ISSUE 46 Fall 2020

NU SCI

hindsight

Fall 2020

TABLE OF CONTENTS

LETTER FROM THE EDITOR

As we wrap up another calendar year, another semester, these closing months give us a chance to look back and reflect. 2020 has been one for the history books, perhaps a little too much history. It hasn't been an easy year for anyone, and there's some solace in sharing that, but why would anyone want to remember what happened this year?

This year was one where we saw protests for racial justice, devastating wildfires exacerbated by climate change, a monumentally important U.S. presidential election, and of course, a grueling pandemic on top of all of that. Despite all of this hardship, it's difficult not to stare back at the tumult. From Lot's wife looking back at the destruction of Sodom and Gomorrah to Orpheus looking back at Eurydice in the Underworld, it's only human nature to turn back and gaze upon what we ought not to. If we don't try to make sense of any of it, then what was it all for?

Hindsight is a meditation on looking back to look forward with clearer eyes. Yesterday is behind us; we can't go there anymore, yet we cannot forget it either. All learning is of the past but done in the present, so whatever we can salvage from the rubble can be used to rebuild a better future.

Our writers have taken their own backward glances and have critically inspected errors in past polling, faulty forensic science, time travel, and science (mis) communication. Mistakes and challenges are certainties in life, but it's the lessons we take from them that give the chaos meaning, and as always, NU Sci has created profound pieces to do exactly that.

I would be remiss if I did not look back at the phenomenal work our members continue to produce each issue and extend my appreciation for the fantastic efforts of our writers, designers, and photographers.

I hope we can all look back and be proud of ourselves — if not for what we've done, for where we are now or for where we will be.

Without further ado, please take a look back with us, as NU Sci presents "Hindsight."

Binh Dang
Editor-in-Chief

STAFF

Cover Photos:
Front by Ian Hay, Back by Brooke Arnold

A world without plastic?

The pros and cons of plastic

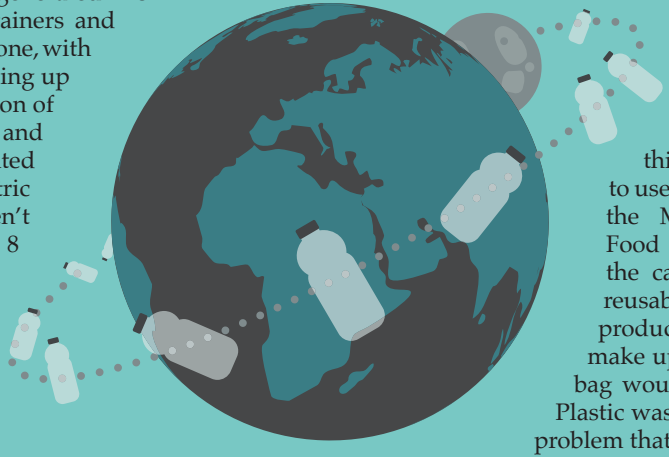
BY CAILEY DENONCOURT, BIOENGINEERING & BIOCHEMISTRY, 2022

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

Tea bags, coffee cups, clothing, soda cans, and gum are only a select few items that surprisingly all contain some form of plastic. The more obvious plastic water bottles, bags, electronics, and containers further display how humans live in a plastic-filled world. Although innovation and standard of living have greatly improved since its invention, plastic comes with some serious consequences, which raises the question: is a plastic-less world better than the current plastic-filled one?

Most plastics are categorized as polymers, consisting of repeating monomers with various side chains that allow for different physical and chemical properties. Plastic, with its many types and applications, engenders innovation at the expense of the environment and human health.

According to the United States Environmental Protection Agency, the U.S. generated 14.5 million tons of plastic containers and packaging in the year 2017 alone, with 70 percent of the plastic ending up in a landfill. The accumulation of plastic waste, domestically and internationally, has amounted to a total of 8.3 billion metric tons. However, landfills aren't the only problem. About 8 million tons of plastic are dumped into the ocean every year. The almost indestructible plastic releases harmful chemicals that poison the water, and floating waste is often ingested by aquatic animals, causing them to choke and starve.



The tremendous environmental impact of single-use plastics is killing the planet's wildlife along with the environment itself. Since humans are completely surrounded by and dependent on plastics, they are also negatively impacting themselves as they are exposed to toxins in them multiple times a day simply through the air, consumer products, food, and water. One major chemical, bisphenol A (BPA) is an industrial chemical that is used to make certain plastics and resins. This chemical is often found in the plastics of containers and water bottles, where it can seep into the food or liquid within. Because BPA disrupts the normal functions of the brains and prostate glands of fetuses, infants, and children, the FDA recommends using BPA-free plastic containers as well as avoiding heating plastic to prevent the possible breakdown that could release more BPA.

With so many damaging health and environmental effects it would seem plastic should be removed, but without plastic, the modern world would be nowhere near as innovative it as is today.

Plastic has helped keep food fresh longer, allowing for less food to go to waste and ultimately less methane to enter the atmosphere. Plastic has enabled the advances that we see in modern medicine, as many research labs use equipment and supplies that are made of various plastic materials. Plastic also helped with sterility. Because plastic is so cheap and easy to mass produce, personal protective equipment, such as gloves, are essential for working in the lab, and disposable syringes allow for the easy administration of millions of vaccines and other drug products. In addition, technological advancements would not be possible without plastic because its insulating properties allow for necessary wire insulation and computer motherboards.

Plastics compose essentials, but they also find themselves in convenience, an ease that comes at the cost of millions of gallons of fossil fuels each year. The simplistic solution to this environmental price would be to use reusable bags instead. However, the Ministry of Environment and Food in Denmark found in 2018 that the carbon footprint of producing a reusable bag is so much greater than producing a plastic one that in order to make up for this difference the reusable bag would have to be used 7,100 times. Plastic waste is not the only environmental problem that humans face, and trying to find replacements causes trade-offs like increasing carbon emissions or logging. Thus, rather than looking into alternatives, research has shifted into finding environmentally friendly ways to break down plastic. For instance, in a 2014 study in Beijing, researchers have been examining the possibility of degrading polyethylene using caterpillars from the wax moth, *Galleria mellonella.* Although the results are promising, more research into degradation efficiency needs to be conducted to support using the method as a feasible solution to the plastic problem.

To revisit the question — would the world be better without plastic? The answer is not as straightforward as some might have initially thought. There is much research to be done before a plastic-free world is imaginable, but the damage to the environment and humans themselves is forcing researchers to look into environmentally friendly alternatives and other creative solutions.

Environ. Sci. Technol. (2014). DOI: 10.1021/es504038a

PHOTO BY SHUTTERSTOCK

The search for *the Midas touch*

BY JASON DENONCOURT, CHEMICAL ENGINEERING & BIOCHEMISTRY, 2023

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

For centuries, alchemists, ancient forerunners of chemists, set out to transmute one element into another. This prospect attracted people of a variety of different professions from miners to natural philosophers to goldsmiths. Even physicians of ancient times grew interested in alchemy, as many saw the biochemical reactions within the human body as transmutational processes.

Today, alchemy is synonymous with a process known as chrysopoeia — the transmutation of a base metal, like lead, into gold. Alchemists believed that, along with traditional metallurgical practices, there was one unique ingredient required for chrysopoeia: the philosopher's stone.

Though sharing many similarities with the scientific method, alchemy was a science reflective of its time. With alchemists dating back far before the Gutenberg printing press — in times of limited intellectual exchange, religious dominance, and sovereign rule — the records of alchemy share greater resemblance to mythical stories than a modern, scientific journal. For instance, Chinese alchemists were known to have incorporated the fundamentals of *feng shui*, and European alchemists were known to have considered astronomy in their search for the philosopher's stone. Additionally, alchemists were notorious for secretly recording the procedures and ingredients of experiments in riddles, allegories, and pictures. This was likely strategic and presented alchemy more as a magic than a science, as the secret procedures helped to ensure successes and failures were kept private.

Though a philosopher's stone was never discovered and chrysopoeia was never achieved, alchemy and the quest to turn lead into gold has captured the imagination of people for centuries — a success in synthesizing the philosopher's stone meant a life of tremendous wealth and power. Ultimately, the failing of ancient alchemists was their rudimentary understanding of chemistry — years away from even a basic form of the periodic table. Much of their work was built on the false assumption to treat non-compounds, pure elements, like compounds. A pure metal is simply an element, not a hybrid, and cannot be transformed into a new substance under any conditions accessible to the ancient alchemists.

After years of failure and limited progress, alchemy was soon dismissed as a pseudoscience, and those associated with the practice were branded as charlatans. Despite a tumultuous history, alchemy did ultimately lay a foundation for physical science and chemistry. Though the end goal of alchemy was unachievable, alchemists were some of the first to think critically about the structure and formation of chemicals and compounds. Additionally, though record-keeping methods were often secretive, alchemists were true experimentalists, developing new techniques to achieve a scientific goal. Some of the most famous scientists in history were known to have had interests in alchemy, including Irish-born chemist Robert Boyle, Swiss-born physician Paracelsus, and English physicist Sir Isaac Newton.

With today's understanding of elemental structure, the transmutation of an element is actually possible and, in fact, very common. As an element is defined by the number of protons in its nucleus, the addition of a hydrogen atom, or proton, or the splitting of a larger element would result in a new element. For instance, in experimental fusion reactors, heavy isotopes of hydrogen merge to form helium, and in commercial nuclear reactions, uranium breaks down into xenon and strontium.

Chrysopoeia is also possible with today's technology. For example, over 30 years ago, scientists at the Lawrence Berkeley National Laboratory produced very small amounts of gold from bismuth, an element next to lead on the periodic table. This was achieved using a particle accelerator, where beams of carbon and neon nuclei slammed into bismuth at the speed of light. This optimized collision sheared off part of the bismuth nucleus, removing four protons. Since bismuth has an atomic number of 83, the removal of four protons resulted in the element that had 79 protons, which was gold.

Ultimately, bismuth was used as the starting material instead of lead because the final isolation of gold was easier. However, the dream of lead into gold is still possible and just as straightforward as bismuth into gold or mercury into gold, though even more expensive. The particle accelerator used in this experiment costs about $5,000 per hour. This corresponds to a cost over $1 quadrillion per ounce of gold, which far exceeds the going rate of less than $2,000 per ounce.

PHOTO BY PIXY

REENVISIONING QUANTUM PHYSICS:

THE CURIOUS SAGA BETWEEN GRAVITY AND SUPERPOSITION

BY ANNABELLE MATHERS, CIVIL ENGINEERING, 2022

DESIGN BY KAI GRAVEL-PUCILLO, PSYCHOLOGY, 2022

One of the tenets of quantum physics is the concept of superposition, which, like in the oft-lectured case of Schrödinger's cat, occurs when a particle exists in multiple states and locations at once. A common misinterpretation of the phenomenon remains that particles seemingly maintain this dual existence until observed. In fact, the particle's collapse of superposition into a single observable state is not due to human observation. The exact cause has been under scrutiny for decades, and even the widely favored gravity hypothesis has always faced skepticism. This skepticism reached a new high in a September 2020 study involving some of the very proponents of the gravitational explanation, throwing the entire concept of superposition into contention.

The idea that gravity limits superposition first rose to prominence in the mid-20th century through the work of physicists Károlyházy Frigyes and Lajos Diósi. Roger Penrose, a 2020 Nobel Laureate in Physics, greatly contributed to this idea as well and continues to investigate it in light of the new discoveries. The gravity hypothesis posits that, when a particle is in superposition, its gravitational field undergoes significant stress, as the field also must be in two places at once. Unable to withstand this physical state, the gravitational field collapses, eliminating the second particle state.

Unfortunately, the technological ability to detect and confirm this gravitational collapse remained nonexistent until recently; this issue has historically been a source of skepticism. A group of scientists, including Diósi, devised an experiment to measure the behavior of the particle and the gravitational field.

Spanning between 2014 and 2015, the experiment took place in the Gran Sasso National Laboratory in Italy, which lies 1.4 kilometers beneath the Earth's surface, far from large amounts of natural radiation. Avoidance of such external radiation was crucial in order to detect radiation emitted from particles in collapsing superpositions. Current understanding of physics requires that, upon gravitational collapse, particles move erratically, releasing energy in the process. When charged and moving, the particle emits radiation in the form of a photon. By observing a collection of particles, experts sought to amplify the radiative signal, finally creating a potential way to sense this gravitational behavior.

This collection of particles — in the form of a germanium crystal — emitted electrical pulses as a result of instances of elevated radiation from the germanium protons experiencing superpositional collapse. An outer layer of lead and an inner layer of electrolytic copper enclosed the crystal to further decrease exposure to unrelated, natural radiation. In particular, the scientists looked for the more amplified gamma rays and X-rays. They already knew that the rate at which the germanium atoms emitted these rays in all directions related to detectable energies released. After two months of experimentation, results were orders of magnitude smaller than expected, and the team only detected 576 photons released, which was very close to the natural radiative state of 506 photons. In other words, the team did not detect the sudden increases in energy expected with gravitational collapse; there was no evident link between the gravitational field and superposition.

It seemed simple, there was no significant increase in energy; therefore gravity, which required such energetic behavior, was not the answer to the collapse of superposition. This hypothesis had lasted decades and was seemingly gone in an instant, yet the results are not quite that simple. While the results of this experiment may not entirely eliminate the gravity hypothesis, they acknowledge a multitude of shortcomings: a continued lack of effective gravity-sensing techniques, the idea that gravity could conceal its behavior, and simply a lack of understanding of superposition. Scientists still do not completely disregard gravity, as hope remains that improved technology and unimagined methods can reinstate the hypothesis. Currently, experts are attempting to manufacture superpositions of large groups of particles so that they no longer have to depend on unobvious and natural radiative tendencies. The question of whether gravity, or another unnoticed interaction, conceals the energetic effects also remains relevant. Furthermore, the implications of energy loss through gravitational collapse might challenge energy conservation.

Although the gravity hypothesis faces many challenges, scientists are only more motivated to rework the supporting models and science. Questions and previously unnoticed behaviors brought forth by this experiment, contribute to another tenet of science — the simple persistence toward greater knowledge. Whether or not gravity is the answer, its consideration has enhanced the investigations of quantum physics and likely will continue to do so in the future.

Nature Physics (2020). DOI: 10.1038/s41567-020-1008-4

PHOTOS BY SHUTTERSTOCK

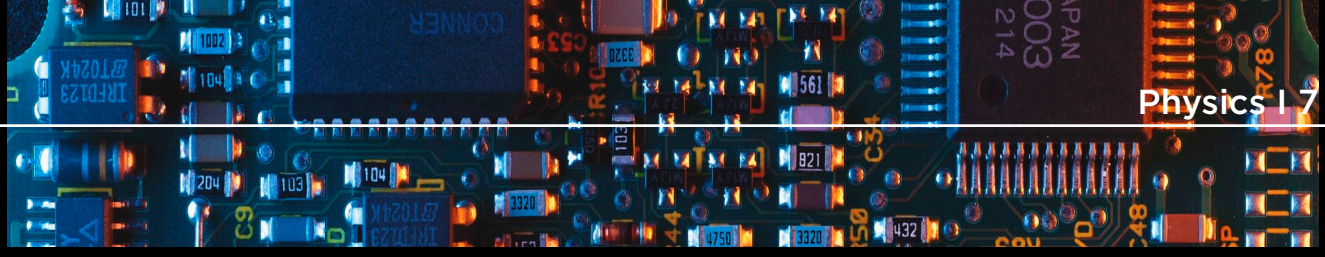


PHOTO BY UMBERTO

USING QUANTUM COMPUTING TO MAKE A 'VIRTUALLY' UNHACKABLE INTERNET

BY EMILY CHEN, DATA SCIENCE & BIOCHEMISTRY, 2023

DESIGN BY CARINA HALCOMB, EXPERIENCE DESIGN, 2024

The world has become increasingly reliant on the internet, whether it's social media, classrooms with online assignments, or research, depending on virtual simulations. Technology is becoming increasingly powerful and with that follows more powerful hackers. While the appearance of hackers is inevitable, the United States and China are leading the race to develop a system to protect the internet using concepts of quantum computing technology to create an internet that is virtually unhackable.

Imagine a game of telephone, where one message is being relayed across a room through 10 people. Each person whispers the message they hear to the next, and as they whisper, people who are passing by might hear, or the person they intend to whisper it to can hear it wrong. By the time it gets to the last person, the message probably changed, and the people who were eavesdropping might have gotten parts of the message that weren't intended for them to hear. That's what our internet is now. Signals, or in this example, the message, degrade over long distances, and every time that message is relayed to the next "repeater," it is vulnerable to eavesdropping.

> "The United States and China are leading the race to develop a system to protect the internet using concepts of quantum computing technology to create an internet that is virtually unhackable."

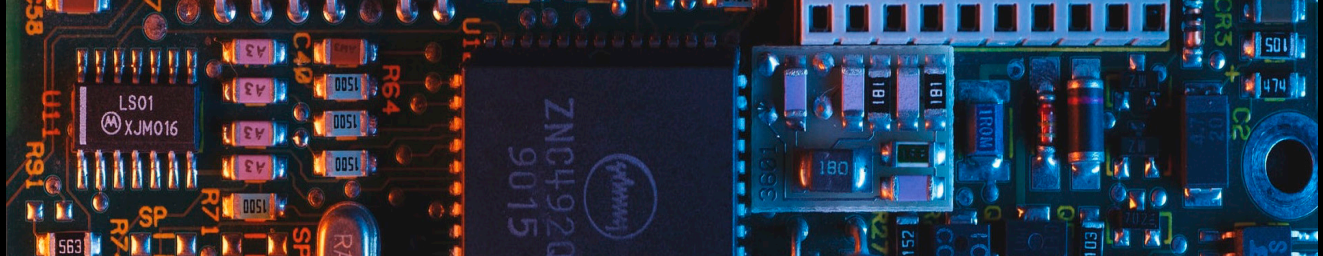
Now imagine that game of telephone, but instead of passing a message by whispering, each one of those 10 people passes along a note. The note is easier to hide from people trying to eavesdrop, and the message can't be misinterpreted or changed because it is written down on a piece of paper. This new system is very similar to a quantum computing system. Quantum computing systems use photons of light to send messages. This method allows the message to be sent more accurately and faster because of two major concepts: quantum entanglement and superposition.

Quantum entanglement is the phenomenon of the existence of two events that are coincident. If you open your sock drawer and you pull out a left sock, you know there's a right sock in there to match it. In this scenario, the two events of finding each sock are entangled. This concept can translate into quantum mechanics: if one event happens somewhere in the world (e.g., a specific photon of light is emitted), the other event will instantaneously occur, no matter what the distance between them. As a result, messages can be delivered almost instantaneously with a variety of entangled particles.

Superposition, the concept that a particle can be in two states at once, furthers the security of data in quantum computing systems. Using this concept, a message can be conveyed in several quantum entangled particles that are each in a superposition of states. When representing information, the particles can be 0 and 1 in binary at the same time. Particles with superpositions are significantly harder to decipher because they don't only mean one thing, and instead of sending the message signal to multiple repeaters like in a classical computing system, the message is encoded into entangled pairs of photons in a superposition of states. After the message is delivered, it is translated using a quantum decrypting system. Using this process, data can be sent in a more secure and efficient way.

This quantum computing system requires the ability to create and manipulate photons for every message that one wishes to send. After these photons are controlled, their properties of quantum entanglement and superposition can be used to more efficiently and securely transfer data and send messages over long distances. The first domains that this system will be used with are most likely the financial and healthcare sectors. But just like the transition to a fiber-optic network, the transition to a quantum computing network is going to take time; however, after working on a quantum computing network for decades, this new network is closer than we think.

Journal of Electronic Science and Technology (2019). DOI: 0.11989/JEST.1674-862X.90523016



Time capsules blinking in the sky

BY ISABELLE BRANDICOURT, ELECTRICAL ENGINEERING, 2024

DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING, 2024

Everyone remembers the first time they wished on a shooting star, recognized Mars by its reddish tint, or realized the glimmering, dusty sweep across the blackness was actually the Milky Way. Peering into the night sky has a certain magic that has continually drawn our gazes upwards and outwards from every corner of the Earth. But what are we ever actually looking at? Energized particles flinging around in nothingness? Fiery space rocks? Collections of energy? There are many definitions for what we see in the night sky, but perhaps most striking is not *what* they are but *when* they are: looking into space means peering into the past.

Just like any energy traveling through the media of time and space, light does not appear instantaneously. It takes time, even an infinitesimal moment, to get from the source to the destination. For example, it takes 2.5 seconds for light to travel to the Moon and back and 3 whole minutes for light to travel to Mars and back. Light from the Andromeda Galaxy, a twin of our own Milky Way, takes 2.5 million years to travel across space into our telescopes. Also called "lookback time," this heightens the romanticism of retrospection, the thought that gazing into space reveals the occurrences from centuries, even millennia, ago. But how old is the light we are seeing? Does this constitute looking into the past? These are questions that scientists have been trying to answer for decades.

Just as physicists and astronomers have developed classical theories of time and space, Albert Einstein crashed into the field in the early 1900s with wild theories bending previously linear concepts. He postulated that time and space were interrelated, woven together as a space-time fabric. Gravity — the same force involved with dribbling a basketball, falling down stairs, and moving ocean tides — causes this fabric to stretch and distort, introducing curvature into the space-time surface. Light follows this curvature as it travels through space and, to an external observer, follows an inexplicable, distorted path. Recall one of those spiral wishing wells: you set a coin spinning on its edge at the outside of the well, and it will spiral down towards the center of the well, eventually falling into a small hole at the center. Objects of significant mass act like the hole at the center of the spiral wishing well, bending the nearby space and drawing objects into circular motion around them. Since light travels at a fixed speed no matter what — another groundbreaking discovery by Einstein — time itself must slow down as light travels into a gravitational well. Therefore, when looking into space past billions of these wells caused by massive stars, galaxies, and black holes, time is continually bending and twisting, further complicating the situation.

All of this conceptual thinking is swell, but does it answer the question: does looking into the universe equate looking back in time? The answer is yes, what we see is technically from the past. We are seeing light from astronomical objects as they were when that light was emitted, anywhere between a few seconds to billions of years ago. The billions of light years of the dynamic universe build a storied, nonlinear path for light to travel through, twisting and bending by the laws of general relativity. So the next time you gaze at the night sky, appreciate the invisible forces in space, and contemplate the beautiful complexity behind each tiny pinprick of light.

PHOTOS BY SHUTTERSTOCK

I HAVE A JOKE ABOUT THE NOBEL PRIZE, BUT ONLY WHITE MEN WILL GET IT

BY KAELEN ENCARNACION, BIOLOGY & ENGLISH, 2021

DESIGN BY YECHAN YANG, BEHAVIORAL NEUROSCIENCE, 2021

In 1895, Swedish scientist and industrialist Alfred Nobel drafted a will stating that most of his fortune be reserved as prizes "to those who, during the preceding year, shall have conferred the greatest benefit on mankind." Presented within the categories of Physics, Chemistry, Physiology or Medicine, Literature, Peace, and Economics, the Nobel Prizes have come to be considered the most prestigious awards in their respective fields.

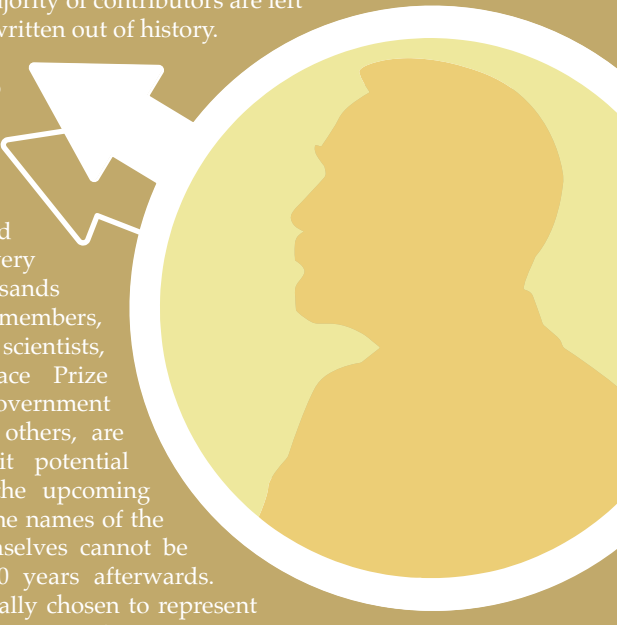
In the 119 years since the first Nobel Prize was awarded in 1901, there have been 930 individual laureates. Of those laureates, 57 of them are women (13 of which are women of color), 57 are Asian, 17 are Hispanic, and 16 are Black. In total, women and minorities make up not even a fifth of all Nobel Prize winners. Nobel himself stated, "It is my express wish that when awarding the prizes, no consideration be given to nationality, but that the prize be awarded to the worthiest person, whether or not they are Scandinavian," yet the "worthiest" people seem to be almost exclusively white men.

Today, research teams can consist of a plethora of students, postdoctoral researchers, and technicians, but their collective work is typically credited to a single investigator. While the Nobel Peace Prize can be awarded to individuals or organizations, only up to three people can share the prize in each of the other categories. This restrictive system has practically ensured that many important collaborators will go unrecognized, especially those from already marginalized backgrounds.

Not only does the Nobel system perpetuate the myth of the "lone genius," just short of asserting that most are white and male, it also reinforces the idea that history is written by the victors, or in some cases, the survivors.

The first Nobel Prize in Medicine went to Emil von Behring in 1901 for the discovery of antitoxins, but not to his close collaborator Shibasaburo Kitasato, a co-author and equal contributor in their research for the treatment of diphtheria. In 1962, the Nobel Prize in Medicine was awarded to James Watson, Francis Crick, and Maurice Wilkins for discovering the double helix structure of DNA, but not to Rosalind Franklin, whose foundational work was central to their work, simply because she died four years prior. This underlines another limiting condition upheld by the Nobel Committee: a prize cannot be awarded posthumously, unless the announcement was made before the recipient died. Astronomer Vera Rubin, with her discovery of dark matter, is widely considered to have been robbed of a Nobel Prize in Physics in this same way.

Because such a prestigious prize only recognizes up to three people and has historically omitted researchers from marginalized groups, it creates a problematic "winner-takes-all" reward system, bolstering the reputations of a select few while the vast majority of contributors are left in the shadows, written out of history.



So who gets to choose the winners? The nominators of the Nobel Prizes are shrouded in mystery. Every year, thousands of academy members, professors, scientists, past Nobel Peace Prize laureates, and government officials, among others, are asked to submit potential candidates for the upcoming year. However, the names of the nominators themselves cannot be revealed until 50 years afterwards. They are specifically chosen to represent as many countries and universities as possible, but the candidates they select do not share this same diversity. Once all the nominations are finalized, the Nobel Committees of the four prize-awarding institutions vote on the winners.

Historically, STEM fields have been dominated by white men. While U.S. colleges and universities are becoming increasingly diverse, there are still systemic barriers that inhibit underrepresented groups in higher education. Fewer tenure positions for them means they lack the job security that would grant more freedom and time to pursue further academic research. And because the Nobel Prizes are typically awarded to tenured professors or famous scientists at prestigious research institutions, this usually means older, established white men take the cake.

The Nobel Prize paints an unfair picture for a young, aspiring scientist: when you see mostly white males being recognized and immortalized in the history books as "great scientists," it's hard to imagine yourself sharing a place among them if you don't look like them.

Alfred Nobel died in 1986, but in 2020, there's no reason for the list of Nobel laureates to resemble the scientists of Nobel's time more than our own. Credit is far overdue — the Nobel Prize highlights the need to promote more diversity in STEM and properly award the "greatest benefits" that come from it.

PHOTO BY SHUTTERSTOCK

STATISTICAL SLIP-UPS

The problems with political polling

BY CARA PESCIOTTA, PHYSICS, 2022
DESIGN BY PREETI MAKARAM, COMPUTER SCIENCE & COGNITIVE PSYCHOLOGY, 2024

If Americans learned anything from the 2016 presidential election between Donald Trump and Hillary Clinton, regardless of party affiliation, it was that polls cannot be trusted. Pollsters wildly missed the mark in 2016, with the *New York Times* giving Clinton an 85 percent chance of winning, FiveThirtyEight predicting a 71.4 percent likelihood, and *Reuters* gambling 90 percent in favor of Clinton. News sites all but inaugurated her before voting even began, but she did not win the presidency.

In this year's presidential election, FiveThirtyEight gave Joe Biden an 89 percent chance of winning. As I repeatedly refreshed the news on my phone on election night, this number did not provide much clarity for what the result would be. How can statistics that sound so certain sometimes get it so wrong? In these instances, it is not always that the statistics are incorrect, but rather, there are limitations to polls and statistical methods that must be factored in along with the final percentage.

In analyzing the reliability of a political poll, one must first take into account who is conducting the poll. With the internet allowing almost anyone to survey large samples, it is important to identify trustworthy sources. The most trustworthy sources are organizations with factual reporting and little-to-no political leaning. Untrustworthy sources can manipulate methodology to best suit their desired outcome by asking leading questions and polling from unrepresentative samples. Although it is impossible to completely eliminate these inaccuracies, reliable sources will help mitigate their effect on data and allow for meaningful analysis that takes them into account.

The most common methodologies of polling today are online and telephone surveys, employed by sources like *CNN, Fox News, Politico,* the *Associated Press*, and the Pew Research Center. However, since these sampling formats require participants to actively engage, biases are introduced that create an unrepresentative sample. The Pew Research Center has shown voluntary samples "tend to overrepresent adults who self-identify as Democrats, live alone, do not have children and have lower incomes." To correct for underrepresentation in certain demographics, sources can weigh different variables. This is where untrustworthy sources have leeway to mislead the public and where reliable sources attempt to improve statistics.

Since 2016, sources like Gallup, the *New York Times,* and the Pew Research Center have increased the number of variables that they weigh to better represent the national population. They suspect that a significant contributor to incorrect predictions in the 2016 presidential election stemmed from demographics that were not accounted for, and they now include upwards of 10 variables in their poll assessments rather than three or four.

This may sound like an easy fix, and incorporating new variables will certainly improve polling in the future. However, the last two elections brought additional factors that could have an influence on the reliability of polls. In the 2016 election, the general disapproval of both candidates is thought to have led to many voters not deciding who to cast their vote for until very close to Election Day, if they voted at all. In this year's election, Americans voted during a pandemic, which had a significant impact on voters' plans for Election Day. Although polls aim to be nationally representative, factors like these could alter the outcome of the election regardless of what a national poll suggests.

The 2016 election also emphasized the difference between the popular vote and Electoral College outcomes, with Clinton winning the popular vote by 2.9 million votes but Trump surpassing her electoral votes by 74 electors. The Electoral College is a system in place to help equalize state interests when there are large state population disparities, which changes the effect of a vote on the election outcome depending on where the voter lives. Statistics that claim to represent the likelihood of a candidate winning do not take the electoral system into account, only representing the popular vote outcome. In this sense, pollsters' claims in 2016 were not wrong — more Americans were in favor of Clinton even though Trump won the election.

Political polling relies on both the pollster and general public to be successful. Pollsters should continue to account for undersampled groups, reduce biases, and be transparent in their methodologies while the public should be active in their role of finding trustworthy sources and understanding the limitations of statistics. Political polls should not be regarded as the end-all, be-all, but with a healthy balance of knowledge and skepticism, polls can be trusted and used as a tool in gauging public interests.

PHOTO BY SHUTTERSTOCK

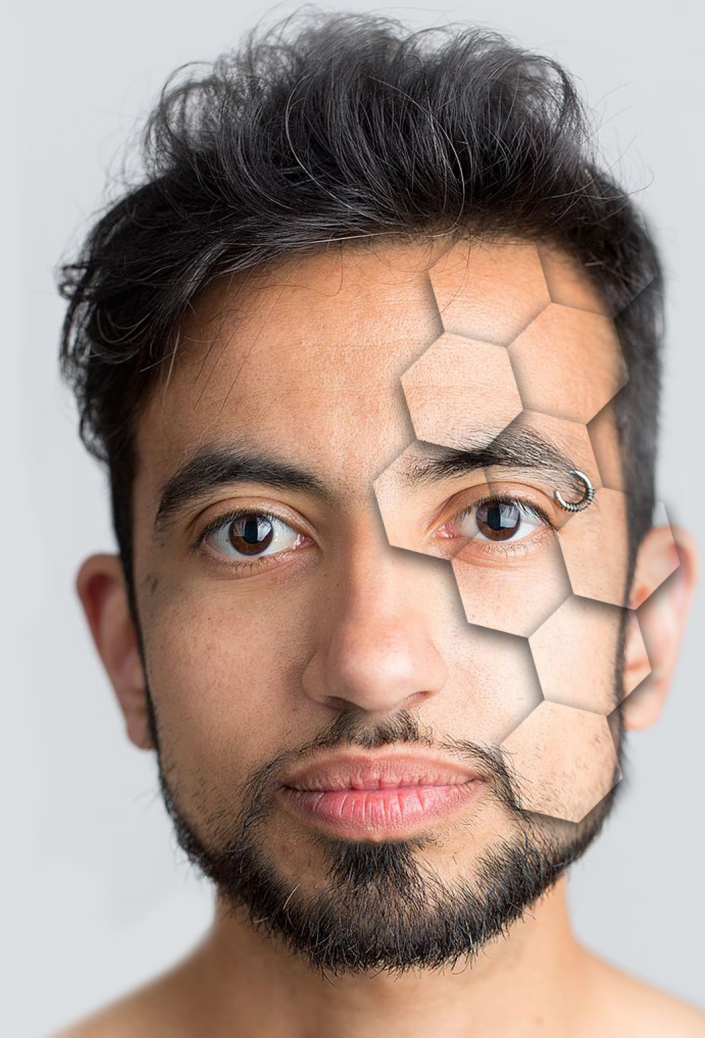
AT-HOME ANCESTRY TESTING:
A microcosm of the state of diversity in science

BY SAGE KUMAR, BIOLOGY, 2023

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

Genetics. Genomic sequencing. DNA. While the technical aspect of genetic testing may appear daunting to most, the personal touch of at-home testing kits has made companies, like 23andMe, millions of dollars. The kits are marketed as a novel, individual adventure and as gifts for birthdays, the holiday season, and Father's and Mother's Day. The aspects of identity and family origins included in these services further personalize their products, with results having the potential to open consumers' eyes to heritage that they may have never known about otherwise. Results can have significant personal meaning and cultural implications for customers. With this in mind, they should be relatively accurate, right?

For proper context, we must first understand the basic schematic of 23andMe's genetic testing methods. After obtaining a sample, the service focuses on the customer's single-nucleotide polymorphisms, or SNPs. SNPs are single-base copying errors that are inherited from one generation to the next and are therefore great indicators for measuring genetic events in human populations.

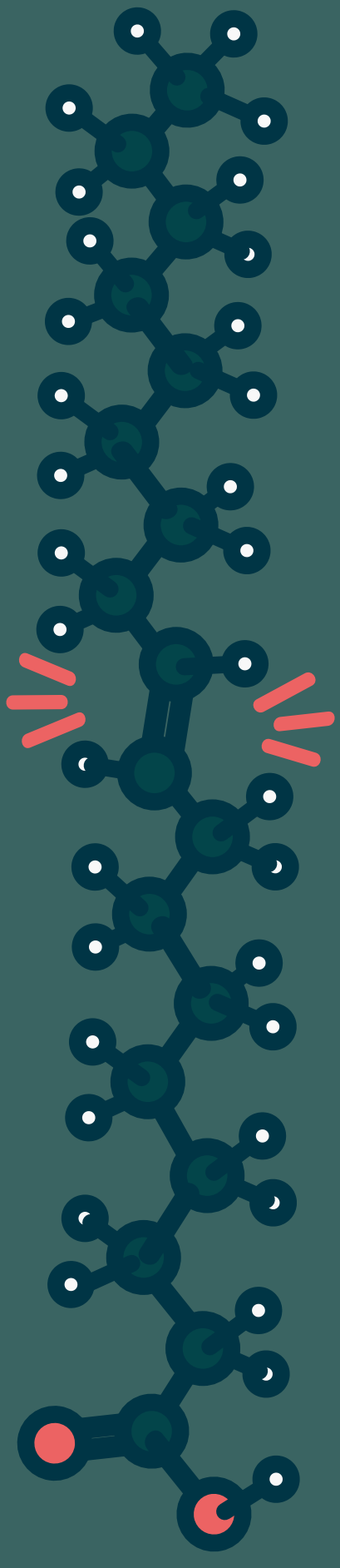


Genetic testing services detect and compare SNPs using a microarray chip, a tool covered with probe sequences that are engineered to be complementary to certain SNPs. When exposed to the microarray, the SNPs that researchers are looking for will adhere to the chip and then be visualized. As of 2017, the company uses the NCBI Human Reference Genome to compare SNP patterns and Illumina's Global Screening Array v5 chip, which tests for around 650,000 individual SNPs. The upgrade to this chip yielded improvements regarding ethnicity testing because of its expanded capacity and accuracy when analyzing non-European samples and its data's ease of use across multiple platforms and testing companies.

Despite the chip upgrade, certain inherent limitations and characteristics of 23andMe's testing methods seem to fall short with regard to diversity. The current 45 reference populations that customers' ethnicity results are sorted into are mostly found within Europe, with 15 populations found under the European umbrella. Europe also has almost a third of 23andMe's 150 recent ancestor locations, which give users insight into where their ancestors might have lived in the past two centuries, with 40 falling within the categories of "Northwestern European," "Southern European," "Eastern European," "Ashkenazi Jewish," and "Broadly European." The other global regions, "Central and South Asian," "East Asian and Native American," "Subsaharan African," "Western and North African," and "Melanesian" all compose the remaining two-thirds of the system's categories. Subsequently, the level of precision and detail when it comes to data sets that originate from these areas is much lower than samples from Europe. For example, European customers' results have the potential to pinpoint their ancestry down to a country or town of origin, while the Native American subgroup spans all of North, Central, and South America.

What's the reason for this huge degree of discrepancy? It mostly comes down to availability and amount of reference data per population. With more data sets from one general geographic region of origin, 23andMe can elaborate and create more subgroups by cross referencing with the sequences they know of. This positive feedback loop is evident in their European schematic and provides a reason for the lack of similar depth in other populations: a relatively homogeneous, white pool of genetic testing participants. While 23andMe and similar services have technical ethnic accuracy under their belts, the industry has some work to do regarding precision, detail, and diversity. At-home testing kits may sound like a novelty, but this field's location at the intersection of genetics, data privacy, bioethics, and representation is far from inconsequential.

PHOTO BY WIKIMEDIA SVERIGE, EDITED BY MARISSA KEESEY



Trans fats: Miracle food or fad faux pas?

BY CLAIRE BOHLIG, MECHANICAL ENGINEERING, 2023
DESIGN BY ETHAN WAPLE, DATA SCIENCE & BIOLOGY, 2023

You may have been warned to stay away from fatty foods, eat fat-free, or cut fat from your diet, but just 100 years ago companies were heralding a new type of fat as the food of the future, a healthy addition to all meals and necessary for a balanced diet. This new fat was hydrogenated fat, known today as trans fat or trans fatty acid.

Hydrogenated fat got its name from a process called hydrogenation. In 1897, French chemist Paul Sabatier discovered metal catalysts could be used to create hydrogenation reactions to manually add hydrogen atoms into chemical structures. Building off this discovery in 1901, German chemist Wilhelm Normann successfully used this reaction to hydrogenate liquid fat into a special semi-solid fat, today known as trans fat or saturated fat depending on the locations of hydrogen.

There are two broad categories of fats, saturated and unsaturated. Saturated fat is when every carbon on the chain has two hydrogen atoms bonded to it with single bonds. This fat is found in butter or other solid, naturally occurring fats. Unsaturated fats are when some carbons in the chain don't have two hydrogen bonds so adjacent carbons form double bonds to become stable. These double-bonded carbons can have two orientations, cis and trans. Cis occurs when the hydrogens are on the same side of the carbon backbone and are in vegetable oils or fat found in nuts. Trans occurs when the hydrogens are on different sides of the carbon backbone, found in margarine or manufactured butter, and holds the fat in a semi-solid state at a large range of temperatures. This was the fat Wilhelm created, and it was an overnight hit.

Popularity soared during the 1930s. In a time of economic depression where fresh food and natural fats, like animal fat and butter, were especially rare, trans fats could be easily and cheaply made from vegetable oil. So manufacturers switched from natural animal fat to trans fatty acid. Soon, they discovered that because of its semi-solid properties, trans fats extended the shelf life of foods and were better at fat frying because of an increased melting point. By World War II, trans fats were used in almost all packaged foods and kitchens, its popularity aided by butter and animal product rationing during the war. Trans fats were marketed as healthier since they were made in a lab, not produced by fatty animals. At this point you might be wondering — when does fat become the villain?

The miracle of trans fats was debunked in the 1980s and 1990s when studies, spurred by a national obesity epidemic, found trans fats not only increased the levels of the most harmful serum cholesterol, low-density lipoprotein (LDL) cholesterol but also lowered the amount of the most helpful cholesterol, high-density lipoprotein (HDL) cholesterol. The harmful LDL cholesterol clogs arteries and can cause heart attack and stroke after excessive buildup. A study of 85,095 women over the course of eight years found that women with a higher intake of trans fatty acids had increased levels of LDL cholesterol and were more likely to develop heart disease, the leading cause of death in America.

Trans fats are a stellar example of what public policy and consumer awareness can do. In 2006, new U.S. Food and Drug Association (FDA) labeling regulations required manufacturers to report grams of trans fats per serving. Customer awareness created a consumer selection against trans fats that drove manufacturers to lower the levels of, or completely remove, trans fats in foods. The Centers for Disease Control and Prevention found Americans' trans fat blood-levels dropped 58 percent from 2000 to 2009.

Then in 2015, the FDA moved to ban all partially hydrogenated oils, the food-manufacturing term for trans fats, by marking them as no longer "generally recognized as safe." The ban was set to go into effect on June 18, 2018 but was pushed to January 1, 2020 because of time extensions for food manufacturers to find alternatives.

The next big "miracle food" diet might be worth a second look. Just 100 years ago, trans fats were considered a scientific miracle. It wasn't until the 1990s that scientists found its effects, so it is critical to think critically about new fads.

The Lancet (1993). DOI: 10.1016/0140-6736(93)90350-P

WEATHERING ANY STORM

What it means to be human

BY YAEL LISSACK, BIOENGINEERING & ETHICS, 2021 DESIGN BY ASHLEY LUO, PHARMACEUTICAL SCIENCES, 2021

Fifth grade science class taught us that chimpanzees are our closest living relatives, but what about other closely-related species who are no longer living? Through millions of years of evolution, *Homo sapiens* has come to dominate Earth as the only surviving hominid species. However, this wasn't always the case, and our presence as the dominant bipedal humanoid species is the result of our ancestors' evolutionary achievements. What made humans outlast others, and what does it tell us about *Homo sapiens?* After millions of years, why are we alone?

A hominid is defined as any member of a family of primate mammals that stands upright on two legs. The first known hominid species is thought to be *Sahelanthropus tchadensis*, a bipedal primate that walked the earth approximately 7 million years ago. The 2001 finding of this species's fossils in modern-day Chad provides evidence of what is most likely the first primate to walk on two legs — our oldest known relative. As the name suggests, however, this primate is not a member of the *Homo* group and is thus only our distant cousin, who we may thank for the ability to walk on two feet.

One of our best-known ancestral hominid ancestors is *Australopithecus afarensis*, which gained international recognition when the "Lucy" fossil was unearthed. Similar to other early hominid species, *A. afarensis* had the capability to walk both upright and climb trees, giving them the unique ability to adapt more quickly to different habitats — a strength that allowed them to survive for millions of years. This adaptability to changing environments is the central theme of the variability selection hypothesis: key events in human evolution were shaped by environmental instability rather than precise adaptation to a single type of environment. This hypothesis differs from previous theories of evolution, claiming that human success lies not in the evolutionary mastery of any particular ecosystem but rather in our capacity to solve challenges that span various environments.

> "Though many human species, including our own, co-existed with each other for thousands of years, we ultimately remain alone in our humanity."

The success of one of our most recent hominid ancestors, *Homo erectus*, further validates this hypothesis. About 1.9 million years ago, this species was thriving across Asia in a myriad of habitats such as mountains, forests, grasslands, and even marine biospheres — many of which oscillated from periods of severe aridity to monsoonal rain. The advancement of the species was not due to their precise physical adaptations to any one of the aforementioned habitats but due to their ability to survive and thrive in all of them. The benefit of this adaptation was mirrored by the rapid population growth of *Homo neanderthalensis*, *Homo florensis* (the "Hobbit"), and *Homo sapiens* for hundreds of thousands of years afterward. Ultimately, these other human groups went extinct for a variety of possible reasons: resource competition, violence among hominid species, severe climate change, and an increase in carnivorous tendencies. Though many human species, including our own, co-existed with each other for thousands of years, we ultimately remain alone in our humanity.

So, what does it really mean to be human? The jury is still out on an official definition. If we examine this question through an evolutionary lens, perhaps being human means weathering the harshest of environments — being able to face a difficult situation and nonetheless prevail. Though differing abilities between human species are ultimately what drove some to extinction, *Homo sapiens'* unique ability to not only learn but *benefit* from hardship has allowed us to endure. Through our outstanding adaptability, *Homo sapiens* have come to a point where we have now altered our environment to suit our needs. Ironically, on account of our own advancement, we have modified our environment to such a point that now, in a period of increasing climate instability, we have fewer options than ever before. Biodiversity is at an all-time low, habitat destruction jeopardizes global food and water security, and rising sea levels threaten entire nations. Our quest to mold the earth in our image is robbing us of the conditions that made us prolific in the first place. The question remains: what does it mean to be human in a world that may no longer be able to keep up with our needs? Now, more than ever, it's up to us to decide.

Evolutionary Anthropology (1999). DOI: 10.1002/(SICI)1520-6505(1998)7:3<81::AID-EVAN3>3.0.CO;2-A

PHOTO BY PIXABAY

Where it all began

An account of the competing theories about the origin of life on Earth

BY JOHN DROHAN, DATA SCIENCE & BIOCHEMISTRY, 2023
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

All cells come from pre-existing ones, an important aspect of cell theory that is universally accepted by biologists today. But where did that first cell come from? By what process did the first cells appear, and how do they differ from cells now? Understanding these ancient life forms on Earth will inform researchers where else in the universe life might appear. To study this, it is important to first comprehend how modern cells function.

Every organism on Earth today, from the sponges in the sea to the fungi in the forest, revolves around the central dogma theory of molecular biology. The central dogma, involving DNA, RNA, and proteins, is an explanation for the flow of information stored within genes in biological systems. In the majority of organisms, genetic information is stored as DNA, which serves as a blueprint for designing cells. To utilize this information, the cell undergoes a process called transcription, which uses DNA strands as a basis for creating complementary strands of RNA. The resulting RNA is then sent into the cytoplasm of a cell and translated into a protein using ribosomes, an organelle. This entire process — from transcription to translation — is referred to as gene expression and creates the functional proteins that control almost all the mechanisms within a cell. In a real organism, DNA is constantly replicated and transcribed. The classification of a cell is determined by the levels of expression for different genes. For example, in humans the same DNA is found in both muscle cells and neurons, the only distinction being the genes that are expressed.

It is speculated that the earliest versions of life did not operate within the bounds of the central dogma because DNA had yet to evolve. It is theorized that all life was based on the reactions of RNA molecules in the RNA world. Instead of acting as the intermediate between DNA and proteins, RNA served as a catalyst, or molecule that increases the rate of reactions in cells. Although reactions catalyzed by ancient RNA were much slower than reactions using modern enzymes, the RNA catalysts were much simpler to synthesize. Scientists have argued that DNA evolved much later, and its prevalence today is the result of its advantages over RNA, mainly being its stability, both over time and in lower pH conditions. While relying on the RNA world theory is tempting, many researchers today struggle to recreate conditions that could have supported the formation of early RNA molecules. For example, since RNA replicates better along a temperature gradient, biochemists argue that life must have appeared near a source of heat. However, on infant Earth, most heat sources such as volcanoes would have had a pH too low for stable RNA molecules to form. So it's clear that even though scientists believe life started with RNA, the environment in which the first RNA molecules appeared remains a mystery.

Abiogenesis is the process by which organisms are spontaneously created from non-living sources. While the RNA world theory argues that RNA served as the non-living source of life, it still does not explain what created the first living creatures. The question remains: what drove these molecules together to form what we recognize as the first cells?

The primordial soup theory argues that the organic molecules necessary for life existed in abundance because of reactions catalyzed by lightning and ultraviolet radiation. This means that simple substances such as ammonia or methane reacted in the presence of high energy to form the first organic molecules. These molecules stayed in the ocean where they combined to form the first cells. Primordial soup was the leading origin of life theory for nearly 80 years. However, scientists remain unable to form organic compounds under the same circumstances, arguing that constant energy is necessary to create organic molecules. That is why, in recent years, researchers have studied hydrothermal vents deep within the ocean as the potential origin of life. The chemistry of modern cells mirrors chemical reactions that occur near hydrothermal vents, and the energy generated by the volcanic activity would enable the formation of organic compounds needed for RNA synthesis.

The hydrothermal vent theory is promising, but there is room for much research before we can pinpoint the exact origin of life on Earth. Hopefully one day, biologists' understanding of how life emerged on Earth will enhance researchers' knowledge of the larger universe, aiding in the search of exoplanets and alternative life forms.

Nature Reviews Microbiology (2008). DOI: 10.1038/nrmicro1991

PHOTO BY SHUTTERSTOCK

Understanding climate change

Meet the scientists looking backward to help predict the future

BY NOAH HAGGERTY, APPLIED PHYSICS, 2024

In 2014, the United Nations Intergovernmental Panel on Climate Change, the world's leading voice on the matter, released its latest assessment report, delivering stunning predictions of the potential consequences of human-driven climate change in the 21st century. At the same time that the U.N. panel in Geneva prepared the report for release, an international team of climate and ocean scientists left port — headed for Alaska. They hoped to uncover one of the greatest missing pieces in scientists' understanding of past climate change: what had happened in the North Pacific directly after the last ice age from 9,000 to 19,000 years ago. The expedition lasted two months, during which the team traveled to five sites to drill sediment cores, which act as geological time capsules, storing information in their chemical make-up. Climate expert and Northeastern professor Dr. Daniel Douglass elaborates, "The transition out of the last ice age is a good chance to study how changes occur." Furthermore, comparing these results against current climate models, Douglass says, "is the best way to find and correct any mistakes that may exist in the models and gives us more confidence in the accuracy of their predictions going forward."

In 2020, the analysis of the North Pacific core samples is finally reaching completion in the form of a detailed string of scientific papers. Dr. Alan C. Mix, a climate and ocean researcher at Oregon State University and member of the expedition team, explains, "Each paper builds on the previous one, such that the puzzle picture is starting to emerge, and it appears to be pretty important as one of the 'missing links' in global climate evolution."

One of the first pieces of the puzzle was published in 2015 by Dr. Summer Praetorius, a former student of Mix. The paper made headlines announcing a link between abrupt ocean warming and expansive oxygen-deficient regions, coined "dead zones" because of their inhospitableness to life. Praetorius postulated that hotter water, which cannot hold as much dissolved oxygen as cooler water, accelerates the chemical processes undertaken by small marine lifeforms, like plankton. These processes further remove oxygen from the water by packaging it with organic material, creating a runaway feedback loop in which a small amount of ocean warming in a region can cause a significant depletion of oxygen. The paper warns that ocean temperatures in this century are likely to increase at a rate beyond anything measured in the past, and the consequences for marine life, as well as human fisheries, could be catastrophic.

> "It appears to be pretty important as one of the 'missing links' in global climate evolution."

Another former student of Mix, Dr. Jianghui Du, utilized the expedition's data to add another piece to the puzzle in a 2018 paper, linking the release of carbon dioxide into the atmosphere to the strength of ocean circulation. Through computer modeling and simulation, Du determined that ocean currents pulled from a massive carbon dioxide reservoir sitting at the bottom of the Pacific and circulated it to the surface, releasing the carbon dioxide into the atmosphere. The model also showed melting glacier water as the likely culprit of increased circulation, resulting in yet another climate feedback loop where melting glaciers lead to a release of carbon dioxide from the ocean, further warming the planet.

Since the expedition in 2013, an astounding 500 papers detailing the mechanics of the past North Pacific have been published based on the expedition's data. Nearly a decade of work has culminated in two groundbreaking papers recently published by the team, finally piecing together the story of the North Pacific. They determined that the melting of the Cordilleran Ice Sheet over western Canada and Alaska had caused multiple feedback loops in the Pacific Ocean, triggering a global climate shift. The melting had created a cascading climate effect that devastated marine ecosystems through the creation of dead zones, warmed the Antarctic region, contributed to the melting of eastern North American ice sheets, and led to a global increase of atmospheric carbon. The papers solidified the North Pacific as a key player in both past and future global climate events.

The insight these findings provide into modern anthropogenic climate change is indispensable. Discussing this significance, Mix says, "The projected scales of [human-driven] change, estimated by models, are far beyond the range of changes observed in our history... and we now know that the Pacific is intimately involved in rapid global changes." As the planet continues to warm, Mix hopes to return to the North Pacific to study the marine geologic record from periods even warmer than where we're headed.

Science (2020). DOI: 10.1126/science.aba7096
Deep Sea Research (2020). DOI: 10.1016/j.dsr.2020.103341
Nature (2015). DOI: 10.1038/nature15753
Nature Geoscience (2018). DOI: 10.1038/s41561-018-0205-6

PHOTO BY SHUTTERSTOCK

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

SCIENTIFIC RESEARCH'S UNSAVORY PAST

BY BINH DANG, ENGLISH, 2022
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

Content Warning: This article discusses but condemns racism, ableism, and eugenics

Before seeing a single patient, every doctor learns the ultimate maxim of healthcare: *primum non nocere* — first, do no harm. The principle of nonmaleficence is essential to medicine, and this ethical tenet grants the field a strong level of trust among the public. Despite this oath and reputation, the fields of medical and research ethics have had a history of moral wrongdoing — even though most, if not all, research organizations codify their ethical guidelines today. To understand the emphasis on bioethics today, we must look back to the most sinister parts of medical and scientific research.

In the 1830s and 1840s, phrenology, the study of skull shapes and their correlation to mental ability, was a popular science in the United States and was used to justify violence and supremacy over Indigenous Peoples and African Americans. Today, we can confidently scoff at this field as pseudoscience, but its very real consequences were championed in the name of science and physiology. Physicians used phrenology to conclude that Black people were mentally inferior to white people and therefore a separate species that didn't deserve to be treated as human. These racist scientists used the same justification to remove Native Americans from their homelands, claiming that they were a barrier to societal progress.

Fortunately, society did progress enough in the right way to abandon that maliciously false practice, but another more sinister one would take its place. One of the most renowned medical research laboratories in the world, the Cold Spring Harbor Laboratory in New York, was home to the Eugenics Records Office from 1910 to 1939. Their scientists sought to improve the genetic quality of the United States, and they advocated for removing unfit genes from society through exclusion or forced sterilization. They targeted people with physical disabilities, people with mental illness, people of color, and immigrants. The researchers in these labs weren't fringe ideologues either — they successfully testified before the United States Congress to pass the Immigration Act of 1924, barring Jewish, Arabic, East Asian, and Eastern European people from entering the country. Even more startling, state legislatures enacted forced sterilization laws, and these policies led to the sterilization of as many as 70,000 people deemed "feebleminded" by eugenicists, with that figure being composed primarily of people of color and people with mental illnesses or impairments.

One of the most infamous experiments on people of color is the Tuskegee Syphilis Study that took place from 1932 to 1972. The U.S. Public Health Service and Centers for Disease Control and Prevention, in tandem with Tuskegee University, enrolled 399 men with syphilis and 201 healthy men in the study, promising them free medical exams and treatment for "bad blood" (a general phrase that included syphilis, anemia, and fatigue). The subjects agreed to the experiment; however, they had not been informed of the true nature of the study: to observe the untreated progression of the disease. The participants were never treated for their syphilis, even when penicillin became a common treatment in 1947. As the patients went on untreated (or treated with placebos), the advisory panel for the study stopped the experiment in 1972, and it became a reckoning for informed consent in research studies after it was exposed to the public.

> "Unfortunately, there are many more examples of unethical experiments, both in the United States and abroad, that have perpetuated dangerous conclusions."

These dark moments in scientific research are important to highlight and learn from, but their caveats hardly make them real science. They were all done unethically, used poor methodologies, and had little to no scientific grounding. Phrenology is a pseudoscience, eugenics was founded on a rudimentary understanding of genetics and co-opted by racists (including Adolf Hitler and Nazi Germany), and the Tuskegee Experiment was futile and ethically unsound. Unfortunately, there are many more examples of unethical experiments, both in the United States and abroad, that have perpetuated dangerous conclusions under the guise of impartial science.

It's important to realize that science can be weaponized by people with malintent. It's lauded as an objective practice — indisputable fact. However, we must recognize when some practitioners don't affirm the essential maxim of *primum non nocere* and try to take advantage of the ethos of the field. As physicians, researchers, and people intent on making the world better and more knowledgeable, we must look at the past to be cognizant of the innately intertwined relationship between science and its politicization. In doing so, we can build a better, more ethical future for everyone.

PHOTO BY SHUTTERSTOCK

Forensics: Factual or faulty?

Advancements in forensic science give new light to old cases

BY MAYA KRAUSE, ENVIRONMENTAL SCIENCE, 2022
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

On September 30, 2020, Lacino Hamilton was released from a prison near Detroit, Michigan after serving 26 years for a crime he did not commit — thanks to a piece of DNA the size of a grain of salt. The DNA technology used to clear Hamilton did not become widespread until the late 1990s, after Hamilton had been tried and convicted. To date in the United States, 375 people have been exonerated by DNA evidence as developments in the accuracy of forensic science in the past 30 years have given new light to the validity of prior criminal convictions.

The process of identifying a perpetrator of a crime can involve many different methods, but police typically rely on eyewitness identification through police lineups to initially identify suspects. However, eyewitness accounts are actually more unreliable than many people assume. Psychologists have found that in recounting a previous experience, eyewitnesses can incorporate other information into their memory unintentionally, introducing inaccuracies to a person's recollection. A 1995 study had subjects read accounts of four events from their lives, one of which, unbeknownst to the subject, was an event that had never occurred. When asked about the events they had read about, nearly one-third of subjects recalled having experienced the false event; two weeks later, 25 percent of subjects still recalled having experienced the event. This study shows that an individual can misremember events when it is suggested that the event occurred in a certain way. The results of this study are consistent with criminal cases in which the person was later cleared with involvement in the crime. Eyewitness misidentification contributed to the convictions of nearly 70 percent of the 375 people in the United States who have been exonerated by DNA evidence.

> "Nearly one-third of subjects recalled having experienced the false event."

DNA technology became more reliable in the mid-1990s, and the use of DNA evidence in the identification of criminal perpetrators by law enforcement is now common. Across all humans, the composition of the majority of DNA is nearly identical, but researchers have found that within certain sections of DNA, there are repeated sequences that vary in length across individuals. Short tandem repeats (STRs) are one type of repeated sequence that can be easily compared across individuals. In order to identify an individual as being the perpetrator of a crime, the FBI compares 13 key STRs from the DNA found at the crime scene to the STRs of the individual suspect. If the STRs of the crime scene DNA do not match the STRs of the individual, the suspect is excluded as the perpetrator. If the STRs of the crime scene DNA match the STRs of the individual, then this is strong evidence that the individual is the perpetrator, however, more evidence is needed to form a definite conclusion because of the possibility of chance matches.

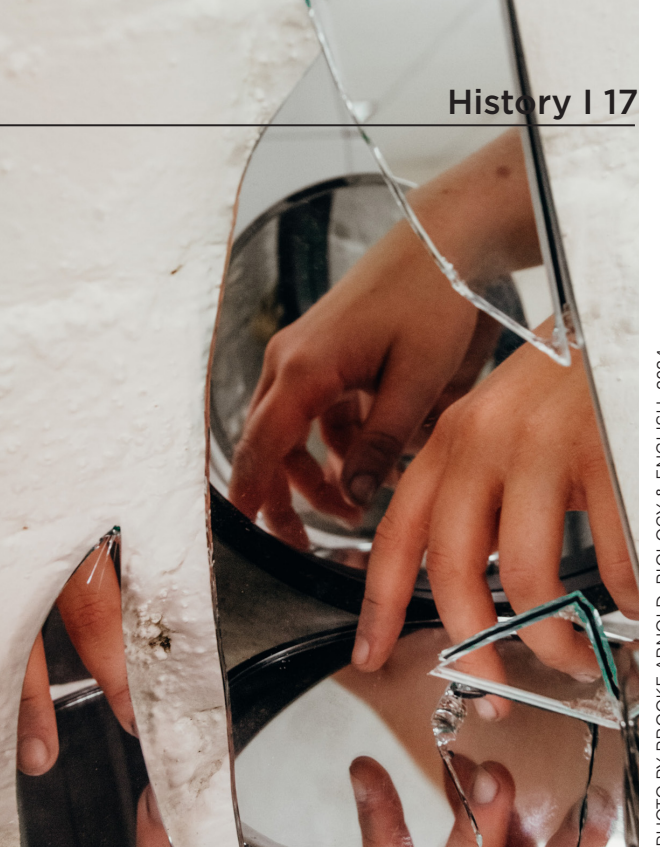


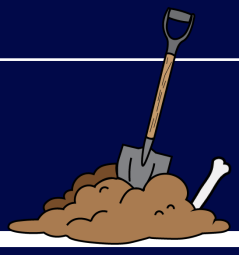
PHOTO BY BROOKE ARNOLD, BIOLOGY & ENGLISH, 2024

While developments in forensic science have led to the reexamination of prior convictions, the misapplication of forensic science has also led to wrongful convictions. Faulty forensic science has contributed to the wrongful convictions of 45 percent of the 375 people exonerated by DNA evidence. Often, this is due to methods that were accepted at the time but now have been disproven. One notable example of this is in fire science. For many years, arson experts identified an intentional, acceleratant-based fire using the appearance of the scene of the fire after the fire was put out. A 1994 study by the National Fire Protection Association (NFPA) found that many of these physical features could be present in either intentionally set fires or accidental fires. Many arson experts refused to accept the findings of this report until the early 2000s. In 2004, Cameron Todd Willingham, who had consistently pleaded innocent for not starting the house fire that killed his three children, was executed, despite all of the physical features of that fire having been identified in the NFPA report as features that could be present in accidental fires.

Advancements in forensic science over the past 30 years have led to the reevaluation of many criminal cases, including those in which the convicted individual had been incarcerated for the majority of their life for a crime they did not commit. As law enforcement agencies continue to reexamine cases using modern scientific developments, it is important to remember the impact that forensic science has on the lives of people such as Cameron Todd Willingham and Lacino Hamilton, whose lives have been lost or forever changed because of the failures of forensic science.

Psychiatric Annals (1995). DOI: 10.3928/0048-5713-19951201-07

THE BONE EXPERTS



BY BEIYU (PAM) LIN, BIOLOGY, 2021

DESIGN BY EVAN DIAZ, ARCHITECTURE, 2025

Mainstream media can't seem to get enough of classic true crime. New shows constantly attempt to showcase crime from a unique angle in order to keep audiences engaged: how can they make their show original and compelling in comparison to countless others? Some networks turn to highlighting a subspecialty of crime that hasn't historically been shown. For example, in the television show "Bones," the life of forensic anthropologist Temperance Brennan is followed as she deftly uses clues from the bones of victims to solve high profile crimes. While the field may seem too glamorous and niche to exist outside of television, forensic anthropology is a real tool used by law enforcement agencies to help solve many facets of a crime.

Anthropology is a wide field that encompasses the study of human origin, behavior, culture, language, and physical remains or artifacts. Physical or biological anthropology is a subset of this large realm that focuses on the aspect of human variation and evolution. Forensic anthropology is even more specific: it is the application of biological anthropology that utilizes skeletal analysis techniques from archaeology to help law enforcement solve criminal cases. Analogous to reading from a book, anthropology helps express the stories that skeletal bones hold.

"While the field may seem too glamorous and niche to exist outside of television, forensic anthropology is a real tool used by law enforcement agencies to help solve many facets of a crime."

Once human remains are identified, they are typically brought to a medical examiner's office, so anthropologists can extract as much information as they possibly can. This can include the age, race, height, and gender of the deceased individual. Extensive analysis of the bone can even lead to clues about cause and time of death, which is pertinent information in any crime investigation. The demographic characteristics that can be deduced from skeletal analysis, such as race and sex, are often revealed using various techniques and focusing on different parts of the body. For example, in determining the sex of a deceased individual, forensic anthropologists typically rely on visual observation of the pelvis and skull to make a definitive conclusion. This is due to innate differences between males and females; female pelvises are shaped to allow for a birth canal and their skulls tend to be smoother and more slender than their male counterparts'.

Analyzing human remains to speculate on cause or time of death can be more complicated than the simple visual observation used for demographic characteristics. Cases where cause of death is determined through forensic anthropology are usually those that include some kind of trauma to the body. Trauma can be antemortem, perimortem, and postmortem; this means that it can be inflicted before, during, or after death, respectively. A big question in forensic anthropology that must be answered when examining trauma is whether the trauma itself is perimortem or postmortem. This discrimination requires an expert to be familiar with the different reactions of fleshed versus dry bone in response to injury; this differentiation can be vital in determining if a certain trauma was the cause of death or if it was inflicted after the individual was already deceased. Antemortem traumas, such as broken bones that have healed, are less useful in determining cause of death but can serve as a tool in crime scene investigation by revealing long-history patterns of injury or abuse.

Forensic anthropology can reveal many vital factors that help solve a crime. Historically, the field has played large roles in not only crime scene investigation but piecing together missing puzzle pieces of history. One exemplary instance of this was the examination of skeletal remains from the Virginia settlement of Jamestown; using evidence of axe trauma to the head, knife cuts in bone, and location at which the remains were found, forensic anthropologists discovered that the individual had actually been cannibalized. This information was crucial in determining that the civilians of Jamestown must have suffered from starvation in the winter of 1609–1610. By looking at how forensic anthropology has been useful to historians and law enforcement in the past, one can expect that its role will only increase as technology gets more complex. While the forensic anthropology shown on television may already seem indispensable, its real-life counterpart is even more so.

Forensic Sciences Research (2019). DOI: 10.1080/20961790.2018.1523704
Laboratory Medicine (1998). DOI: 10.1093/labmed/29.7.423
The Internet Journal of Biological Anthropology (2008). DOI: 10.5580/20a2

COVID confusion

Can science move too quickly? When it comes to research, faster isn't always better

BY WALTER STADOLNIK, BIOENGINEERING, 2024

As 2020 draws to a close and the pandemic rages on, it's worth examining the role that science has played in both the prevention and politics of COVID-19. While doctors and nurses have battled the virus from the front lines, public health experts have waged war on an equally relentless scourge: COVID-19 misinformation. Since January, when the virus first made landfall in the United States, medical experts have faced an uphill battle to keep the public informed amidst the contradictions of skeptical politicians — chief among them President Donald Trump. Although non-scientific sources deserve the lion's share of blame, the scientific community played no small role in fueling pandemic confusion.

In the breakneck race to find effective medicines and flatten the curve, scientific journals were inundated with research of wildly varying quality. According to an article published in the *Journal of the American Medical Association* (*JAMA*), submissions to *JAMA Network Open* increased by a factor of 200 percent since 2019, with a projected total of 1350 studies being published by year's end. To accommodate the staggering pace of research, journals began drastically decreasing the time budgeted for editing and peer review. According to an article by Dr. Serge Horbach, a researcher at Radboud University in the Netherlands, "compared to articles published in the same journals before the pandemic, turnaround times have decreased on average by 49%." For many coronavirus researchers, however, these efforts to expedite the review process fell short, especially when compared to the increasingly popular venue of preprint servers. By providing a means of quickly and publicly disseminating findings prior to peer review, preprint servers such as *medRxiv* and *arXiv* have enabled researchers to achieve the timely publishing demanded by a rapidly evolving pandemic. Accelerating, or altogether eliminating the peer review process, however, does not come without risks.

Back in mid-April, Horbach warned that "legitimate concerns can be raised on whether speeding up the review process might harm the process' ability to filter incorrect or invalid findings." One major testament to the risks of preprint was the case of a paper published by researchers including Stanford's Dr. John Ioannidis on the preprint server *medRxiv*. Ioannidis's paper quickly came under fire for its misleading conclusion that the mortality of COVID-19 was around 0.17 percent — little worse than the flu. Yet despite the server's disclaimer that the article "has yet to be evaluated and so should not be used to guide clinical practice," it has nonetheless provided politicians with ammunition to oppose lockdowns and stay at home orders, often in defiance of National Institutes of Health and World Health Organization public health recommendations.

The consequences of expedited review have even reached *The Lancet*, a journal amongst the most prestigious in medicine. In one article published on May 22, researchers including Dr. Sapan Desai detailed the results of a study on hydroxychloroquine as a COVID-19 treatment, which employed data collected by Desai's Surgisphere company. The study "did not observe any benefit of hydroxychloroquine or chloroquine" and even linked the drugs to an increase in mortality. Confronted with the possibility of patient endangerment, WHO's hydroxychloroquine trials were abruptly halted. It wasn't long, however, before the legitimacy of Surgisphere's data was called into question. Upon investigation, the bulk of the data appeared to be fabricated or fraudulent, with purported patient numbers in excess of case numbers in some regions, and none of the "671 hospitals in six continents" mentioned in the paper having attested to providing Surgisphere with data. Digging into Desai's past and Surgisphere's history, *The Guardian* found that Desai had been named in three medical malpractice suits, and that Surgisphere's employees, numbering in the single digits, included an adult model and a science fiction writer. *The Lancet* article, along with others using Surgisphere's data was retracted as suspicions mounted. Although most major hydroxychloroquine trials resumed shortly thereafter, the redaction of this likely fraudulent study from a preeminent journal of medicine represents a massive oversight in the scientific review process at a time when politicians were downplaying the validity of medical science to the general public.

With COVID-19 cases spiking once more in the U.S., the need to adhere to effective, science-based guidance is more pressing than ever. And with a Pew Research Center survey finding some 78 percent of Americans concerned by the fast pace of vaccine approval, investing in public confidence in medical science could make all the difference in ensuring public cooperation. After a year of breakneck research, it appears that slow and steady could be the key to winning the race against COVID-19.

JAMA (2020). DOI:10.1001/jama.2020.15194
bioRxiv (2020). DOI:10.1101/2020.04.18.045963
PLoS Biology (2019). DOI:10.1371/journal.pbio.3000151
medRxiv (2020). DOI:10.1101/2020.04.14.20062463.
JAMA Intern Med (2020). DOI:10.1001/jamainternmed.2020.6319
Lancet (2020). DOI:10.1016/s0140-6736(20)31180-6.

PHOTO BY SHUTTERSTOCK

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

NEU's declassified school survival guide

BY ANUSHKA BISWAS, CELL & MOLECULAR BIOLOGY, 2023

The plight of 2020 has shaken our lives as we knew them, and understanding and adapting to our current situation is certainly no easy task. The burden of figuring out the rest of your life as a young adult was seemingly not hard enough on its own. Searching for guidance myself, I turned to my primary source of on-campus wisdom and experience: Northeastern's science professors. Turns out, you can learn just as much beyond the classroom as you might from a lecture.

Love What You Learn, Learn What You Love

Almost every professor I spoke with emphasized the importance of pursuing your passions more than anything else. Jude Mathews, a professor of organic chemistry, finds it essential "to find something you enjoy in life and pursue it" and to "push for something you're passionate about." Mathews herself did not graduate with the intention of being a professor, yet she claims that teaching is the one job where she truly enjoys waking up to go to work every day. Similarly, Louise Skinnari, a physics professor, believes that by doing something you are interested in and excited about, you are setting yourself up for success.

Meredith Sweeney, an instructor for Biology Project Lab, wants students to know that there comes a point in your life when grades don't matter as much in hopes that this advice may take some of the stress off and place the focus on learning instead. Biology professor Aaron Roth advises students to not necessarily worry about what their future career may be but, instead, follow what they enjoy learning and keep in mind that their career will take shape.

> "Take your opportunities, even if you're afraid that you can't, you'll be surprised and there are people that want to see you succeed."
>
> — Aaron Roth, Professor of Biology

Surpassing the Sciences

A common theme presented by science professors was, ironically, the significance of subjects beyond science. Sweeney's one regret was that she didn't further explore other subject areas and careers and wishes she had. Mathews advocates for STEM students to explore different areas of science, be open to new ideas, and take courses in non-science areas as she believes it will make you an overall better scientist. Despite being a biology major, one of Roth's favorite classes in college was 20th Century American Poetry. Skinnari suggests that all students, regardless of their specialty, picks up a bit of programming; she guarantees that it will be useful for almost anyone.

Mark Patterson, a marine and environmental sciences professor, might have known that he was meant for an aquatic career at age six, but he especially wants students to know that it's essential to try new things. There should be no pressure in finding the "perfect" discipline to get locked into; many individuals have latent skills that they aren't aware of before they try something new.

Patience Is a Virtue

For new students and all those still searching for their passions, you may find it helpful to hear that Mathews confided that she never liked general chemistry when she took it. Likewise, Roth disliked introductory biology enough to actually change his intended career path from pre-med.

Even if you find what you are looking for, the road forward may be bumpy. Patterson did mention that it may take a few months, a year, even a decade before you truly hit a stride. But, if you find something that really hooks you and draws you back repeatedly, do not let failure discourage you when initially trying something.

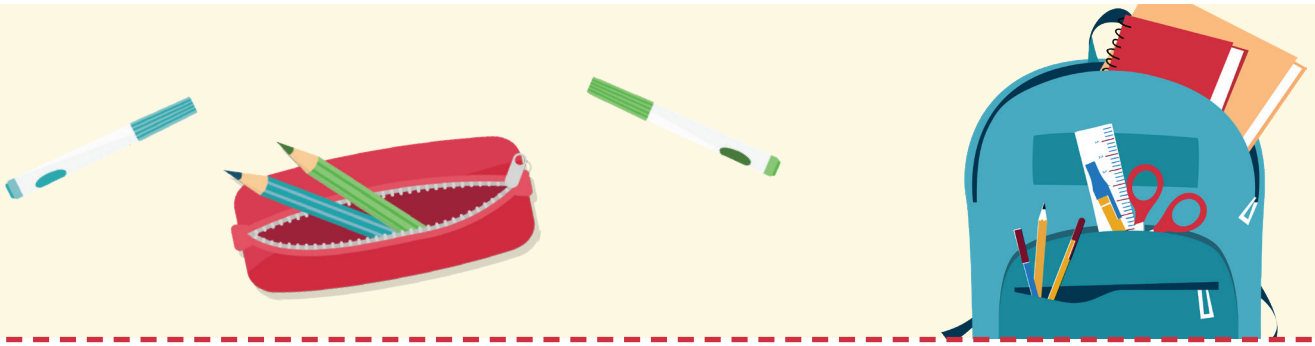
Think It Over, Trust Your Gut

As you move forward through the years, many of you may have to make some big decisions. Both Patterson and Skinnari encourage students to follow their gut reactions. Although, that does not mean you should completely disregard the value of thinking over an important decision. Patterson believes you should sleep on big decisions, perhaps make a pros and cons list, then forget any potential over-analysis and trust your instincts. Skinnari wishes that she herself did not spend as much time in her past being overwhelmed by the possibility of making the wrong decision. Rather, she points out that, if you truly cannot come to a consensus, you most likely have good options all around.

> "Making a career in science is challenging enough, you should never have to expend energy trying to avoid harassment."
>
> — Gail Begley, Professor of Biology

A Letter for the Ladies

Being a graduate student in a time when it was not common for women to do so, especially in STEM, Professor Mathews encountered a lot of hostility from her peers. Based on her experiences, Mathews has a message for women looking to pursue careers in male-dominated industries: "Stand your ground...Don't let anybody mistreat you, don't let them use you, but just go for it because what you're doing will help other women in the future." She hopes she can continue to see a change in STEM-related fields.



20 Thoughts about 2020

This year has been tumultuous for us all and many professors share your grievances. Here is a positive spin on dealing with 2020.

What is the biggest lesson you have learned from the circumstances of 2020?

"Adaptability is a really important skill. Being able to pivot and adjust as circumstances change is critical to mental well-being and productivity."

— Jennifer Bowen, Professor of Marine & Environmental Sciences

"We all need to work harder at being kind to one another and really listening to understand other perspectives."

— Mary-Susan Potts-Santone, Professor of Biology

"People given the correct information and told the truth about motivations will do the right thing."

— Aaron Roth, Professor of Biology

"It's just kind of the reminder that society does move through these things, that they are temporary, and that we can get back to normalcy in time."

— Meredith Sweeny on the parallels between World War II and the COVID-19 pandemic

"Treat the person with the least power as if they have the greatest power."

— Mark Patterson, Professor of Marine & Environmental Sciences

When considering how the on-going pandemic influenced our perception of science, a few professors presented an interesting dichotomy of thought. Potts-Santone felt "we need to improve science education across the country so that people understand, value, and trust the evidence and ideas from scientific experts over those of politicians and even the media." Meanwhile, Sweeney came to realize "how important science is and also how imperfect it is at the same time." Science does not present us with instantaneous cures or perfect tests, but instead, the government, media, producers, and everyday citizens need to collaborate to get through this tough time. Roth upholds that the dynamic nature of science is the exact reason why you can trust scientists as opposed to those who are stubborn in their beliefs.

Lastly, all professors felt as if 2020 emphasized what was truly important for them — whether that be to value time with family, to be civically engaged, or to take that long-deserved vacation — this past year has brought forth much reflection on and appreciation for the finer things in life. Of course, in hindsight, a lot more is easier said than done.

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

BUILDING A GREENER FUTURE STARTS WITH THE BUILDINGS THEMSELVES

BY LOUISE HOLWAY, CIVIL ENGINEERING & ARCHITECTURE, 2021
DESIGN BY SAM KLEIN, DESIGN, 2022
PHOTO BY PIXABAY

While cities cover only 2 percent of the Earth's land area, they house upwards of 55 percent of the world's population and account for a whopping 70 percent of greenhouse gas emissions. It is estimated that nearly 70 percent of the population will live in cities by 2050 and bring with them a hefty carbon footprint. While architects, engineers, and planners race to keep up with the ever expanding urban development in a sustainable way, the answer may be in the buildings themselves.

Green buildings aim to minimize energy usage, water usage, greenhouse gas emissions, and site disturbances like displacing wildlife and polluting water and air, and they can improve the mental and physical health of the occupants. To be a certified green building, the United States Green Building Council (USGBC) must recognize and grant a LEED certification based on a point system awarded from the start of construction to the final design. Some methods of a green building may include high-efficiency light fixtures, passive heat and light optimization, water conservation techniques, tight building envelopes to reduce heat loss, and environmentally friendly or recycled building materials.

David Fannon, associate professor and advisor for the MS in Sustainable Building Systems at Northeastern, suggests a four-step process for designing sustainable buildings. He "starts by reducing the demand for energy." An example of this is optimizing sunlight to rely less on artificial lighting. Once energy needs are determined, Fannon "meets those loads passively to whatever extent is possible, and uses efficient machines and equipment when it is not." If there is a need for cooling, window placement could provide cross ventilation. The final step of Fannon's method is to "power those machines with renewable sources."

Making these changes can go a long way in reducing the building's environmental impact. A study from the Department of Energy reviewed 22 LEED-certified buildings and found they averaged 34 percent lower carbon emissions, 25 percent less energy usage, and 11 percent less water usage compared to a typical building. In addition to building function, the USGBC reports that LEED projects have collectively diverted more than 80 million tons of waste from the landfill. These energy savings translate into a 19 percent reduction in operating costs, meaning that they can be a long term investment.

While green buildings are becoming the status quo, many developers shy away because of their seemingly daunting costs, but many solutions actually save money. A tight envelope reducing unwanted heat loss and heat gains might "eliminate or reduce the size of mechanical equipment, perhaps yielding first cost savings on HVAC, as well as operating savings from energy and maintenance for the life of the building," states Fannon. This is just one of the numerous examples of how a green building can be, well, green!

Green buildings also have numerous benefits for occupants' health. Air quality is one of the pillars for a green building. According to a study from the American Public Health Association, improved air quality can improve cognitive function and reduce absenteeism due to airborne diseases, asthma, allergies, and stress.

In a 2016 study from Harvard University and Syracuse University, scientists observed the productivity of analytical information workers (e.g., architects and engineers) while blindly changing the indoor air quality measured by air changes per hour, level of volatile organic compounds, and level of carbon dioxide. They found that higher air quality led to better decision making along with improved preparation and strategy during a crisis. They also tested people who worked in LEED certified and traditional buildings and found that the former performed better across the board.

Biophilic design is often used in green buildings and responds to humans' need to connect with the outdoors by incorporating natural elements like plants, natural materials, natural light, water, and sounds into buildings. A 2015 study found that workers who are exposed to greenery in the workspace report a 15 percent increase in well-being, 6 percent increase in productivity, and 15 percent increase in creativity. Other benefits include a decrease in stress, more oxygen, fewer airborne toxins, and less artificial light.

As cities expand with a growing population, concern for carbon emissions is of utmost importance. Green buildings not only serve their occupants, but they are a way to "protect the health, safety, and welfare of the public," says Fannon. Development is inevitable, and green buildings can pave the way for a sustainable future. So next time you see the LEED certified symbol on a new building, stop to smell the fresh air!

Environmental Health Perspectives (2016). DOI: 10.1289/ehp.1510037
American Public Health Association (2010). DOI: 10.2105/AJPH.2009.180687

Genes across continents

Investigating genetic diversity in Arabian horses

BY AUDREY GALLIER, COMPUTER SCIENCE, 2023
DESIGN BY NICHOLAS BERRY, MECHANICAL ENGINEERING, 2024

Arabian horses are often considered the most beautiful horse in the world, distinguished by their dish-shaped face, large eyes, and high tail. They originated in the Middle East over 2,000 years ago, and they are capable of enduring heat and traveling long distances. Whether by accident or by strategic breeding, many European horses contain traces of Arabian blood, as they were often used to strengthen athletic horses' gene pools. However, among horse professionals, Arabians are known for genetic defects related to inbreeding, including severe combined immunodeficiency and epilepsy. How did such a well-established breed develop these problems, and what can breeders do to improve genetic wellness?

The more diverse a gene pool is, the healthier and more stable the population will be. With lower genetic diversity, disease traits are not diluted as they would be in a healthy population, so diseases can become prominent in the genome. In the wild, these traits emerge when a bottleneck effect occurs and population numbers decrease dramatically. In comparison to this natural event, the effects of domestic breeding can be even more drastic. The "popular sire effect" decreases genetic diversity through the use of one perfect specimen to produce many offspring with the goal of improving the breed or raising another award-winning horse. This effect has been exacerbated by new breeding technologies like artificial insemination, which allows many mares worldwide to be impregnated by a single individual.

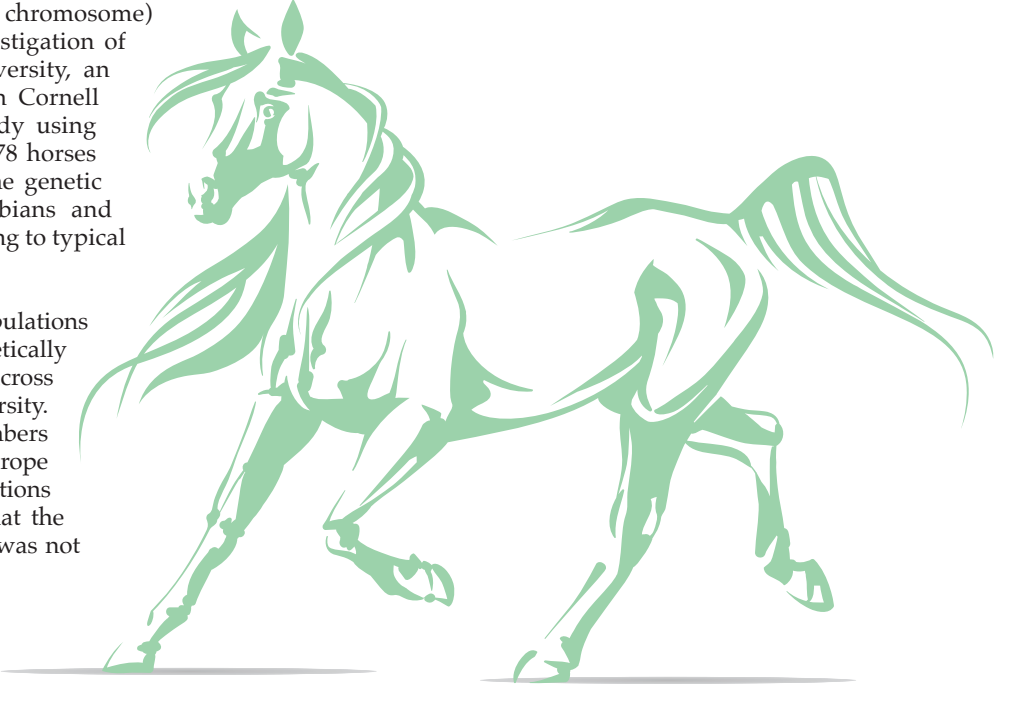
The most reliable indicators of genetic diversity are alleles, which are variations of the same gene within a population and have the same function but translate to slightly different phenotypes. A large variation of alleles and heterozygosity (two different alleles on the same chromosome) indicate a diverse gene pool. In an investigation of Arabian horses' genetic history and diversity, an international team of scientists based in Cornell University conducted an eight-year study using these and other metrics. They studied 378 horses from 12 countries, aiming to uncover the genetic links between different strains of Arabians and identify areas of the genome corresponding to typical Arabian characteristics.

The researchers found that established populations of the breed in the Middle East are genetically diverse, but the subpopulations across continents suffer from low genetic diversity. This deviation is likely because small numbers of founder animals were exported to Europe and the Americas, and the resulting populations were inbred. Additionally, they found that the trademark "dished," concave face shape was not always there, becoming more pronounced over the last two centuries. Beauty standards and globalization likely pushed breeders towards a more standardized version of the breed.

Arabians' influence on the Thoroughbred breed is a widely accepted part of horse history — three Arabian geldings famously formed the basis for these racing horses. However, based on analysis of the Y chromosomes, these geldings were likely not Arabians but a different, similar Asian variety. To further complicate matters, the researchers found traces of Thoroughbred ancestry in Arabian racing horses which were thought to be pure Arabians. This analysis reveals that centuries-old tales and pedigree records cannot be trusted when tracing horses' ancestry, and a population's genetic makeup cannot be assumed.

This eight-year study uncovered possible paths toward improving the health of Arabian horses. Relying on pedigree information and recorded history to maintain healthy breeding patterns is not trustworthy, so breeders need to use genetic technologies to both identify inbreeding and fix associated problems. Breeding between different subgroups could help diversify the gene pool, and involving horses from the original Middle Eastern population would be even more ideal. Competitions could also be restructured to prioritize the horse's health over physical perfection. The Arabian's rich history and impressive beauty aren't going anywhere, so it is our responsibility to ensure its future health.

Scientific Reports (2020). DOI: 10.1038/s41598-020-66232-1
PHOTO BY SHUTTERSTOCK



From caveman to modern man:

The development of the human brain

BY MARIA HARSVIK, BEHAVIORAL NEUROSCIENCE, 2023

Imagine a hypothetical contest comparing the intelligence of all organisms with a brain. It can be reasonably guessed that the winner would be the human brain. Yet, what makes our brains superior to other organisms if it's not the largest or even the most complex? To answer this question, researchers face the daunting task of tracing the brain's development throughout human evolutionary history.

Over the past 7 million years, the size of the human brain has tripled, with the most growth occurring in the past 2 million years. The brain has grown to accommodate changes by accentuating regions involved in communication, problem-solving, and advanced cognitive functions. For instance, in the *Homo habilis* which appeared 1.9 million years ago, the Broca's area within the brain underwent an increase in size due to the expansion of language. Interestingly, in the past 10,000 years of human existence, the brain has actually shrunk overall. One factor that has been hypothesized to cause this change is limited nutrition as populations switched from hunter-gatherer to agricultural diets. However, the size of the brain rebounded in the past 100 years as industrial societies improved childhood nutrition.

When analyzing the development of the human brain, neuroscientists often compare the modern human's brain to that of the Neanderthal's. The main difference between modern and Neanderthal brains comes down to the shape rather than the size. Based on analysis of endocranial casts of human fossils, 300,000 years ago, the brain size of early *Homo sapiens* was already in the range of present-day humans. This evolution occurred gradually in the *Homo sapiens* lineage, and present-day human variation in brain shape was reached between 100,000 and 35,000 years ago. Modern human brains are described as globular with a steep frontal part and an enlarged round cerebellar area. Neanderthal brains are not globular like modern human brains but instead anterior-posteriorly elongated.

Furthermore, scientist Suzana Herculano-Houzel at the Institute of Biomedical Sciences at the Federal University of Rio de Janeiro, found that the distribution of neurons also enhances the human brain in comparison to other species. Human brains have approximately 86 billion neurons, with 16 billion in the cerebral cortex. This part of the brain controls mental talents. In comparison, orangutans and gorillas have significantly fewer cortical neurons, approximately 9 billion. In general, the main difference when comparing human and nonhuman brains is that humans have the most cortical neurons of any species. Humans don't necessarily have denser brains, rather we have evolved mechanisms to accommodate these extra cells. The human brain also consumes 20 percent of the body's total energy, leaving scientists to wonder how the humans evolved to sustain the brain. One theory is the expensive tissue hypothesis, which suggests that a metabolic trade-off occurred, allowing the brain to grow to its current size and power while the energy-use of the gut decreased. For instance, primates that have larger brains have smaller intestines.

Looking at the human genome provides an understanding of the physiological adaptations that allowed for significant brain growth. Gregory Wray, an evolutionary biologist at Duke University, analyzed a family of genes involved in the movement of glucose energy, with one member of the family active in brain tissue and the other in muscle. If there was a metabolic trade-off as described by the expensive tissue hypothesis, then these specific genes would behave differently in humans and chimpanzees. Wray and his team's results indicated that within the regulatory regions for the muscle and brain glucose-transporting genes, there were significantly more mutations than expected by chance. An increased amount of mutations suggests that these regions underwent accelerated evolution. Wray concluded that evolutionary pressures resulted in a modification of human regulatory regions, which caused energy from the muscles to be channeled to the brain. Therefore, the gut likely shrunk, so the brain could grow to its current size.

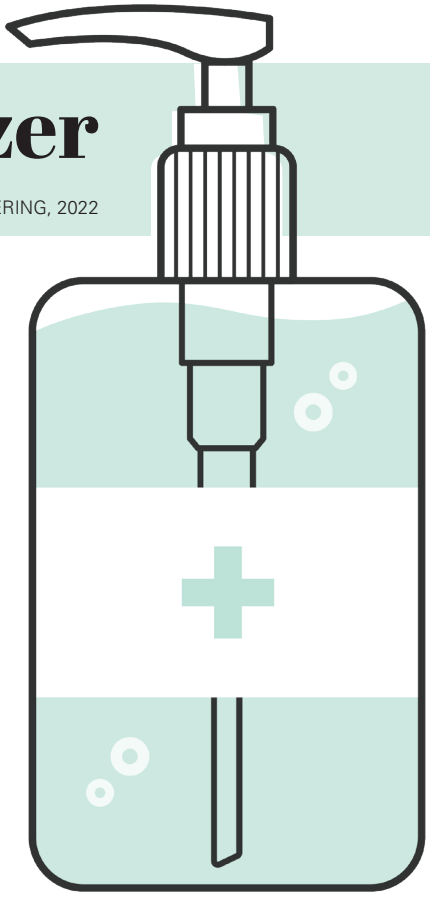
Evolutionary changes throughout history have allowed the human brain to grow to its current size and capacity, ranking us at the top for animal intelligence. Contrary to popular belief, size alone is not the differentiating factor from our Neanderthal ancestors; rather, the change in shape indicates the strengthening of parts of the brain involved in complex mental abilities. Our brain has also evolved to hold the most cortical neurons because of a metabolic trade-off with the gut. All of these changes have contributed to the high-level functioning of the modern human brain, and neurological research in the future will only further our understanding of this complex history.

Scientific American (2013). DOI: 10.1038/scientificamericanmind0713-76b
Scientific Advances (2018). DOI: 10.1126/sciadv.aao5961

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022
PHOTO BY SHUTTERSTOCK

The perils of hand sanitizer

BY AMANDA BELL, DATA SCIENCE & BIOLOGY, 2023 DESIGN BY KATIE GREEN, BIOENGINEERING, 2022



What if hand sanitizer was actually increasing our risk of viral and bacterial infection? While hand sanitizer has emerged as a panacea for preventing viruses and bacterial diseases, is it as reliable as we think? The impacts of consistently using hand sanitizer are of even greater importance now amidst a global pandemic, in which the World Health Organization (WHO) has suggested using alcohol-based hand sanitizer as a preventative measure against contracting COVID-19. The alcohol-based hand sanitizers recommended by WHO consist of hydrogen peroxides and a concentration of either 80 percent ethanol or 75 percent isopropyl alcohol. Taking these three ingredients into consideration, what are the impacts of consistently using hand sanitizer?

Hydrogen peroxide is the least concerning ingredient when it comes to human health and overusing hand sanitizer because its concentration in hand sanitizer is typically below the 3 percent limit.

Ethanol, on the other hand, is slightly more concerning than hydrogen peroxide. In a study published in *BMC Infectious Diseases*, researchers found that the concentration of blood ethanol in all participants using hand sanitizer over a period of 20 minutes for 30 seconds at a time remained well below the acute toxicity concentration; however chronic toxicity was not able to be determined. Ethanol toxicity through dermal contact is more likely when skin is immature, which applies to children under the age of 3, or damaged because skin absorbs more ethanol when it is damaged. Other concerns of using ethanol-based hand sanitizers include irritation, redness, dryness, and itching, which could lead to skin damage and later ethanol toxicity over a long period of time. In other words, avoid using ethanol-based hand sanitizer several times a day over several months because it can lead to a toxic level of ethanol in the body.

> "Overusing hand sanitizer also increases risk of infection because it allows microorganisms like bacteria to develop resistance against hand sanitizer."

Isopropyl alcohol impacts the skin similarly to how ethanol does, but has more serious effects if ingested. According to a review in *Science of the Total Environment*, isopropyl alcohol is completely absorbed and metabolized within 2 hours and will irritate the lining of the stomach and lead to death if more than half a cup of a 70 percent solution is consumed, but it would be difficult to consume that much regardless of the consequences.

However, the biggest concern with alcohol-based hand sanitizers is not the ingestion of it, but rather its ability to increase the skin's permeability and deprive the skin of oil and water. This leads to the typical dryness and roughness associated with using too much hand sanitizer, as well as hands stripped of natural, good bacteria that fight off pathogens. Medical experts believe that consistently overusing hand sanitizer will increase one's risk of infection because dry, damaged hands promote the growth of bacteria and viruses and lack the bacterial defense system needed to keep out pathogenic bacteria and viruses.

Overusing hand sanitizer also increases risk of infection because it allows microorganisms like bacteria to develop resistance against hand sanitizer. This is most problematic in hospitals where hand sanitizer is frequently used and a wide range of microorganisms exist. A research study published in the *International Journal of Biology and Biotechnology* found that almost all gram-negative bacteria are already resistant to common hand sanitizers like Safeguard and Purell. It's only a matter of time before bacteria become resistant to all hand sanitizers on the market.

So what should we take away from these research findings? First of all, do not ingest hand sanitizer. Second, avoid using hand sanitizer multiple times per day and do not use hand sanitizer when you can use soap and water instead. Lastly, research published in *Emerging Infectious Diseases* suggests rubbing your hands with hand sanitizer for about 30 seconds to fully deactivate the novel coronavirus. Hand sanitizer is no doubt an effective way to prevent contracting a virus, including the coronavirus, so long as it is not overused.

Sci Total Environ. (2020). DOI: 10.1016/j.scitotenv.2020.140561
Emerging Infectious Diseases (2020). DOI: 10.3201/eid2607.200915
BMC Infectious Diseases (2007). DOI: 10.1186/1471-2334-7-117

PHOTO BY SHUTTERSTOCK

CAN YOU BE GENETICALLY PREDISPOSED TO SPEAK A CERTAIN LANGUAGE?

BY CATRIN ZHARYY, BEHAVIORAL NEUROSCIENCE, 2023
DESIGN BY ETHAN WAPLE, BIOLOGY & DATA SCIENCE, 2023

One thing science does very well is teach us how little control we have over the universe — this includes our own thoughts and behaviors. We might be the masters of our fates, but we cannot change the machinery in our bodies that has been meticulously designed over thousands of generations of *Homo sapiens*. When it comes to nature versus nurture, one behavior that has always been totally attributed to nurture — the environment one is raised in — is our first language. This long-held belief is what makes a study published in May 2020 so remarkable: it has provided evidence to support that the language one speaks is linked to their genetic code.

Understanding the biological basis of language presents a "Which came first: the chicken or the egg?" conundrum. A Hindi speaker's neurons might fire a little differently than those of an Arabic speaker, but is that because of biological differences that have existed since birth? Or, have their life experiences shaped their neural connections differently?

When it comes to genetics, however, things are more straightforward because life experiences cannot change the code itself. In 2007, two scientists from the University of Edinburgh did a statistical analysis on 983 genes from the genomes of people from 49 different populations around the world. They tried to connect the dots between the specific genes, the people who expressed them, and the languages they spoke. Ultimately, they found significant correlations between people who spoke tone languages and had particular versions (alleles) of the genes *Aspm* and *Mcph*.

A tone language is one that uses pitch to elucidate a word's meaning. English speakers use tone to indicate the meaning of *sentences* (like raising the pitch of one's voice at the end of a sentence to indicate a question) but not individual words, so it is not a tone language. Tone languages make up about half of the world's 7,111 languages and are most spoken in Central Africa and Asia. The specific alleles of *Aspm* and *Mcph* that the 2007 study homed in on happen to be most concentrated in people from these areas.

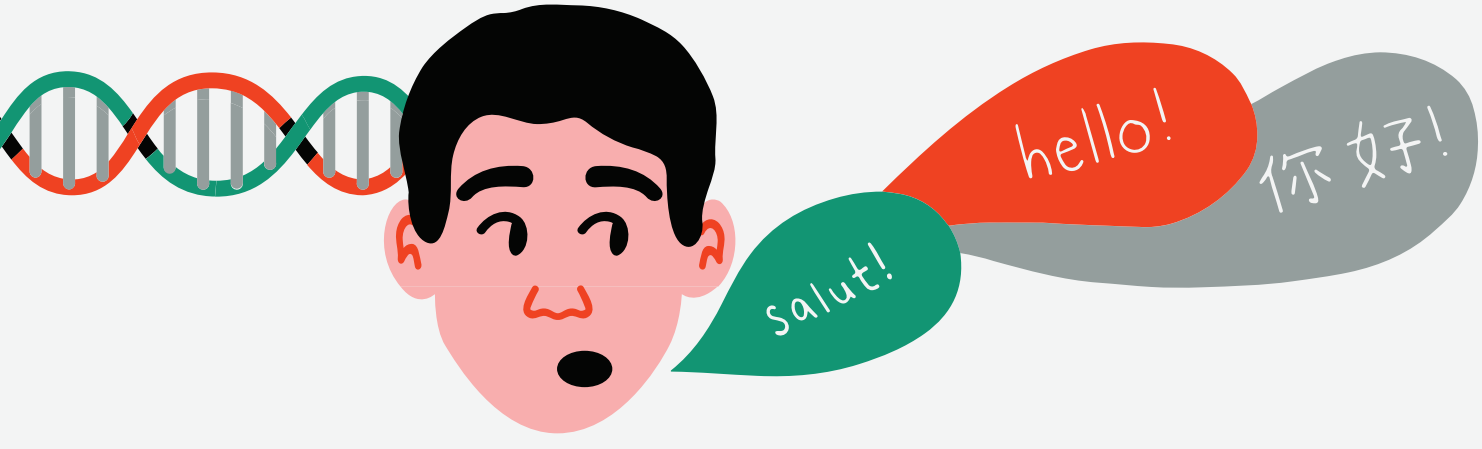
> "THEY TRIED TO CONNECT THE DOTS BETWEEN THE SPECIFIC GENES, THE PEOPLE WHO EXPRESSED THEM, AND THE LANGUAGES THEY SPOKE."

Excited by this finding, the researchers proposed the genetic-biasing hypothesis of language evolution: certain alleles of genes can affect language evolution by predisposing its carriers to use certain linguistic features (e.g. proportion of vowels to consonants, subject-verb order, or tone) in their speech. The idea is that these features are first used in speech inadvertently, then shared among members of the same community and through generations, eventually getting preserved in the modern version of the ethnic group's language. Now, 13 years later, we have the first direct evidence to support this fascinating hypothesis. Professor Patrick Chun Man Wong and his colleagues from the Chinese University of Hong Kong came together from six different departments to design and perform an experiment to test the link between nine alleles from three different genes and speakers of Cantonese (a tone language). The researchers genotyped 426 native Cantonese speakers, surveyed them about their life experiences and measured their lexical tone perception. This test involved playing the same syllable for the participant in three pitches. In a series of 204 trials, the participant had to identify whether the third syllable had the same pitch as either the first, the second, or neither prior syllable.

The researchers found that, on average, people with the *TT* allele of the *Aspm* gene performed 3.69 percent better on the lexical tone perception test than those who did not (a statistically significant difference). In the statistical analyses they performed to isolate the influence of genetics, the researchers removed the possible influence of confounding variables, so this increase in lexical tone perception is purely due to the allele. Interestingly, using survey data, the scientists also found that people without the *TT* allele can match the performance of those with it on the lexical tone perception test if they have had musical training. So not only is this study important for the scientific community, but it points to musical training as a possible early intervention for children who have communication disorders and speak tone languages.

Considering current globalization and immigration trends, many fewer people today speak the same language as their ancestors. But even if we don't share any experiences with our ancestors, we know we share their DNA. Those enigmatic strands of molecules know us best — perhaps even the secrets to our inner universes.

National Academy of Sciences (2007). DOI: 10.1073/pnas.0610848104
American Association for the Advancement of Science (2020). DOI: 10.1126/sciadv.aba5090



The paradox of leukemia and cleanliness

BY EMILY TAN, DATA SCIENCE & BIOLOGY, 2024
DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

For most of our lives, it has been engrained in us that illnesses are primarily caused by unhygienic environmental factors. However, in the case of leukemia, recent studies have shown that it may very well be the opposite. With an annual incidence in the United States of approximately 3,800 children per year, leukemia is the most common form of pediatric cancer. Contrary to popular belief, leukemia is actually a general term used to describe cancer that affects blood-forming tissues such as bone marrow or lymphatic tissues. It encompasses a variety of cancers such as acute lymphocytic leukemia (ALL), acute myeloid leukemia (AML), and chronic lymphocytic leukemia (CLL).

“Though research cannot pinpoint specific infections that are guaranteed to prevent childhood leukemia, these hypotheses indicate that an infant’s environment plays a bigger role in the development of leukemia than their genetics.”

ALL is the most common form of leukemia found in children and has risen by 55 percent in annual cases since 1975. While modern treatment options cure 80 to 90 percent of pediatric ALL patients, long-term consequences, such as declines in neurocognitive function, endocrine health, and overall health, continue to affect patients well beyond their treatment period, thus giving rise to the need for preventative care.

One outstanding hypothesis labeled the “infection hypothesis” suggests that childhood leukemia may be the result of an abnormal response to common infections. There are two models of this hypothesis: epidemiologist Leo Kinlen’s population-mixing hypothesis and British biologist Mel Greaves’s delayed infection hypothesis. Kinlen’s hypothesis suggests that a lack of herd immunity combined with the migration and mixing of different populations leads to higher incidence rates of leukemia across the board. Greaves’s hypothesis, which is more specific to ALL, claims that the immune system anticipates and requires microbial infectious exposure either in-utero or during infancy, which has lasting effects on immune function and general health. Though research cannot pinpoint specific infections that are guaranteed to prevent childhood leukemia, these hypotheses indicate that an infant’s environment plays a bigger role in the development of leukemia than their genetics. In fact, a 2013 study found that less than 10 percent of childhood leukemia is attributed to genetic risk factors.

Epidemiological evidence in multiple studies conducted with regard to postnatal patterns of infection supports Greaves’s hypothesis. A 2005 study used data compiled by the UK Children’s Cancer Study Group in the 1990s for analysis of the delayed infection hypothesis in the context of daycare attendance during the infants’ first 12 months of life. The study showed that formal daycare attendance, defined as attending a facility with at least four other children two times a week, within the first three to twelve months of life had a significant protective effect on the risk of developing ALL and B-Cell Precursor Acute Lymphoblastic Leukemia (BCP-ALL), a form of ALL where an excess of B-cell lymphoblasts are found in the bone marrow and blood. However, later research conducted in California, Scandinavia, and France suggest otherwise, causing debate about the reliability of using daycare attendance as a metric for testing Greaves’s hypothesis. Nevertheless, between assessing daycare attendance and recalling particular infections in infancy, daycare attendance is the more acceptable metric, as it relies on raw data in comparison to potentially inaccurate parental recall.

Another potential postnatal pattern of infectious exposures in infancy that Greaves analyzed is birth order. Several studies in California, the United Kingdom, and France conducted between 2001 and 2015 found a strong correlation between birth order and ALL risk, with firstborn children being at higher risk for leukemia. Furthermore, breastfeeding and the method of delivery also impact a child’s risk for ALL. For example, multiple studies have reported a significantly increased risk of ALL with caesarean delivery, which bypasses the microbial exposures associated with normal vaginal birth. Postnatal decisions, such as the length of breastfeeding, also play a big role in infants’ risks of ALL. Across 17 case studies, it was found that there is a 10 to 20 percent reduced risk of ALL when the breastfeeding period is longer than six months.

Across the three postnatal patterns of infections Greaves analyzed, it was confirmed that there indeed was a correlation between the environment during infancy and the risk of ALL. Thus, he inferred that clean homes also contributed to the risk of ALL. Against most conventional public health advice, perhaps experiencing some infections and dirt would be a beneficial, calculated risk in childhood.

Int J Cancer (2013). DOI: 10.1002/ijc.28266
BMJ (2005). DOI: 10.1136/bmj.38428.521042.8F
Nat Rev Cancer (2018). DOI: 10.1038/s41568-018-0015-6
Pediatrics (2016). DOI:10.1542/peds.2015-4268H
Curr Probl Pediatr Adolesc Health Care (2016). DOI:10.1016/j.cppeds.2016.08.004

PHOTO BY SHUTTERSTOCK

ROOT INTELLIGENCE: ARE PLANTS CONSCIOUS?

BY SARA GANNON, BEHAVIORAL NEUROSCIENCE, 2021 DESIGN BY KAI GRAVEL-PUCILLO, PSYCHOLOGY, 2022

With recent quarantining and social distancing measures, many people have sought out companionship in an unexpected way: buying more plants. For those of us who have experienced the successes and losses of caring for houseplants, it is quite evident that these organisms are highly responsive to their environment—whether that be light, soil pH, or humidity. Based on recently published studies of plant awareness and consciousness though, it is becoming clear that we have overlooked just how perceptive these companions are.

Originally proposed by Charles Darwin, the idea that plants possess their own neurobiology distinct from animals' is now a common belief among botanists and biologists alike. In recent history, biologists have discovered many phenomena that support this theory including action potentials, or cell communication via bioelectricity, in Venus traps and underground communication occurring between plants via electrochemical signaling. Scientists even discovered that plants are capable of memory and can be trained to stop responding to particular stimuli, such as touch, from their environment.

In 2018, Dr. Masatsugu Toyota and his team at Saitama University in Japan, discovered that plants release a nervous-system-like signal in response to "painful" stimuli. The group reported that the plant *Arabidopsis thaliana*, a small flowering plant native to Eurasia, uses a rapid and long-distance signaling pathway to communicate to the rest of the plant when one section of the plant is wounded. This long-distance signaling takes only seconds to minutes to reach distant leaves. The team proposes that the signaling mechanism involves calcium ions released at the site of the wound and are then received and propagated via receptors throughout the rest of the plant. Unexpectedly, the receptors used for signal propagation in the plant are very similar to glutamate receptors in mammals, which serve an identical function in mammalian long-distance signaling pathways. The concept that a plant is capable of communicating wounds or pain to the rest of its body suggests that plants may have a signal propagation network within them that functions similarly to our own mammalian nervous system. Nevertheless, does the fact that plants possess a nervous-system-like network mean that plants must have some capacity for consciousness? It's unclear.

In an attempt to study this question, Dr. Ken Yokawa from the University of Bonn in Germany and a team of international collaborators studied the effect of anesthesia on plants. In humans, anesthesia is used to disrupt electrical signals that lead to movement; this team of researchers found that anesthesia had the same effect on plants. The study showed that, just like in humans, appropriate doses of anesthesia immobilized plant organs by blocking action potentials and disrupting normal intra- and intercellular processes. Action potentials are a fundamental part of animation in humans, animals, and plants alike, which is why anesthesia, disrupting these bioelectrical circuits, works on all three. The Venus flytrap, where action potentials allow the plant to "attack" prey by closing the trap and initiating the digestive processes, was completely unresponsive to prey-like stimuli when anesthetized. In humans, consciousness is generally attributed to action potentials and electrical signaling within the brain, and it is well known that most of this electrical activity ceases during anesthetization leading to an unconscious state. This study shows that anesthesia affects plants similarly to how it affects humans; electrical signaling is disrupted and motion of the plant ceases after receiving a dose of anesthesia. And, similar to humans, the dose is capable of "wearing off" and the plants, in essence, "wake up" and return to normal movement and respond as they normally do to environmental stimuli. This inspires the interesting question of whether or not this means plants themselves are capable of consciousness.

Throughout the course of human history, consciousness has been attributed not only to humans but to an ever-expanding subset of animals. This recent research in plants indicates that perhaps the capacity for consciousness extends outside of the animal kingdom. It may be time to redefine what it means for an organism to truly be conscious of the world around them.

Science (2018). DOI: 10.1126/science.aat7744
Annals of Botany (2018). DOI: 10.1093/aob/mcx155
Science (2018). DOI: 10.1126/science.aau9813

PHOTOS BY SHUTTERSTOCK

A dog's memory

BY JOSEPH VALENTI, BIOLOGY & DATA SCIENCE, 2023

DESIGN AND PHOTO BY SAM KLEIN, DESIGN, 2022

When it comes to teaching children, there are multiple different styles of learning, including visual, auditory, and kinesthetic. In other words, kids learn best from either what they see, hear, or do, respectively. To try and encompass these different styles, teachers and parents attempt to teach using activities that focus on all three methods. When it comes to a different breed of learners, though, they are not given the same consideration — those trainees being man's best friend: dogs!

Most pet owners stick to getting their dogs to form associations between verbal commands and certain actions, but one study by Emory University suggests that most dogs may not be auditory learners. The study attempted to explore whether visual, auditory, or olfactory learning was the most effective for establishing memories connected to a stimulus. To do this, the scientists used fMRI to study changes in a dog's level of interest with a certain stimulus. For the visual trials, the researchers would present a plastic pineapple or flamingo that the dogs had not seen before. For the auditory trial, they maintained similar conditions but instead used two auditory cues said by the owner: "Callooh" and "Frabjous." Finally, the third set of dogs were tested by olfactory method using isoamyl acetate and hexanol as the stimuli. For each trial, the dogs were separated into two groups, rewarded and non-rewarded, with the latter acting as a negative control for their response to being exposed to the stimulus without a reward association.

Studying the caudate, amygdala, and parietotemporal areas of the brain, the researchers were able to gauge the dogs' rates of interest in the stimuli before and after rewarding or not rewarding the dogs. They found that olfactory and visual stimuli evoked much higher levels of interest in the rewarded dogs, whereas the auditory stimuli did not catch the attention of the dogs anywhere near similar levels. This indicated to the researchers that dogs may not be great auditory learners, and perhaps, training dogs using verbal cues, as is commonly done, might not be the best method.

Another interesting study done by Texas Tech University investigated the relationship between behavioral persistence and olfactory learning in dogs. Behavioral persistence is an animal's inability to change certain behaviors despite positive or aversive stimuli, which typically would lead to change; this is the major reason why some dogs cannot be trained and certified to be service or police dogs. The study used two different tests, a resistance to extinction test and an odor discrimination test. The resistance to extinction test involved an apparatus where dogs were trained to pull a lever to receive a treat. Once trained, the dogs would no longer receive a reward, and after that, the time it took for the dog to stop pulling the lever was measured. The odor discrimination test used two bins: an empty one and one containing a diluted odor that the dog was conditioned to remember. If the dog rooted in the conditioned bin, it succeeded, but it was counted as a failure if the dog rooted in the empty bin or ignored both bins.

This experiment showed that dogs that scored high in the olfactory discrimination test were more likely to give up the behavior of pulling the lever during the resistance to extinction test, whereas ones scoring lower on the olfactory test were more persistent. This led researchers to believe that dogs are more inclined to change their behavior if they previously had adequate olfactory conditioning. Perhaps the best way to train a dog to stop chewing up shoes is not through scolding but through smell.

When it comes to different learning styles, dogs seem to be just as complicated as humans. Perhaps the way dogs are normally trained is not as strong of a method as previously thought, and training dogs using olfactory or visual cues would be more effective.

Scientific Reports (2018). DOI: 10.1038/s41598-018-32990-2
Behavioral Processes (2019). DOI: 10.1016/j.beproc.2019.01.010

Fantastic fields of vision

Owl's eyes, explained

BY OLIVIA CLAUSEN, ECONOMICS, 2021

Do you ever wish you had eyes in the back of your head? While most humans can only turn their heads 90 degrees in each direction, owls can turn theirs 270 degrees each way. This is more than any other vertebrate can turn its head, giving owls the highly sought after ability of being able to watch their own backs.

Owls have several adaptations that make this possible. First, they have twice as many vertebrae as humans, and their long necks create an S-shape. The upper region of their neck is responsible for a *yaw* movement, which is a rotation around the vertical axis and allows for owls' impressive head-turning abilities. The lower region is responsible for a *rolling* movement, or rotation around the horizontal axis.

More importantly, owls only have one occipital bone — the bone at the top of the spine, while humans have two. A common comparison between having one or two occipital bones is thinking of how much easier it is to pivot on one heel than two.

A 2013 Johns Hopkins University study illuminated another trait that gives owls the ability to turn their heads so far each way. If a human tried to turn their head much more than 90 degrees, not only would their vertebrae break but they would also likely die from a stroke due to tears in the arteries. Researchers found that owls' vertebrae contain holes that essentially protect their arteries from breaking as they turn their heads. Between their singular occipital bone and protected arteries, owls are well-suited for 270-degree head turns.

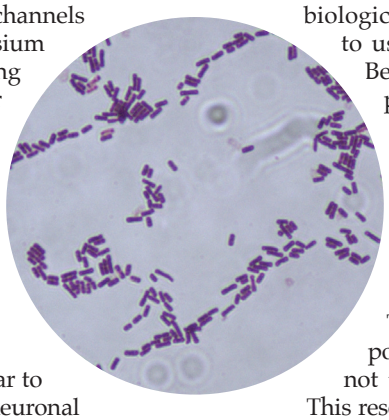
Owls depend on their neck adaptations to make up for their lack of peripheral vision. There are two parts of one's field of view: the overall field one can see as they move their eyes and a binocular view, which is what can be seen with both eyes at once. As such, the binocular view encompasses a smaller field. The field of view for humans is 180 degrees, of which 140 degrees are binocular. The field of view for owls is 110 degrees, of which 70 degrees are binocular. Despite their smaller range of peripheral vision, owls still manage to see quite a wide range — even behind their back!

Journal of Anatomy (2017). DOI: 10.1111/joa.12616

Microbe Memory: How biofilms can store information

BY JULIA BREED, CELL & MOLECULAR BIOLOGY, 2021

Can microbes form memories? Earlier this year, researchers at the University of California San Diego demonstrated that, yes, certain bacteria can remember complex patterns. After exposing a biofilm of *Bacillus subtilis* to blue light stimulation, researchers observed intermembrane potassium ion channels change shape. This change caused potassium ions to be released from the cell, leaving the inside of the membrane with a lower concentration of potassium than the outside. This phenomenon is referred to as hyperpolarization, and a cell in this state is negatively charged. The new membrane potential persisted after exposure; the biofilm was able to retain the pattern — namely the UCSD logo — for several hours.



This mechanism of action is strikingly similar to how neurons store information. When a neuronal pulse, or action potential, occurs, sodium ions flood into the cell, resulting in a depolarization of the membrane. Membrane-based memory occurs in neurons when they experience protein modifications, which alter how ions flow in and out of the cell. After treatment with the blue light, *B. subtilis* potassium channels remained open temporarily. Their response to external ionic stimuli changed, suggesting that perhaps some features of neurons sprung from this ancient bacterial system.

Bacterial biofilm memory could potentially be used for biological computing, a technology that seeks to use living tissue to store and process data. Because individual cells can change the physical characteristics of their membranes, they act as living binary code — with states of zero or one. Thus, the biofilm is a heterogeneous platform that could imitate the digital information storage and processing that have drastically shaped the technological world.

The continued exploration of membrane potential-based memory shows that DNA is not the only way to store information in cells. This research not only helps explain the roots of the nervous system but also paves the way for a new potential application of biology, providing a glimpse into the past and the future of cell function.

Cell Systems (2020). DOI: 10.1016/j.cels.2020.04.002

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

PHOTOS BY SHUTTERSTOCK AND WIKIMEDIA

WHAT SCIENCE SAYS ABOUT "BOUNCING BACK"

BY SHELLEY SEUNGHYE JEON, PHARMACY, 2025
DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

It's more common to hear about recovery in the context of physical disorders than mental ones; the phrase "recovering from a hip injury" rolls off the tongue easier than "recovering from opioid use." What creates this stigma around the discussion of mental recovery? One reason may be that struggling with mental health has yet to be fully normalized in society; another reason may simply be the lack of research on recovery from mental disorders, even among those with immediate physical consequences such as drug addiction.

The metrics used to measure the impact of substance abuse typically encompass the burden of disease, disability, and premature mortality — examples include number of deaths, overdoses, relapses, and monetary losses. What's interesting about these statistics is that they are all measured pre-recovery — as deficits rather than surpluses, relapses over recoveries, and burden over benefit. The literature on the successful resolution of alcohol and other drug (AOD) problems is limited, which could unintentionally frame our understanding of AOD abuse with negative outcomes only. Contrary to this assumption, in 2018, it was estimated that 22.35 million American adults had recovered from previous AOD problems. With this seismic population of recovered individuals in the United States alone, the existing body of knowledge on recovery should be made more accessible and arguably as commonplace as knowledge on the side effects of the disorder.

Research on the potential for recovery is generally hopeful across various types of substance abuse, though severe damage may be irreversible. For instance, a 2012 study examining chronic inhalant abuse found that impairments were fully reversed after 15 years of abstinence. However, those with lead encephalopathy (lead poisoning), a severe consequence of chronic leaded petrol abuse, saw little recovery. The lack of cognitive improvement following both 2 and 15 years of abstinence likely indicates irrevocable neurological damage.

In another study regarding the use of benzodiazepines — a class of drugs mainly used to treat anxiety, panic attacks, and depression that include Valium and Xanax — researchers found that long-term benzodiazepine users saw improvements in all cognitive categories after discontinuation. The study suggests that even after more than 10 years of benzodiazepine dependence, previous users are able to experience positive changes in visuospatial, attention, and problem-solving abilities after just three months of abstinence. However, the data still indicates a significant impairment in most areas of cognition compared to control groups, even following discontinuation. The study concluded on two schools of thought, stating that while some aspects of recovery are certainly possible, long-term benzodiazepine use creates permanent deficits or deficits that take longer than six months to recover. The researchers urged "extreme caution" in the long-term use of benzodiazepines and implored professionals and patients to weigh the potential clinical benefits against the possibility of dependence and cognitive impairment.

> "Not only does stopping smoking prevent the accrual of more lung damage, it has the potential to 'reawaken' these hidden communities of healthy cells."

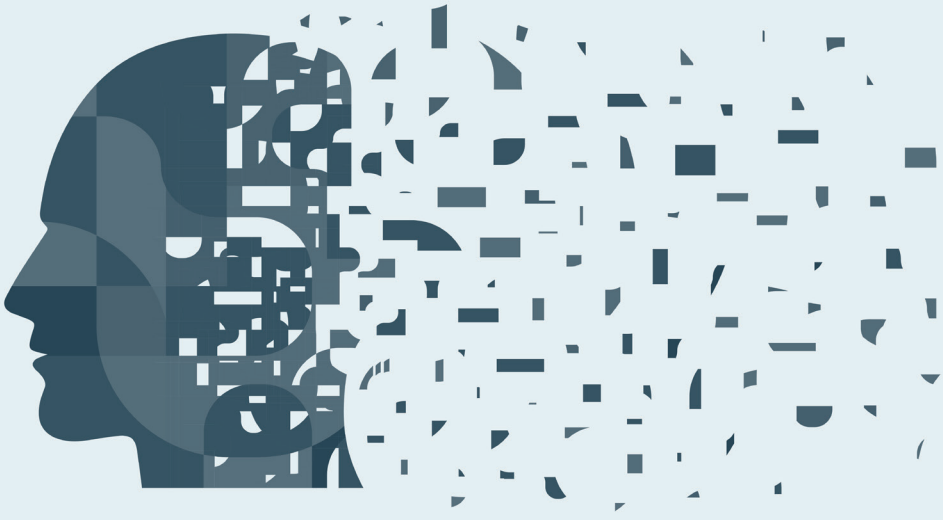
Another study published in January 2020 revealed the fascinating regenerative capacity of the lungs of ex-smokers. A groundbreaking discovery they made was of a distinct niche of healthy bronchial cells hidden in ex-smokers' lungs, even those who had smoked for multiple decades. This population of healthy cells was reported to be near-normal in its mutational burden (i.e., number of cell divisions), exposure to tobacco carcinogens, and telomere length (sequences at the ends of chromosomes that deteriorate over time), despite neighboring tobacco-affected, highly mutated cells.

Stunningly, these healthy cells occur at a fourfold higher frequency in ex-smokers compared to current smokers — suggesting that not only does stopping smoking prevent the accrual of more lung damage, it has the potential to "reawaken" these hidden communities of healthy cells. The low mutational burden and long telomere length of these healthy cells suggest that they could be recent descendants of stem cells, protecting against lung cancer by slowly replenishing the cells exposed to tobacco carcinogens. Though it is not yet understood how these cells avoid the high rates of mutations seen in neighboring cells and why they proliferate after smoking cessation, the restorative capacity of the lungs is undoubtable.

The body's ability to bounce back from both cognitive and visceral harm is expansive, limited only by irreversible damage. Though research has a ways to go in understanding the full scope of AOD abuse recovery, current research elucidates the possibility of meaningful rehabilitation for substances ranging from tobacco to clinical antidepressants. New research on the potential of recovery is not only empowering for individuals for whom recovery can become a science-backed, realistic goal but also an important step toward including the role of recovery as a key metric in future addiction-related research.

Addiction (2013). DOI: 10.1111/add.12124
Archives of Clinical Neuropsychology (2004). DOI: 10.1016/S0887-6177(03)00096-9
Nature (2020). DOI: 10.1038/s41586-020-1961-1
Drug Alcohol Depend. (2017). DOI: 10.1016/j.drugalcdep.2017.09.028

PHOTOS BY SHUTTERSTOCK



Losing your train of thought with traumatic experiences

Is it for the best?

BY HIBA HUSSAIN, BIOENGINEERING, 2024

A single traumatic experience can shape the rest of one's life for better or worse — but more likely for the latter. This idea is certainly disturbing, as almost 70 percent of adults in the United States, or 223.3 million people, have dealt with a traumatic experience such as abuse, violence, or grief. Young adults and adolescents are no exception to these eye-opening statistics, and at least a third of those who experience trauma will develop post-traumatic stress disorder (PTSD) throughout their lives.

If traumatic experiences are this common, how does the brain process them so that victims can go on to survive and thrive? Scientists across the world are seeking answers to this question to improve our understanding of the brain and develop the most effective therapies to help patients from succumbing to their trauma.

According to Dr. Darlene McLaughlin, a psychiatrist at Texas A&M College of Medicine, the brain typically deals with traumatic experiences by dissociating from them. A typical example of dissociation occurs when daydreaming, and more serious cases can lead to the development of dissociative and mental disorders. Scientists think that there is only a certain amount of trauma a person can go through before dissociating from an experience, and this threshold varies based on age, genetics, and environmental factors.

Researchers at the University of Basel in Switzerland have made promising discoveries relating to why certain people are able to dissociate from traumatic memories more than those who aren't able to. Vanja Vukojevik and her team studied survivors of the Ugandan Civil War and the Rwandan Genocide. They discovered more gene regulation by DNA methylation in both groups of the survivors. Specifically, the survivors had stronger regulation of the gene *Ntrk2*, which in the past has been linked to memory formation. As a result, those with stronger regulation of *Ntrk2* were less likely to develop PTSD, as the increase in regulation alters brain activity in the regions of the brain responsible for memory. Vukojevik and her team hope to continue their study of trauma to understand the intrinsic complexities of the brain.

While Vukojevik studies the effects of trauma on a subcellular level, several scientists are also exploring its effects on the cellular level and in the brain. One of the most notable is Professor Johannes Graff and his team at L'École Polytechnique, who have discovered a group of neurons that are responsible for remembering glimpses of a traumatic memory. In order to find this group of neurons, they pinpointed a phenomenon called fear attenuation, which involves subduing an original memory's trace of fear with one that has been rewritten and considered to be safer.

The researchers used genetically modified mice with fluorescent proteins that could respond to neuronal activity, and they trained the mice with fear-inducing exercises. They discovered that neurons in the dentate gyrus, a part of the temporal lobe in the brain known for episodic memories, lit up. Next, Graff used exposure-based therapies, similar to those used on humans, to reduce fear in the mice. Surprisingly, some of the neurons active when recalling traumatic memories were still active when the mice no longer showed fear, meaning that storing and forgetting memories are controlled by the same group of neurons. In this way, these neurons act like a light switch when remembering a traumatic experience, ultimately leading to attenuation of fear.

The research completed by Vukojevik and Graff is incredibly promising and may lead to the development of specialized therapies in the future. However, the current most effective treatments for trauma continue to be cognitive behavioral therapy (CBT) and eye movement desensitization and reprocessing (EMDR). Both of these therapies aim to expose the patient to small parts of the traumatic event in short intervals through talking about the experience and allowing new memories and associations to be formed so that the trauma is not all-consuming. EMDR and CBT are widely used with PTSD patients, and with good reason, as the most effective way to overcome trauma is to speak about it with a trusted mental health professional. While it is tempting to block out traumatic memories forever, it is far more effective to seek help and therapy, even if it requires taking that extra step of courage to reach out. If you are a Northeastern student and just need to talk to someone, please use Find@Northeastern (1.877.233.9477) for 24/7 mental health support.

Science (2018). DOI: 10.1126/science.aas9875
PNAS (2020). DOI: 10.1073/pnas.2008415117

PHOTO BY SHUTTERSTOCK

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

Alternate realities or malleable memories?

BY SHREYA NAKHAWA, CELL & MOLECULAR BIOLOGY, 2023

When it comes to our memories, the expression "hindsight is 20/20" isn't exactly accurate. We've all experienced a time when we remembered something wrong, even if we haven't realized it. In reality, there is a scientific reasoning behind misremembering events. Furthermore, the misinformation effect also acts at a group level, playing an important role in what we call the Mandela effect.

When there are gaps in our memory, we tend to fill those gaps using the information we learn after the fact, or information from other sources. This information melds with our personal experiences and can create false memories of something that did not actually occur. Reconstruction of memory occurs because our memories are malleable and can be influenced by external factors, such as social interactions and external information; this is called the misinformation effect. A prime example of the misinformation effect is errors in eye-witness testimony, which is one of the leading causes of wrongful convictions. In fact, the American Psychological Association postulates that one in three eyewitnesses makes an incorrect identification, an exhibition of the misinformation effect in action.

In addition, memories of events can be altered not only at an individual level but also at a group level. Collective memories are memories of events that are widely shared by individuals in the community. Since the collective memory of an event is reshaped by many different people and sources of information, a community's collective memory of an event can differ from reality. A community's collective memory can also tie people together and shape the group's current identity. One example of differences in collective memory is different countries potentially remembering World War II differently.

People within the same community interact with each other and converse about shared experiences, which can shape the memory of an event. In conversation, some details are included, and some details are left out. Subsequently, it is difficult for both the speaker and the listener to recall the details that were not mentioned in conversation. This phenomenon results in a "shared reality," or a reshaped memory of the event that is similar for everyone in the community.

When this "shared reality" differs from the reality of an event, this is called the Mandela effect. Some have proposed that the Mandela effect is a result of alternate realities, causing different groups of people to remember the same event differently. However, this phenomenon can actually be explained by the misinformation effect applied at a group level.

A study by de Vito et al. in 2010 investigated the malleability of memories and how the collective memory of an event was reshaped by the community to differ from reality. In particular, this study looked at the Bologna Massacre, one of the deadliest terrorist attacks in Italian history in which a bomb exploded in the main railway station of Bologna, Italy. The previously working clock outside the station was damaged and stopped working at 10:25 CEST, symbolizing the time of the attack. This study aimed to investigate the recollection of the status of the clock before the attack — whether it was working or if it had always been set to 10:25. Most of the people who were interviewed misremembered the status of the clock before the attack and thought it was always set to 10:25. As de Vito et al. said, "individual memory distortions shared by a large group of people develop into collective false memories." The stopped clock became a symbol of the massacre, which was perpetuated by the media. This symbol overwrote many individuals' accurate memories of the clock working and resulted in the formation of a distorted collective memory.

In this situation, the misinformation effect acting on an individual level was perpetuated through social interactions and conversation about people's shared experiences. This culminated in an error in the community's collective memory. Rather than two communities experiencing alternate versions of the same event, malleable memories caused the misremembering of the event everyone experienced.

Looking back on events that were experienced by the whole community, one may find that their memory of that event may not be entirely accurate. Social interactions within the community and widely circulated media can affect a group's collective memory, resulting in inaccuracies recalling a historical event. The misinformation effect and the malleability of our memories allow us to reshape our own memories and experiences based on external influences.

Journal of the Experimental Analysis of Behavior (2011). DOI: 10.1901/jeab.2011.96-343
Frontiers in Psychology (2012). DOI: 10.3389/fpsyg.2012.00257
Frontiers in Psychiatry (2014). DOI: 10.3389/fpsyt.2014.00102
Cortex (2012). DOI: 10.1016/j.cortex.2008.08.002

PHOTOS BY SHUTTERSTOCK
DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

TO PANIC OR NOT TO PANIC

THE IMPACTS OF HUMAN BIAS ON THE PANDEMIC

BY LILY WEBER, BIOLOGY & ENGLISH, 2023

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

For just a moment, think back to January 2020. People were just hearing stirrings of the novel coronavirus outbreak escalating in Wuhan, China. Cases were on the rise in numerous countries. Some people panicked instantly. Others were seemingly in denial. Months later, as cases reached an all-time high, many could no longer afford to ignore the problem. Yet, even now, as the United States has reached an unprecedented number of new cases per day, there are still those who downplay the virus or even question its existence as a threat entirely. The multitude of reactions people have had to the virus raises an interesting question: what are the psychological factors at play? Why do people react (or not react) the way they do?

The answer to these questions lies in cognitive and psychological biases. There are many biases that play into how we have responded to the pandemic. According to Halpert et al. in 2020, one such factor is known as the "identifiable victim effect." Essentially, people are far more likely to respond to a crisis when it impacts someone they know. In other words, when the only exposure someone has to the virus is through the news, they aren't likely to take it as a serious threat.This may account for disparities in how people have responded to the pandemic; those who have had an affected friend or family member may have adhered far more stringently to federal guidelines than those who have not.

> "It is vital that we take a critical look at our innate biases to be best informed when dealing with adverse events in the future."

Bottemanne et al. in 2020 posit that human optimism bias has also had a significant impact on public perception. Optimism bias describes the tendency for people to be optimistic about their odds of avoiding adverse life events. This is due to human tendency to ignore unfavorable information in favor of positive information, resulting in the evident discrepancy between the dire nature of the official warnings versus people's perceptions of the likelihood they will be affected. This discrepancy was supported by Dolinski et al. in 2020, who found that despite increasing cases and deaths, U.S. citizens saw their probability of contracting the virus and infecting others as lower than the rest of the population. Even as those around us may go through adverse events, we remain steadfast that we will beat the odds. For those who have hosted large gatherings or gone against social distancing guidelines, human optimism bias may very well be the culprit.

On the other hand, certain human tendencies have led to heightened responses to the pandemic. One memorable example is the panic that caused people to buy toilet paper early on. While some saw the trend as ridiculous, others insisted that it was a smart move. This showcases the bandwagon effect in all of its glory. The bandwagon effect dictates that humans are more likely to adopt a behavior if they perceive that others are doing the same. As people began to frantically buy massive quantities of toilet paper, others observed this behavior and adopted it as well. As more people rushed to stores, it was picked up by media outlets who in turn reported on the phenomenon. Thus, more people were exposed to the behavior and presumed that everyone was doing it, causing even more people to rush out of their homes and into stores. It was a vicious cycle whose only real outcome was toilet paper shortages in stores.

By virtue of being human, biases are not always avoidable. However, their potentially devastating impacts can be mitigated by imparting a sense of awareness to the community. By educating ourselves on psychological biases, we can help ensure that we are responding to emergencies in the best way possible, without allowing biases to cloud our thinking. This becomes especially important when looking back at crises that have passed, and it is where hindsight bias comes into play. Hindsight bias is when people feel that they "knew it all along" once an event has come to pass. In the context of the COVID-19 pandemic, while people may have been skeptical of the magnitude of the situation initially, hindsight bias dictates that many may look back and declare that they knew how bad the situation would get. This has dangerous implications, as it can lead to overconfidence in our level of preparedness for similar events in the future. It is vital that we take a critical look at our innate biases to be best informed when dealing with adverse events in the future. Otherwise, hindsight will not always be 20/20.

PHOTO BY SHUTTERSTOCK

JAMA (2020). DOI: 10.1001/jama.2020.11623
Frontiers in Psychology (2020). DOI: 10.3389/fpsyg.2020.02001
Journal of Clinical Medicine (2020). DOI: 10.3390/jcm9051464
Perspective on Psychological Science (2012). DOI: 10.1177/1745691612454303

FACIAL BLINDNESS AND MASK WEARING: A LOOK INTO PROSOPAGNOSIA

BY EMMA TUSUZIAN, PSYCHOLOGY, 2023
DESIGN BY CARINA HALCOMB, EXPERIENCE DESIGN, 2024

PHOTO BY BRIAN ASARE

Running into a friend looks very different during the COVID-19 pandemic: both parties pause and take extra moments to scan for familiar cues on their mask-wearing counterpart. When trying to recognize masked neighbors or peers, people must rely more on clothes, hair, mannerisms, and other elements to identify the person in front of them. The new normal of mask wearing is changing the way people recognize each other and form connections.

Human ability to recognize faces is powerful, and its complexity can be hard to understand. While it is normally extremely efficient, the pauses that masks create highlight the significance of noticing and processing faces in socialization. People are experiencing a small taste of facial blindness when the faces around them are covered, forcing them to rely more heavily on other identifying features in the absence of facial recognition. Though research is still young, recent preprints suggest that people are less able to recognize others with masks. People vary in their ability to recognize faces with limited information, which is suggested by what researchers call the "head scarf effect." Participants from Egypt and the United Arab Emirates, where many women cover their hair, performed better than British and American participants at identifying faces when only the eyes, nose, and mouth were showing. In Asian countries, where wearing protective masks in public was an established norm before the pandemic, facial recognition may also be a smaller hurdle. Still, the growing cultural shift of wearing masks has put more attention on people's abilities to recognize one another, especially when as many as one in fifty people may experience lifelong challenges from difficulty recognizing faces *without* masks.

Facial blindness, formally known as prosopagnosia, is a neurological disorder characterized by an inability to recognize faces. Some may struggle to recognize familiar faces or even their own, and others may be unable to differentiate between unknown faces. There are even severe cases in which people cannot distinguish faces from objects. Some forms appear from birth, and other facial blindness can develop from brain trauma or neurodegeneration. The disorder is not a result of deficits in vision, intelligence, memory, or learning but is instead associated with the fusiform gyrus, an area of the brain that activates in response to faces. Abnormalities in the right fusiform gyrus, a certain fold in the brain involved in facial perception and memory, are often associated with prosopagnosia, indicating the brain has a highly developed and specialized system for facial perception. Some levels of prosopagnosia are present in children on the autism spectrum and may contribute to hindered social development.

Developmental prosopagnosia has a large impact on lives, as children may have difficulty recognizing friends and teachers, leading to potential social struggles. Some adults with prosopagnosia may choose careers that do not require frequent face-to-face contact, avoiding similarly difficult situations. It is also common for those with this disorder to struggle in following films or television shows because they are unable to recognize different characters between scenes. According to *Cell Press*, people with prosopagnosia often grow up mistakenly "attributing their face recognition difficulties to attention deficits or poor memory" before becoming aware of their disorder. Some develop anxiety and depression from facing persistent social challenges.

Individuals with developmental prosopagnosia learn to follow alternative cues to replace facial recognition. For example, this may involve characteristic facial features such as a unique nose or other factors like voices, hairstyles, and clothing. Social situations in which such cues are unavailable, such as within environments needing similar clothing or where voice cues are not present, are often difficult for those with prosopagnosia. A change in an identifying feature like hair or an addition of a hat can lead to misidentification. This use of new cues bears some resemblance to how we work around our lack of facial perception during the COVID-19 pandemic, leading every individual closer to understanding prosopagnosia and reminding them not to take their abilities for granted.

When abilities or senses are limited, they can become important learning opportunities for those who do not normally have these limitations. The brain is incredibly adaptive, and neurodivergent people can thrive under a range of challenges. As wearing face masks has become the new normal, observing its social and behavioral effects over a long timespan can reveal within every individual some of the limitations faced by people with prosopagnosia.

Perception (2015). DOI:10.1068/p7940
PsyArXiv (2020). DOI:10.31234/osf.io/zjmr8

MUSIC AS A FORM OF TREATMENT TO ALZHEIMER'S PATIENTS

BY SUYASH SAU, BIOCHEMISTRY, 2024 DESIGN BY KAI GRAVEL-PUCILLO, PSYCHOLOGY, 2022

For hundreds of years, music has provided humans with a means to enjoy themselves and reduce their stress. Whether it is the serenading melodies of jazz or the flashy beats of hip-hop, music has provided people with a type of natural mood enhancer. Recently, medical research has suggested that music can significantly help people with the infamous Alzheimer's disease. A neurological disorder, Alzheimer's progressively affects a patient's memory and cognitive functions. The primary group at risk is people over the age of 65. In early stages of the disease, patients often suffer from slight memory loss, which during later stages of the disease can develop into severe memory loss, speech impediments, and disturbed sleep. While music does not address the cause of these symptoms, music therapy has been shown to alleviate emotional stress and access buried memories left untouched by the disease.

According to Dr. Graff-Radford of Mayo Clinic Hospital, the reason music is able to help with Alzheimer's disease is because musical memories are often comparatively unaffected by it. Another unique study was done by researchers in 2015 that proved that musical memory is spatially distributed throughout the human brain by using neuroimaging devices such as MRI scanners. This astonishing discovery suggested that musical memories were relatively unaffected by Alzheimer's compared to other memories because unlike other memories, musical memories are dispersed within the brain.

Another common symptom of Alzheimer's disease during middle and late stages is agitation and behavioral issues. There have been tests in which a patient's family played music that the patient often listened to before suffering from Alzheimer's disease. During these tests, patients were seen to behave with reduced anger. Music is able to reduce stress and anxiety amongst Alzheimer's patients, which then allows their family and friends to better connect with them, especially when there is often significant difficulty communicating because of the disease.

Although music is not a cure and cannot reverse the neurological damage within an Alzheimer's patient's brain, it has been proven to be a healthy way to relieve patients' stress and anxiety and reduce agitation and impulsive behavior. In a time where these patients are so vulnerable, it is important for any form of comfort to be provided. Medical research on Alzheimer's continues, and researchers work to one day find a cure for this dreadful disease.

Alzheimer's & Dementia: The Journal of the Alzheimer's Association (2016). DOI: 10.1016/j.jalz.2016.03.001
Brain (2015). DOI: 10.1093/brain/awv148

CAN ENGAGING WITH MUSIC PROTECT AGAINST COGNITIVE DECLINE?

BY LAUREN VOSO, BIOLOGY, 2023 PHOTO BY SHUTTERSTOCK

Cognitive decline, characterized by the loss of memory and higher-level thinking skills, is a natural part of aging, having many causes that scientists are still trying to understand. However, researchers have found that engaging in certain lifestyle choices can increase or decrease later cognitive function. Participating in these activities won't nullify pre-existing genetic factors, but there may be a tentative correlation between certain activities and improved cognitive health.

A review published in *Frontiers in Aging Neuroscience* examined several of these lifestyle changes and the potential impact each could have on reducing the prevalence of dementia, a form of severe cognitive decline. Specifically, the researchers investigated musical experience and the risk of cognitive decline and found a link between people who are musically active throughout their lives and certain cognitive advantages later in life, such as improved ability to perceive speech, increased memory capacity, and more efficient cognitive organizational processes. Although these positive effects are most prevalent in lifelong musicians, researchers have also found that older adults who start engaging with music still gain cognitive benefits. A study on adults who started a six month program where they learned piano for three hours a week found that cognitive benefits not only developed but continued after a three month delay, suggesting that the positive effects persist.

They also discussed two other simple lifestyle changes: exercise and meditation, which are associated with improved cognitive function. The authors note that individuals ought to lead an active lifestyle in youth and continue participating in forms of healthy exercise in older age. Some studies have found that meditation has positive effects on cognitive functioning, but they note that it is harder to confirm this connection as there are no empirical parameters to definitively detect a meditative state.

Beyond these three factors, there are many others that play a role in cognitive health, making it difficult to isolate and prioritize any factor in particular. Researchers are still trying to understand the reasons why each factor improves cognitive functioning. Neuroplasticity, or the ability of neurons to create new connections to grow and reorganize brain networks, seems to be improved by exercise, musical practice, and meditation, which consequently make the brain less susceptible to cognitive decline. Much is still unknown about cognitive decline and the factors that affect it, but it is important to be aware of how certain choices may help our cognitive function in the future.

Front. Aging Neurosci. (2017). DOI: 10.3389/fnagi.2017.00381

VISUAL SNOW SYNDROME
AN EXERCISE IN PERSPECTIVE

BY ASHLEY BROWN, BIOCHEMISTRY, 2024

DESIGN BY YECHAN YANG, BEHAVIORAL NEUROSCIENCE, 2021

For over 200 people across the world, the words "snow" and "static" are neither associated with winter weather nor poor connection on an analog television. This small cohort makes up the documented cases of visual static syndrome, also called visual snow syndrome (VSS). For these people, everything in their sight is overlaid with the characteristic of the syndrome's name: static in the form of black and/or white dots. Outside of this characteristic of the syndrome, there are also a variety of other symptoms ranging from migraines, vision blackouts, and light sensitivity. These symptoms intersect with the stresses of living with a rare condition; those diagnosed with VSS require a resilient mindset to accept their new perspective.

With symptoms primarily related to vision, it is not unreasonable to assume that VSS is an eye disorder; in actuality, though, it is considered a neurological disorder. Most tests indicate the eyes of these patients are not altered from healthy ones, and in fact, many maintain perfect vision. However, Abby L. Metzler and Carrie E. Robertson describe in a review article published in *Current Neurology and Neuroscience Reports* that some evidence incriminates the thalamus, a small division of the brain related to sensory processing, as a potential culprit. Dr. Dominic Ffytche, one scientist studying the condition, led an experiment where he induced similar phenomena in healthy volunteers while studying their brain activity and found that these alterations in the thalamus were similar to those of Charles-Bonnet Syndrome, a condition where people who are blind experience visual hallucinations. Additionally, the thalamus is responsible for tinnitus, another symptom that 63 percent of VSS patients report.

However, the thalamus irregularities do not explain other symptoms such as the migraines that 58 percent of patients endure frequently. In fact, visual static was often misdiagnosed as a migraine aura, a visual disturbance during a migraine, because of the overlap between these conditions before receiving its own diagnosis criteria in 2013. The diagnostic difference between the conditions largely comes down to time span, as VSS is constant whereas migraine auras only occur during a migraine. Because of these similarities though, physicians draw from treatment for migraine auras — although with limited success. Further still, there are theories related to the occipital lobe as well as the lingual gyrus, both being other sections of the brain related to eyesight. With numerous theories but so limited data, it is difficult to place significant weight on one over the other.

The most crippling aspect of any study of visual snow is its limited application due to the rareness of the disease and therein lies the greatest struggles of the disease — the isolation. With a lack of explanation and a lack of treatment, those experiencing VSS fall into a difficult category even further complicated by the lack of public knowledge

LEFT: NORMAL SIGHT RIGHT: SIGHT WITH VISUAL SNOW

PHOTO BY PHILIP MARTIN VIA UNSPLASH

regarding the condition. These differences breed stigma, as rare conditions unfortunately do.

A more direct account of this stigma comes from my own sister, Isabelle Brown, who was diagnosed with VSS in late 2015 following a series of vision blackouts. She describes the process of diagnosis as "long and torturous" because of the layers of authority she had to work with, "bucket loads of testing," and the physician's lack of knowledge. In fact, Isabelle recalls almost receiving a spinal tap and only being saved by a more experienced doctor recognizing the condition based on her description of her vision as "static."

Her primary physical complaint is light sensitivity, which draws attention to her condition. Sometimes she needs to wear sunglasses to avoid eye-strain when watching videos in class, and she cannot look at bright lights for over five minutes without inducing a migraine and burning pain throughout both of her eyes, circumstances that do not go unobserved by her peers. After years of coping with the condition, a frustration Isabelle details is when others, even good-naturedly, attempt to relate by claiming they experience it too, but she quips that "really they just were dehydrated and did not eat enough food." Even the most well-intentioned comments illuminate the stigma and lack of knowledge accompanying a rare disease.

Though, one method to combat this stigma: greater public awareness, which hopefully this article may provide to some extent. Because for those living with the condition, their perspective must shift, literally and metaphorically, to see the true picture; so, a willingness to learn is the least anyone else can do.

Current Neurology and Neuroscience Reports (2018). DOI: 10.1007/s11910-018-0854-2

Mental time travel

A universally human experience

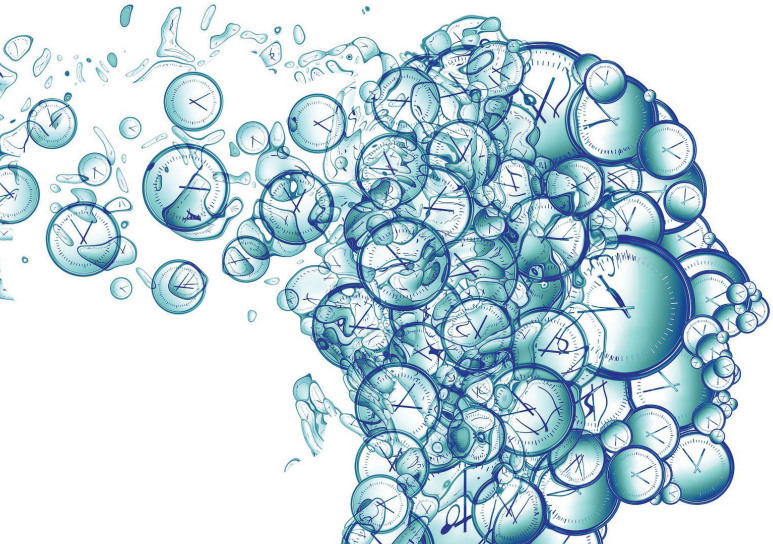
ARTICLE AND DESIGN BY RACHEL LINES, BEHAVIORAL NEUROSCIENCE, 2023

Is time travel only possible in science fiction? Are humans capable of journeying to the past and into the future? Time travel may not be a concept exclusive to "Back to the Future." According to scientists across several disciplines, time travel has a multitude of definitions. In fact, humans engage in several forms.

Firstly, all living creatures on Earth travel time at the same speed of one second per second. In the typical definition of time travel, the time-dilation effect of special relativity describes that a moving clock will appear to tick more slowly when approaching the speed of light. For example, one could travel for a distance of 60,000 light years in a spaceship accelerating constantly at 9.81 meters per second squared and return to Earth having aged only 40 years of time on the ship, while 60,000 years would have passed on Earth. This incredible phenomenon, however, is not the only way humans can travel time. When considering one's personal history and future goals, humans engage in mental time travel — an ability that has played a major role in the development of language.

Mental time travel is based in the ability to recall conscious memory. Conscious memory involves explicit recall and can be separated into episodic and semantic memory. Basic knowledge falls under semantic memory, while personal experiences and autobiographical memories can be described as episodic. Episodic memory allows for mental time travel, creating the ability to journey through past events.

What is the specific purpose of episodic memory? Recalling past events typically results in many errors and distortions, indicating that the sole purpose of this ability must not be to record the past. Instead, researchers at the University of Queensland and the University of Auckland theorized that episodic memory provides information from the past to simulate future events. Through the combination of semantic and episodic recall, humans have the ability to reconstruct past events, consider future possibilities, or create fictional stories. This function may have evolved as a survival strategy, allowing for flexible foresight.



After vividly remembering a past event or imagining a version of the future, we are driven to communicate these ideas to others. Storytelling and the construction of literature, folklore, and television are based in the ability to create episodes driven by recall of personal memory. Researchers have also theorized that language developed as a means to communicate these ideas to others. Language is designed for expression of what will happen, including details on people, locations, and reasons. These are the same qualities that are needed for recalling episodic memory. Therefore, mental time travel is strongly connected with the evolution of language.

All languages accomplish the distinction of present or not present in different ways. For example, Chinese does not have tenses, but time is indicated through adverbs and aspect markers. The Pirahã language spoken by a group of several hundred people in Brazil has two tense-like morphemes. Morphemes refer to the most basic unit of language that cannot be further divided, and the Pirahã speakers indicate whether or not an event occurs in the present through small changes in these units.

Many animal researchers pose the question of whether or not mental time travel is exclusively a human ability; however, it is difficult to observe the difference between episodic and semantic memory in animals. For example, does a dog recall burying a bone, or does it simply know where the bone is buried? About a decade ago, we believed animals were not capable of episodic memory — scientists had decided that examples of presumed mental time travel were limited by a strong instinctual component of behavior in non-human species. More recently, Michael Corballis, a researcher of the evolution of language at the University of Auckland, described the behavioral evidence for mental time travel in many species, including great apes, meadow voles, ravens, scrub jays, and rats, as they were able to demonstrate recall of many different episodes over intervals of up to 45 minutes.

The demonstration of episodic memory in non-human animal species shows that mental time travel may have developed relatively far back in animal evolutionary history. Although technology has not developed to allow humans to time travel utilizing the effect of special relativity, the evolution of mental time travel allows us to relive our past and imagine our future. Through its influence on language, mental time travel brings us closer together, sharing our dreams and stories as we journey through the many imagined versions of our lives.

Frontiers in Human Neuroscience (2019). DOI: 10.3389/fnhum.2019.00217
Philosophical Transactions of The Royal Society (2009). DOI:10.1098/rstb.2008.0301

PHOTOS BY PIXABAY

Stop studying and go to bed

The impact of sleep on learning

BY KELLI VALENTINI, BIOENGINEERING, 2024

DESIGN BY PREETI MAKARAM, COMPUTER SCIENCE & COGNITIVE PSYCHOLOGY, 2024

Most people look forward to finally lying down to sleep at the end of a long day. This can be especially true for college students, as 70.6 percent attain fewer than the medically advised 8 hours per night, according to a study by the National Sleep Foundation. Despite many years of research, the exact function of sleep is still unknown. There are several working hypotheses about the purpose of sleep. It could be for energy conservation, brain thermoregulation, brain detoxification, tissue restoration, or a combination of these. Additionally, there is a mounting body of evidence that suggests sleep is beneficial for brain plasticity, or the ability of neural networks in the brain to change through growth and reorganization, impacting learning and memory. Therefore, getting enough sleep may be just as helpful in a college student's learning process as the studying itself.

The idea that sleeping and dreams can have an effect on learning is not new; Freud observed over 100 years ago that events from the previous day can appear in dreams. However, rigorous scientific research has only recently begun to test the extent of this relationship, and the exact details are still not yet understood. One proposal, the dual process theory, states that different types of memory are dependent on sleep state. The two main sleep states are rapid eye movement (REM) sleep and slow wave sleep (SWS). Procedural memory, or knowing *how* is linked with REM sleep. Examples of procedural memory are remembering how to ride a bike or cook an egg. Conversely, declarative memory, or knowing *what* is dependent on non-REM sleep. Declarative memory can be further divided into semantic and episodic memory. Semantic memory is knowing facts, like the state capitals, and episodic memory involves the recollection of personal experiences or events in an individual's life.

While the dual process theory maintains that sleep state has an effect on how different memory types are stored, the sequential processing theory hypothesizes that all long-term memory formation is prompted by SWS and then consolidated by REM sleep. Consolidation is the conversion of recent learned experiences into long-term memory. Because long-term memory is formed during SWS and stored during REM sleep, the sequential processing theory requires sufficient time in each sleep stage, as well as progression with little interference.

> "However, scientifically rigorous research has only relatively recently been applied to test the extent of this relationship, and the exact details are still not yet understood."

It is theorized that the consolidation process occurs via active communication between the cortex, the thin external layer of the cerebrum in the brain, and hippocampus, a structure in the temporal lobe. The hippocampus converts new short-term memory into long-term memory stored in the cortex. This is supported by the correlation between electroencephalogram (EEG) events of the cortex and hippocampus, suggesting the two areas actively interact during sleep. Additionally, cell pairs that are correlated while a person is awake show similar activity during sleep both within and between the hippocampus and cortex.

Several neurological studies have concluded that sleep is important for the formation of long-term memory. A 2006 study by MIT researchers looked at the reactivation of memory networks during sleep. In the study, rats first slept for 1 to 2 hours, then were awakened to run a maze, and finally entered another sleep period. During SWS, the neuron firing patterns of the rats in the hippocampus and visual cortex coordinated with the awake phase. As mentioned previously, the hippocampus and cortex are vital to the process of memory consolidation, so this experiment provides support for the hypothesis that sleep aids in consolidation and long-term memory formation.

This has also been suggested in humans; a 2004 study from the Belgian Fonds National de la Recherche Scientifique looked at cerebral blood flow measurements as a measure of brain activity and had subjects memorize routes in a virtual town, a declarative spatial memory task. It was found that the same hippocampal areas active during learning were reactivated during SWS. Furthermore, they found an improvement in memory performance the following day.

Studies in both humans and model organisms have demonstrated that neural networks correlated with the conversion of short to long-term memory are reactivated during sleep, and sleep could even result in recollection improvements. However, a correlative relationship is not definitive enough to determine causation, and it is not yet clear if this activation causes consolidation. More evidence is needed to fully elucidate the effects of sleep on memory. Still, these preliminary findings suggest that it's worth it to take a break from cramming and go to bed.

Journal of Sleep Research (2018). DOI: 10.1111/jsr.12749

Nature of Science and Sleep (2014). DOI: 10.2147/NSS.S62907

Journal of Adolescent Health (2010). DOI: 10.1016/j.jadohealth.2009.06.016

Nature Neuroscience (2007). DOI: 10.1038/nn1825

PHOTO BY SHUTTERSTOCK

Follow us: @nuscimag
Read our work: nuscimag.com
Subscribe to our newsletter: bit.ly/nusci
Contact us: nusciencemag@gmail.com

Supported by the
Student Activity Fee

Northeastern University
College of Science