their offspring.

Despite genetic circumstances that have permitted bacteria to become such resilient organisms, humans have played a role in the accumulation of AMR as well. As Alexander Fleming, the man who discovered the first antibiotic (penicillin), correctly predicted "the public will demand [the drug]... then will begin an era...of abuse." Numerous countries have no regulations on the use of antibiotics, leading to overuse. Contributing to the overuse of antibiotics is the incorrect application of them; it is estimated that 30 percent to 50 percent of cases in which antibiotics were used were

either the wrong prescription or superfluous altogether, according to a 2015 article in *Pharmacy and Therapeutics*. With every low dosage of antibiotics prescribed, there is a risk of the strain receiving a genetic mutation that promotes resistance. Another major factor contributing to increased AMR is our use of antibiotics in the agricultural industry. Additionally, according to the 2015 article, approximately 80 percent of antibiotics sold are used in livestock to aid growth and prevent infection—livestock which is then consumed as food by humans. Thus, AMR transpiring in livestock is consequently transferred to humans.

Many countries, realizing the threat AMR poses, have started implementing various regulations on antibiotic use for livestock. The European Union has effectively seen a decline in rates of AMR due to these regulations, and, despite these trends, the United States has instituted far fewer parameters on antibiotic use than necessary.

Educating patients, the general community, and more thoroughly educating clinicians on the dangers of AMR is also a necessary measure to stop the inappropriate use of antibiotics. Education should also include information about preventative measures, such as the importance of vaccines, good personal and food hygiene, and environmental health. For clinics and hospitals, academic stewardship programs have been proposed, which are programs that would implement improved methods of care that would subsequently lower infection rates (and thus the need for antibiotics).

Lastly, research and the development of new antibiotics have been a focal point of the AMR crisis. Until now, many research institutes and pharmaceutical companies have been responding to resistant strains of bacteria by developing new antibiotics that can target

a species of bacteria. However, this solution is unsustainable due to high costs and the low financial reward correlated to this endeavor. The FDA must get involved to facilitate the research and development of antibiotics and improve the ambiguous guidelines that exist for clinical trials.

Despite the general resilience of bacteria, humans play a significant role in promoting resistance, and until we can successfully inhibit resistance among bacteria, we must change our policies, regulations, and methods of care in the interest of global health and human longevity.

PHOTO BY SHUTTERSTOCK

# Pick your poison: It's easier than you think

**O**n September 7th, 1978, Georgi Markov, a Bulgarian dissident of his country's communist regime, was assassinated on a London street. His thigh was injected by a specially modified umbrella with an engineered pellet containing a lethal dose of the poison ricin. He died without a final diagnosis a few days later, and the murderer remains unknown.

Poisons are compounds that can cause harmful disruptions to the body, with effects ranging from nausea to death. Though any substance can be poisonous when enough is in the body, the speed and amount with which a poison acts depend on its pathway into the bloodstream and its chemical characteristics. According to "Management of Poisoning: A Handbook for Health Care Workers," this can be through ingestion, inhalation, absorption through the skin, or injection.

Given the many different mechanisms poisons can damage the body, including drug overdose, detoxification from such substances often requires medical intervention. The body has its own natural protection against toxins largely through the liver's filtration of the blood from toxic byproducts of broken down drugs or alcohol, but concentrated poisons easily overwhelm these regular filtration systems. While poisons are often recorded in history as means for murder, many are found in our daily lives.

In 2002, the FDA approved Botox (Botulinum toxin-A) for the cosmetic purpose of temporarily reducing wrinkle lines. Botulinum toxin is the most poisonous biological substance known, attacking the body's nerves and causing difficulty breathing, muscle paralysis, and even death. A 1981 paper published in *Transactions of the American Ophthalmological Society* first demonstrated the effectiveness of botulinum toxin type A, a

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While poisons are often recorded in history as means for murder, many are found in our daily lives."

specific version of the toxin produced by the same bacterium, for managing strabismus, a condition of the eyes not lining up with one another. It was later approved for many other conditions. In fact, it is used in almost every sub-specialty of medicine, according to a 2010 paper published in the *Indian Journal of Dermatology*. *Clostridium botulinum*, the bacterium that makes botulinum

toxin, is found naturally in many places. These bacteria make spores, which act like protective coatings and help them survive in extreme conditions. While these spores usually do not cause illness even when ingested, certain conditions like "improperly home-canned, preserved, or fermented foods" can cause them to grow and create this incredibly lethal toxin. According to the CDC, though it is rare, this bacterium can cause the severe illness botulism. The 2010 paper describes botulinum toxin as a neurotoxin that interferes with neural transmission by blocking acetylcholine release. As this neurotransmitter plays a significant role at the neuromuscular junction, its inhibition in activity causes muscle paralysis. Despite its alternative use in medicine and cosmetics, this toxin is incredibly dangerous, with its median lethal dose for humans estimated at two nanograms of botulinum toxin per kilogram of body weight when inhaled. This is only three times greater than in foodborne cases, as reported by the World Health Organization.



According to BBC News, the Japanese delicacy fugu, or pufferfish, is so poisonous that for decades, Tokyo chefs who prepare it have been strictly licensed. Obtaining a license takes at least two years of training, which is followed by a test failed by a third of applicants. A 2016 paper published in *Fundamentals of Toxicology* reports that as little as one to four milligrams of the toxin can kill an adult. When preparing pufferfish, chefs intend to get a small dose for mild tingling effects without the more serious symptoms of poisoning.

This poison is tetrodotoxin, a potent neurotoxin named after the Tetraodontiformes order which includes pufferfish, porcupinefish, ocean sunfish, and triggerfish. According to a 2021 article published by StatPearls Publishing, cooking does not destroy the toxin because it is heat-stable. The 2016 paper explains that tetrodotoxin causes paralysis by affecting sodium ion transport in the central and peripheral nervous systems. This prevents the nervous system from communicating and muscles from contracting. Higher doses produce nausea, vomiting, respiratory failure, difficulty walking, extensive paralysis, and death. Tetrodotoxin poisoning is rare in the United States, but a recent U.S. report indicated several cases of people who caught and consumed pufferfish with elevated levels of these toxins and suffered its effects.

For centuries, poisons were studied for their applications in medicine. Learning about their behaviors continues to push our knowledge of the human body's resistances and weaknesses. Though we continue to apply our knowledge of poisons to medical interventions, cosmetics, and other aspects of our lives, we should consider whether or not the risks are worth taking.

# From foreign to familiar

The functions of the female immune system during pregnancy

BY JOSEPHINE DERMOND, UNDECLARED, 2025

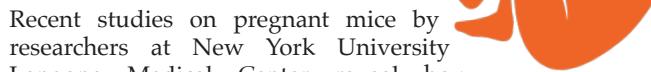
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

**T**he human body is an incredibly complex network of cells and efficient pathways. This network constantly adjusts to maintain homeostasis during life changes—with pregnancy as one of the most drastic. So, what happens when a body must sustain a fetus over nine months? How can an embryo with foreign antibodies develop inside the body? During pregnancy, female bodies undergo exceptional changes to acquire fetomaternal tolerance—an active, yet unresponsive reaction to specific antigens on the embryo. This immune tolerance has prompted several medical studies and developments that could improve organ transplant success rates, understanding of tumor persistence in cancer, and autoimmune disease treatment.

The placenta functions as a vital intermediate structure between the mother and her offspring, serving as the lifeline for the developing fetus. After fertilization, the zygote begins cell replication and leaves the fallopian tube to mature into a blastocyst. If the blastocyst implants, the placenta attaches to the uterine wall. The umbilical cord connects the placenta to the developing fetus, delivering nutrients and oxygen and removing toxic waste products. These components are essential; improper function, implantation, or detachment of the placenta can result in several complications like preeclampsia, gestational diabetes, miscarriages, and stillbirths.

Embryonic tissues and the placenta are semi-allogeneic, meaning they contain cells that don't entirely genetically match the mother. This prompts the question: how does this foreign tissue grow inside of another human and surpass the mother's immunological barriers? Normally, genetic variation between organisms results in different antibody expressions. When disparate antibodies are encountered by immune system cells, a response occurs through a cascade of protein signaling pathways that lead to the production of immune cells. As a part of the innate immune response, natural killer cells, a subset of immune system T cells, are responsible for attacking foreign tissues on mucus-lined membranes inside the body, like the uterine wall. However, when the semi-allogeneic blastocyst implants into the uterine lining, maternal-fetal rejection of the embryo doesn't occur.

Interestingly, uterine natural killer (uNK) cells are still present within the uterus throughout pregnancy and act as immune protectors to maintain a microenvironment that supports fetal development. uNK cells support embryonic growth by causing initial inflammation in the uterine lining vital for implantation. Afterward, uNK cells do not attack the semi-allogeneic placenta or embryo.



Recent studies on pregnant mice by researchers at New York University Langone Medical Center reveal how the female immune system adapts to obtain fetomaternal tolerance while still protecting the mother and the embryo. They discovered that survival of the semi-allogeneic placenta and maturing embryo is a consequence of T cell and uNK cell inactivity in the embryo and structure surrounding the placenta. To prevent the action of these immune cells, the chemokine genes that activate uNK cells and T cells are disabled at the onset of pregnancy. Foreign antibodies from the fetus and placenta are responsible for altering the expression of chemokine genes in the decidua. Also known as epigenetic modification, the deactivation of chemokine genes in the decidua prevents the production of T cells and uNK cells, creating a safety zone for the semi-allogeneic placenta and fetus. Therefore, the mother can sustain the fetus without an immune system attack.

How does this foreign [embryonic] tissue grow inside of another human and surpass the mother's immunological barriers?"

Beyond understanding how fetomaternal tolerance works, this research has many applications. Maternal immune tolerance research can provide insight into tumor growth and survival, improve cancer and autoimmune disease treatment, and boost organ transplantation success rate. Using the findings from the mice study, Jessica Weaver and her team at Arizona State University are making huge strides towards improving health using immune biomedical technology. Weaver and her team are developing a vaccine using the science of fetomaternal tolerance to eliminate the need for prescribed immunosuppressive drugs for organ transplant patients. The vaccine would alter immune response and prevent the body from attacking a foreign organ. Nevertheless, complications in pregnancy-related to failures in fetomaternal tolerance or embryonic damage raise concerns regarding the efficacy of this potential medical technology. Pregnancy loss related to failures in the maternal immune response stirs debate about relying on fetomaternal tolerance science for the vaccine.

Ultimately, further research to better understand fetomaternal tolerance and why it is not always successful could improve pregnancy success rates and support studies for autoimmune diseases, cancer treatment, and organ transplants. As new research emerges about fetomaternal tolerance, the scope of biomedical immune technology expands beyond supporting new life, additionally facilitating the design of novel treatments and innovative medical techniques.

*Science* (2012). DOI: 10.1126/science.1220030

*International Journal of Developmental Biology* (2014). DOI: 10.1387/ijdb.140109ss

# CAR-T cell therapy

## How we turned our bodies into weapons

BY CLAIRE MA, HEALTH SCIENCES, 2026

**C**ancer has been around for as long as humans have. The oldest known case of cancer comes from a bone dating back 1.7 million years ago from South Africa. Its earliest written record comes from ancient Egyptian physician, Imhotep, in which he characterizes an incurable malady that was “bulging and spread all over the breast.”

While solid tumors, like breast cancer, are removable with surgery, blood cancers constantly move around the body, making it impossible to isolate. Blood cancers also target the immune system, leaving the body with no protection and vulnerable to other infections. Chemotherapy, the use of chemicals to treat disease, is good at killing cells but not good at distinguishing between healthy cells and cancerous cells.

But could scientists use human cells as a weapon against cancer? William B. Coley from the Bone Tumor Service at Memorial Hospital in New York is regarded as the father of cancer immunotherapy research. He found that by harnessing the immune system’s natural processes, cancers could be forced into remission. In an experiment, he injected a weakened strain of *Streptococcus pyogenes* into patients’ tumors and activated an immune response, thus achieving durable remissions in a wide variety of cancers. One of the fastest emerging and most promising subsets of immunotherapy is a concept that builds off of Coley’s. Cells from the patient’s immune system are extracted and hijacked to target and kill cancer cells. One of these treatments, chimeric antigen receptor (CAR) T-cell therapy, has shown great promise, particularly in blood cancer.

First-generation CAR T-cells could not persist in the body because none of the identifying molecules that were essential for eliciting an immune response from the T-cells were present. Without them, the first generation was ineffective. The second generation — created in 2002 — consists of two parts: the T-cell receptor component and the antibody component. The T-cell component can signal heavily for neutrophil production, which creates specialized white blood cells that kill cancer. The antibody component helps target the cancer cells by latching onto the identifying proteins found on the cancer.

The procedure for getting CAR T-cell therapy is extensive. First, patients have their blood drawn, in which only the white blood cells are collected. These cells are then sent to the lab, where they are engineered to target specific tumor cells. The patient must undergo a round of chemotherapy to cleanse their body of their old T-cells. The patient further receives infusions with the new T-cells, which now attack and kill the cancer cells.

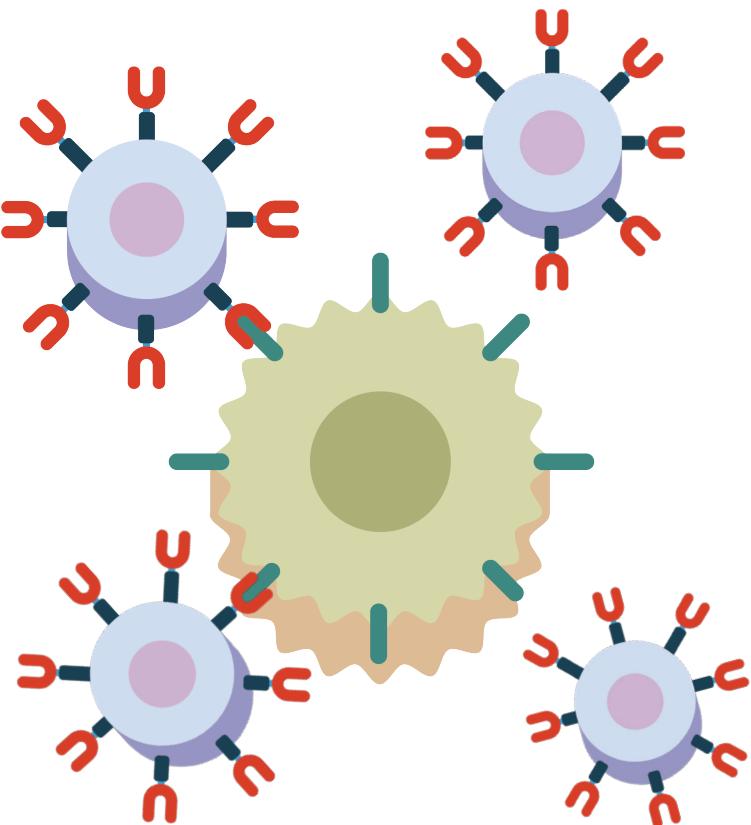
In 2014, the FDA named CAR T-cell therapy a “breakthrough therapy” in treating cancers. After several years of research,

in 2017, two CAR T-cell therapies were approved: one for acute lymphoblastic leukemia and another for advanced large B-cell lymphomas in adults. Although success rates are high and a cure seems promising, multiple side effects need to be monitored.

CAR T-cell therapy can induce excess production of inflammatory molecules called cytokines. This can lead to a potentially fatal side effect called cytokine-release syndrome. Sometimes the symptoms are flu-like. Other times, symptoms include hypoxia (oxygen deficiency), capillary leakage (leaking of the smaller blood vessels), multiple organ failure, and neurological toxicities (including hallucinations, seizures, and confusion). Macrophage activation syndrome can also occur in people with autoimmune disorders, leading to over-multiplication of T-cells and macrophages, which — although treatable with antibodies — cause a great amount of pain and discomfort for patients.

Despite its problems with toxicity and its relative newness, up to 90 percent of people who underwent CAR T-cell therapy are in remission. Relapses have been shown to occur, but with further research, CAR T-Cell therapy can become a promising cancer treatment. Although only two treatments are currently approved, researchers have started to study CAR T-cell therapy with other cancers like multiple myeloma and chronic lymphocytic leukemia.

Without a doubt, these therapies have revolutionized the cancer battlefield. The puzzle is not impossible, but scientists continue to remain headstrong.



# Miracle Pill?

Molnupiravir could be the key to expanding global COVID immunity

BY REBECCA MCCONNELL, HEALTH SCIENCE & COMMUNICATION, 2024  
DESIGN BY DIVYA RAVIKUMAR, BIOENGINEERING, 2025



**W**ith a student vaccination rate of 99.6 percent, according to Northeastern's Life Sciences Testing Center and the Broad Institute, it's easy to forget that we are living through a public health crisis. For many students, the ongoing COVID-19 pandemic has become somewhat of an afterthought; aside from weekly visits to Cabot and masking in public buildings, things are essentially back to normal, or rather the "new normal." However, this sort of normalcy isn't a luxury afforded to all.

Across the globe, thousands of COVID-related deaths occur each day, along with hundreds of thousands of more infections. Though vaccine distribution has, in some wealthier nations, aided in lessening the burden of disease, many low- and middle-income countries remain — for lack of a better term — at square one. Countries in sub-Saharan Africa and the Middle East have fallen far behind the rest of the world, with many missing the vaccination target of 10 percent at the end of September, according to the World Health Organization. *But, why?*

The answer is simple: these countries lack the financial resources and basic healthcare infrastructure that have enabled countries like the United Arab Emirates, Spain, Singapore, and Canada to achieve vaccination rates as high as 90 percent, according to the *New York Times*. With COVID-vaccines being sold to governments by manufacturers at a rate of around \$30 per dose, as reported by NPR, poorer nations (with populations in the millions) can't afford large-scale immunization. Even still, if vaccines are afforded or donated, distribution itself remains a barrier. Per CDC guidelines, both Pfizer and Moderna have strict temperature regulation standards (between -90 and -60 degrees Celsius, and -50 and -15 degrees Celsius, respectively) that enable the efficacy of the vaccines. In countries where many health clinics lack electricity and where healthcare workers are scarce, the widespread distribution of properly-handled and properly-administered vaccines is almost inconceivable.

But a solution could be in sight. Pharmaceutical giant Merck (maker of the NuvaRing, and the HPV vaccine Gardasil), in

partnership with Ridgeback Biotherapeutics, has recently announced that *Molnupiravir*, a new antiviral COVID pill, has concluded clinical trials and is currently awaiting approval for emergency use authorization. According to a recent press release by Merck, Molnupiravir was shown to "reduce the risk of hospitalization or death by approximately 50 percent," and with such promising results, distribution could begin within the coming year.

From a public health perspective, what distinguishes Molnupiravir from the more well-known Pfizer and Moderna vaccines is its method of administration — oral, as opposed to subcutaneous. Because the drug is in pill form, its temperature regulation range is much more forgiving and, instead of visiting a vaccination site, the five-day regimen can be taken by patients at home. Without the need for high-tech, low-temperature medical refrigeration equipment or even medical professionals to administer the drug, Molnupiravir could provide an effective alternative to traditional COVID vaccines. But the question remains: *who will pay, and how?*

**"Without the need for high-tech, low-temperature medical refrigeration equipment...Molnupiravir could provide an effective alternative to traditional Covid vaccines."**

In a display of altruism, Merck and Ridgeback have agreed to license the drug formula to Indian manufacturers who will create a generic version of the pill. This licensing agreement — which both Pfizer and Moderna rejected — will cost Merck and Ridgeback billions of dollars but will allow for reduced treatment costs in lower- and middle-income countries. According to Harvard public health scholars Melissa J Barber and Dzintars Gotham, the contract will allow for the expected cost-per-treatment to plummet from over \$700 to under \$20 per person for the five-day regimen. Though still not trivial, the discounted price will be much more manageable for lower-income governments and will be critical in ensuring the drug's acquisition and subsequent distribution. For low- and middle-income countries, Molnupiravir could be a step in the right direction to close the global health gap that has been further exacerbated by COVID-19.

# A NEW HOPE FOR A PREVIOUSLY INCURABLE DISEASE

BY NICHOLAS LOFASO, UNDECLARED, 2025

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

**I**t has cost millions of dollars in research and made appearances in countless books and movies over the past 100 years. Sickle cell disease (SCD), first described in 1921, is a genetic condition with over 300,000 people born with it every year worldwide. The disease is caused by a mutation in hemoglobin, or proteins in red blood cells that carry oxygen to different parts of the body. People with SCD have hemoglobin that stick together and polymerize, creating long strands in red blood cells that morph into the sickle shape the disease is named for. Sticky hemoglobin doesn't just cause differently-shaped cells, though; the red blood cells don't properly distribute oxygen across the body, leading to frequent hospitalization, blood transfusions, and often premature death.

Existing treatments help some patients, but they are often ineffective, expensive, and fail to address the root of the problem: the mutated and inefficient hemoglobin. This is where CRISPR comes in. A relatively new technology for editing DNA, CRISPR-based therapies and medicines have the potential to revolutionize treatment for diseases that previously had few treatment options. By editing DNA, there are many different ways to potentially cure someone of the disease and restore their red blood cell functionality.

In 2018, CRISPR Therapeutics and Vertex Pharmaceuticals, two biotech companies located in the Boston area, began a clinical trial targeting patients with SCD. Their treatment works by tricking patients' bodies into producing fetal hemoglobin, a certain type of hemoglobin that is typically only produced before birth. Scientists thought this would be easier to do rather than attempt to edit the mutation out of adult hemoglobin. In a 1974 paper published by *The Journal*

of *Clinical Investigation*, researchers noticed that some patients with both the mutation for SCD and sickle-shaped red blood cells didn't have the typical symptoms of the disease. They found that these patients' fetal hemoglobin levels were much higher than most adults, meaning that their bodies never stopped producing fetal hemoglobin. While researchers didn't know why at the time, they saw that these patients lived with few to no SCD complications, meaning that the fetal hemoglobin alone was delivering enough oxygen to keep them healthy.

**“In nearly every way, they've been essentially cured of sickle cell disease.”**

When researchers looked deeper, they found that the gene *BCL11A* is responsible for turning off fetal hemoglobin expression post-birth. For *BCL11A* to be turned on, suppressing fetal hemoglobin, both its promoter and enhancer must be activated. People with these elevated fetal hemoglobin levels have a mutation in the *BCL11A* enhancer found exclusively in red blood cells, since every cell type has a different enhancer for the gene. This means that *BCL11A* never gets activated, and fetal hemoglobin continues to be produced into adulthood.

This mutation is the basis of the 2018 clinical trial. The teams at CRISPR Therapeutics and Vertex Pharmaceuticals use CRISPR-Cas9-based gene-editing technology to destroy this enhancer, allowing patients to produce fetal hemoglobin and hopefully live as if they never even had SCD. More specifically, they extract stem cells from patients, filter out hematopoietic stem cells (blood cells before they're differentiated), and



edit these cells to destroy the *BCL11A* enhancer. While this editing process is ongoing, the patients are treated with chemotherapy to destroy some non-edited stem cells and weaken the immune system so it won't attack the edited cells once they're implanted. After ensuring that the edited cells are safe, doctors re-implant them into the patients.

The first results of this trial were released in June 2021 and were truly remarkable. Seven patients were treated, and all seven showed improvements. They had much higher levels of fetal hemoglobin, no longer required regular transfusions, and had no hospitalizations. In nearly every way, they've been essentially cured of SCD.

This treatment isn't even the only one in development for SCD, though. In another high-profile trial, researchers at the University of California, San Francisco's Benioff Children's Hospital led by Dr. Mark Walters, a pediatric hematologist-oncologist, are working on a new method.

This treatment doesn't focus on fetal hemoglobin; rather, it attempts to repair the mutation in the adult hemoglobin gene, which would see patients start producing normal, non-polymerized hemoglobin that no longer causes red blood cells to have a sickle shape. This study is scheduled to start on December 1 of this year.

CRISPR treatments may be new, but they're already proving themselves to be some of the best tools we've ever known to treat genetic diseases, breathing new hope into places where there was little to none before.

# Eating away at the immortality of plastic

BY ELI PAUL, MATHEMATICS &amp; BIOLOGY, 2024

DESIGN BY KAI GRAVEL-PUCILLO, ENVIRONMENTAL SCIENCE, 2022

**T**raveling back in time 500 years, one would witness the fall of the Aztec empire and experience the Age of Discovery: events that seem like an eternity ago. That is to say, 500 years is a long time. What will the world look like 500 years in the future? Maybe we will have colonies on Mars or the Moon and advanced energy technologies that harness fusion and solar power. It is also likely that the plastic water bottle you have been carrying around for the last week is sitting in a pile of other plastic at the bottom of a landfill.

Common plastics can remain intact for hundreds of years due to their characteristic carbon-carbon bonds that require heaps of energy to make and break and are essentially impossible to form or break in nature. Cheap production and versatility, however, make plastic one of the most prevalent materials. Though some plastics can be recycled, negligence and a dysfunctional system cause most to wind up in landfills or littered around the ecosystem, where they slowly melt over hundreds of years and release toxic residue.

**“ Plastic debris continues to emerge as one of the leading causes of death for many animals.”**

The most well-known effect of plastic pollution is the impact on marine ecosystems. Landfill overflows and plastic waste in sewage systems transport plastic to marine environments worldwide where organisms can easily entangle themselves, restricting movement or making them easy targets for predators. Many organisms also mistake food sources with plastic and ingest it, which can block the intestinal tract and cause reproductive failure. The amount of plastic found in marine ecosystems is steadily increasing over recent decades as more is produced, wasted, and never removed from the environment. As highlighted by a study by W.C. Li at the Hong Kong Institute of Education, despite increased regulations to reduce the hunting of whales, dolphins, and other endangered organisms, plastic debris continues to emerge as one of the leading causes of death for many animals.

Plastics buried in landfills also have less familiar impacts on the environment: detrimental effects on soil. Maintaining sail quality is important for numerous organisms, including humans who rely on soil for food, construction, and medicine. Just as in marine

environments, organisms living in soil will eat plastic. Plastic films in the soil also tend to dry the soil, negatively impacting the growth and health of agriculture. Plastic material in soil is surprisingly motile despite being buried underground, as rainwater contributes to the movement of debris and growing plant roots push it through the ground, eventually pushing plastic into aquifers and other bodies of water. The enduring effects of plastic in the environment have forced many researchers to search for an efficient way to degrade common plastics before ecosystems are irreversibly damaged.

Until a study by environmental scientist Jun Yang at Beihang University in 2014, it was thought that the only way to degrade plastic was by exposing it to high levels of heat, which takes upwards of 500 years. The study observed that Indian meal moths, or waxworms, were capable of eating and digesting polyethylene (PE) films — currently the most used plastic. Their experiment isolated two bacterial strains found in the gut of waxworms to see if they could efficiently degrade PE films, attempting to grow bacterial colonies with PE films as the only food source. After 28 days, they observed significant growth of both bacterial strains, indicating both strains could digest and degrade PE films. The researchers subsequently found that the weight of the PE films decreased and deformations were visible using electron microscopy after the 28 days, further proving these bacterial strains were capable of degrading plastic. Recently in Indonesia, a different strain of bacteria was discovered that has enzymes capable of degrading Polyethylene terephthalate (PET), another common plastic used mainly in water bottles.

These bacterial strains instill confidence that an efficient method of plastic degradation is around the corner. For example, as the gene-editing tool CRISPR develops, it may be possible to enhance these bacterial strains for more efficient plastic degradation or degradation of different types of plastics. Until then, cutting plastic usage and properly recycling remain the best ways to protect our ecosystems so that in 500 years, plastic in landfills does not nullify the advancements of humanity.

*Environmental Pollution* (2018). DOI: <https://doi.org/10.1016/j.envpol.2018.05.008>

*Science of The Total Environment* (2016). DOI: <https://doi.org/10.1016/j.scitotenv.2016.05.084>

*Environmental Science & Technology* (2014). DOI: <https://doi.org/10.1021/es504038a>

PHOTO BY SHUTTERSTOCK

# BRHEARTKEN HEART SYNDROME

BY MAYA BRINSTER, BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY JASMIN PATEL, BEHAVIORAL NEUROSCIENCE, 2025

The metaphor “brokenhearted” is often loosely used to describe someone experiencing various levels of emotional distress. This term, however, is not always a metaphor. In the case of Takotsubo Cardiomyopathy, more commonly known as broken heart syndrome, the heart rapidly weakens after undergoing extreme stress, causing people to suffer from a literal broken heart.

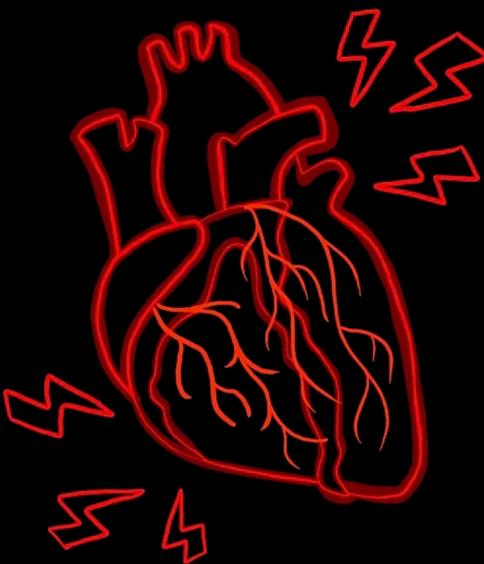
Broken heart syndrome is a temporary condition in which the heart fails to pump blood properly due to a change in the shape of the left ventricle, the heart’s main pumping chamber. In certain cases, extreme emotional or physical stress causes this change in shape. The body naturally responds to stress by producing hormones and proteins to counteract it. One important hormone that regulates stress is adrenaline which triggers the body’s fight-or-flight response in the presence of a possible threat, such as a stressful or frightening event. Adrenaline functions by raising energy supply, blood pressure, and accelerating the heart rate. If excess adrenaline is produced, the small arteries that supply the heart’s blood may restrict, limiting the amount of blood flowing into the heart and ultimately causing broken heart syndrome. Extreme emotional events that essentially stun the heart could trigger these changes. Such events may include car accidents, intense fear, a sudden drop in blood pressure, or domestic violence. Even positive events such as winning the lottery or an overwhelmingly exciting surprise can cause a broken heart.

The syndrome is often mistaken for a heart attack because the main symptoms are similar to those of a heart attack. Both afflictions involve shortness of breath, intense dizziness, severe and sudden chest pain, and excessive sweating. Unlike heart attacks, broken heart syndrome does not involve the obstruction of the coronary artery. It also causes abnormal movements in the left ventricle of the heart. This ballooning causes the left ventricle to resemble a vessel used to catch a type of octopus called tako-tsubo, which is why “Takotsubo Cardiomyopathy” is another name for the syndrome.

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Although many of the symptoms of broken heart syndrome can be life-threatening, the condition may rapidly improve if patients receive proper care. Treatment depends on the severity of the symptoms, but most of the time standard heart failure medications can restore the heart’s normal conditions. These medications include water pills, beta-blockers, or aspirin if the patient’s symptoms include plaque buildup in the artery walls. Death and other complications such as abnormal heart rhythm, obstruction of blood flow, or complete rupture of the ventricle wall are possible outcomes of the syndrome but rarely occur. Normally, the ballooning of the ventricle wall clears within one to four weeks of diagnosis, and most patients fully recover within two months.



Not everyone is at the same risk of developing this syndrome, and it has been found that older women have a much higher chance of experiencing it. An article provided by the Cleveland Clinic reports that about 88 percent of all reported cases have been women between the ages of 58 to 77 years old. The hormone estrogen protects the heart from the effects of other potentially harmful hormones, but levels of estrogen decline in aging women. This could explain why older women are more prone to heart damage under extreme stress. Overall, the number of reported cases of broken heart syndrome is seemingly low. According to a study published in the *Journal of the American Heart Association*, 135,463 cases of the syndrome were reported in the United States from 2006 to 2017. However, these numbers may not be very accurate, as the condition is often mistaken for a heart attack.

Although there are currently no medical treatments to prevent this syndrome, people can reduce the chances of suffering from a broken heart by learning how to manage stress effectively, exercising regularly, eating healthily, practicing mindfulness, and taking time to relax.

# The extraordinary empathy of canaries' immune systems

BY SALMA ALAWI, COMPUTER SCIENCE & BEHAVIORAL NEUROSCIENCE, 2025

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

**A**nimals face numerous dangers, one of them being illnesses. Species have found a variety of ways to protect themselves from diseases, but not much is known about how they affect the physiological state of the individual. A phenomenon surrounding the immune systems of canaries was recently discovered by researchers at the University of Connecticut. The study showed that canaries kickstarted their immune systems simply at the sight of other sick birds.

To discover this, researchers split canaries into groups. They infected one group with *Mycoplasma gallisepticum* (MG), a bacterium that causes conjunctivitis and fatigue in birds. The researchers chose this specific bacterium because it has a notable effect on physical appearance: Infected birds appear extremely tired and their feathers look fluffed out.

The researchers then placed the infected birds in a separate cage so they couldn't infect the rest of the canaries. Then, they placed a group of healthy birds directly in front of the cage with infected birds. For around a month, the researchers collected blood samples from all the birds. Remarkably, as the infected birds appeared sicker, the immune activity of the healthy birds with a direct view of them increased. This was discovered by measuring the white blood cell count and the CH50 complement activity, which are signs of an immune response, in the canaries' blood samples. An immune response is typically launched only upon the discovery of

a bacterium or virus; however, the healthy canaries' immune systems showed a response despite never being infected during the experiment.

So, how do we know that this response was caused by seeing the other sick birds? The two control groups of healthy birds did not experience a significant change in immune activity. They were within earshot and smelling range of the infected birds, but without seeing the sick birds, the immune response never occurred. Therefore, the only healthy birds who experienced a significant increase in immune system activity were the ones in direct view of the infected birds.

Canaries are not the only organism who experience changes in immune activity at the sight of a sick individual. In fact, a similar reaction occurs in humans. A group of volunteers were shown images of either a stressful situation or a person who appeared to be very sick. Afterwards, the researchers took blood samples from the participants and discovered that those who were shown a picture of an ill person had a significant increase in IL-6, which is a protein produced by white blood cells during an infection.

This research can lead to further discoveries about how organisms protect themselves from diseases and how the immune system works.



## FAREWELL AND ALL THE BEST TO OUR GRADUATING SENIOR!



### Kaelen Encarnacion

Biology and English major Kaelen has been a part of NU Sci as a writer and editor for the past four years. It has been a wonderful opportunity for her to pursue her passions in science and writing simultaneously while getting to work with an extremely kind, passionate, and talented group of people. She is immensely grateful that NU Sci took her out of her comfort zone freshman year and gave her a supportive environment where she could develop her creativity and explore ideas outside of her major. She will miss it very much. After graduation, Kaelen will work in the biotech industry in Seattle and help develop therapeutics for patients in need.



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